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CURRENT STATUS OF THE USE OF CENTRAL VENOUS PRESSURE, PULMONARY ARTERY CATHETERIZATION, INFERIOR VENA CAVA VARIABILITY AND PASSIVE LEG RAISE TESTING IN CRITICALLY ILL PATIENTS

Medicine

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ABSTRACT

Fluid resuscitation is considered a cornerstone therapy in the management of critically ill patients. Estimation of volume requirements using an appropriate diagnostic strategy is a cumbersome process and an area of uncertainty. In many studies, clinicians' use of physical examination has been challenged, and several strategies for hemodynamic assessment utilizing imaging and physiologic models have been proposed. Broadly classified into static and dynamic indices, these interventions are based on point measurements as well as variations in the indices. There is no consensus among various societies about ideal testing, which is usually dependent on the clinician's discretion, availability of infrastructure and institutional preference. In this review, we attempt to elaborate the commonly used fluid assessment methods in the medical-surgical and cardiac critical care units.

KEYWORDS

CENTRAL VENOUS PRESSURE MONITORING

Central venous pressure (CVP) monitoring is an assessment of right atrial pressure by using a central venous catheter (CVC), which is considered a reflection of preload. It is represented by a waveform consisting of three peaks (a, c, v) and two descents (x, y); each corresponds to a different aspect of cardiac cycle.

Historical Background:

Modern use of CVC started in 1928 when German physician Werner Forssmann performed the first CVC on himself. In 1959, Hugh and his colleagues inserted a catheter in the right atrium of 25 patients undergoing thoracic surgeries and recorded intra-atrial pressures, concluding that continuous hemodynamic measurement is required for volume assessment. (1) Since then, the use of CVP measurement has become popular in the surgical field, leading to its use in intensive care units (ICUs) to assess fluid responsiveness in critically ill patients. In 1962, Wilson and Grow endorsed the fact that volume assessment through CVP should be considered in severely dehydrated patients as peripheral veins get constricted and cannot provide information on hemodynamic assessment.(2) In 1965, the use of CVP measurement to treat shock was further supported by Lloyd Maclean in an illustrative review of postsurgical patients. (3) In 1969, Loeb and his colleagues demonstrated in 12 shock patients after myocardial infarction that CVP measurement can be used as a tool to guide fluid management, and if CVP is low, plasma expansion should be considered. (4) In the 1970s, the 2-5 rule using CVP became widely acceptable as a quick diagnosis to guide fluid therapy (5). According to this rule, after initiation of fluid, filling pressures should be checked after 10 min. If it is <2 mm Hg, infusion should be continued; if 2-5 mmHg, the fluid should be held and monitored for a further 10 minutes; and if more than 5 mmHg, then fluid therapy should be stopped. Around same time, an article by James Forrester against the use of CVP was published. (6) He argued that CVP correlated poorly with left ventricular pressures and hence did not help in guiding fluid management, especially in patients with myocardial infarction. This notion of hemodynamic monitoring in myocardial infarction patients was further supported by John Cairns in 1979.(7) In 1975, Baek et al studied 22 critically ill patients and suggested that CVP measurement can be misleading in terms of volume assessment and that it is not a reliable index of hypervolemia. (8) Subsequently, the controversy about use of CVP measurement continued to prevail among various groups of surgery, critical care, anesthesiology, cardiology and emergency medicine. Several articles and editorials in support of CVP use were published in the 1990s, such as "More respect for CVP", and "Does this patient have abnormal CVP?" (9)(10)(11)(12) In 2001, Rivers et al published a landmark study showing that early goal-directed therapy targeting CVP of 8-12 mmHg could provide significant benefit, and hence the idea of using CVP monitoring for fluid management for septic patients was supported by surviving sepsis guidelines. (13) Thereafter, the ARDSnet trial compared liberal versus conservative fluid strategy in acute lung injury patients and concluded that there was a benefit in the conservative fluid group using CVP measurements. On the other hand, in the same era, several methods of hemodynamic monitoring were proposed, such as respiratory variation in arterial pulsations and an inferior vena cava collapsibility index. Paul Marik, in his review of articles, argued that "CVP is a measure of right atrial pressure alone; and not a measure of blood volume or ventricular preload". (14-19) In 2014-2015, the Australian ARISE trial, the British PROMISE trial and the US PROCESS trial concluded that EGDT is of no benefit for septic patients, and hence use of CVP for hemodynamic assessment was discouraged in critical care and emergency medicine. (20-22)

Medical critical care patients:

The use of CVP in critical care is limited to the estimation of fluid responsiveness. (1)(2) In an observational study on 2213 patients conducted in ICUs around the world, static markers of preload were still used to test preload responsiveness in almost 33% of cases. (23) In a consensus on hemodynamic monitoring by the European Society of Intensive Care Medicine, it is suggested that CVP can be useful in identifying the type of shock; however, they should always be interpreted together with other variables. (24) In another survey of 2500 anesthesiologist by a 33-question survey, 73% of American and 84% of European anesthesiologists reported that they used CVP to guide fluid management. (25) A Canadian survey of 232 critical care physicians, reported that 90% of critical care physicians use the CVP to monitor fluid resuscitation in patients with septic shock. (26)

Although CVP has been used to estimate right ventricular preload, an indirect estimate of left ventricular volume changes in ventricular compliance, intrathoracic pressures and venous return in a mechanically ventilated patient, there is a poor relationship between the CVP and right ventricle (RV) end-diastolic volume.(27-28) In 1998, Sheldon Magder published an article called "More respect for the CVP" arguing that optimization of cardiac output starts with right atrial pressure, which can be easily measured by CVP, and it also tells about the harmful effects of therapy on heart and lungs.(12) In 2005, Magder supported CVP use once again and concluded that it is not just a digital number, but the waveform can provide reasonable information. (29) Since 1970, the 5-2 rule has been utilized in critical care practice, which implies that the decision of fluid management should be guided by CVP measurement. (5) This rule can be challenged in many patients in whom CVP reading cannot be considered the marker of intravascular volume status. (30) Namkje and his colleagues suggested that elevated CVP can be associated with microcirculatory compromise in septic patient. (31) In view of outcomes of two trials published in 2015, ProCESS and ARISE trials, intensivists have moved away from routine use of CVP for fluid management. At present, CVP has a much restricted role due to the advancement in noninvasive measures of hemodynamic monitoring. (20-22)

Surgical patients:

The use of CVP in the surgical world has been supported by several observational studies. (32) Judson et al suggested that CVP monitoring following coronary artery bypass graft (CABG) surgery can predict early mortality and renal failure. (33) This hypothesis was further supported by Venn and his colleagues for orthopedic surgery cases by concluding that intraoperative CVP monitoring during femoral fracture repair has reduced the length of hospitalization.(34) Buhre et al also concluded that CVP monitoring until 6 hours postoperatively has some effect on RV end-diastolic volume but its ability to indicate change in cardiac volume indices is limited.(35) In a series of 31 patients receiving a renal graft transplant, fluid replacement guided by the central venous pressure was shown to reduce the number of kidneys with delayed function in the immediate postoperative period. (36) Stewart et al, in a series of 194 patients undergoing low-risk CABG surgery, compared CVP monitoring with pulmonary artery (PA) catheter monitoring.(32) They concluded that CVP was associated with fewer complications preoperatively and less time on ventilator, resulting in reduced length of stay in the ICU compared to PA catheterization. A 7.7% lower cost was noted in the CVP group. Smyrniotis et al suggested elevated CVP during major liver resections results in greater blood loss and a longer hospital stay. (37)

With the advent of fast-track management protocols that include patient care using a combination of several evidence-based peri-operative interventions to expedite recovery after surgery, the role of CVP in perioperative hemodynamic monitoring has faded.(37-39) Dunki-Jacobs noted that CVP monitoring requires preoperative placement of a CVC, which can be associated with increased time, cost, and adverse events.(38) Francesca Ratti et al suggested that use of noninvasive methods in laparoscopic surgery is better in terms of intraoperative blood loss, need for transfusions, length of surgery and postoperative results compared to CVP.(39) Claus and colleagues also challenged the importance of CVP in liver transplant in an observational study on 50 patients undergoing living-donor hepatectomy.(40) CVP monitoring did not appear to reduce blood loss compared with patients without CVP monitoring. In centers with extensive experience, CVP monitoring may not be necessary in this highly selective patient population. Domino et al showed that use of central venous catheterization has also been associated with more injuries, liabilities, and complications, such as wire/catheter embolus, cardiac tamponade, carotid artery puncture/cannulation, hemothorax, and pneumothorax. (41)

Coronary care patients:

In cardiogenic shock, hemodynamic monitoring has prognostic value and is helpful in risk stratification. (40-42) Jeger et al concluded that baseline and follow-up hemodynamic parameters are the most powerful tools to predict 30-day mortality in cardiogenic shock.(42) Use of CVP monitoring in coronary care units is accompanied by PA catheterization, as advanced indices are utilized in the management in critically ill patients. Several factors can influence the reliability of CVP, including cardiac arrhythmia, valvular heart disease, pulmonary vascular abnormalities and compliance of vessels. Thus, CVP is only used for assessment of fluid responsiveness as a surrogate for preload. Collins et al concluded that measurement of CVP is not indicated in uncomplicated acute myocardial infarction. Later, Forrester concluded that CVP monitoring in acute myocardial infarction is of limited value and, at worst, seriously misleading. (43)

Quain et al conducted a study on 269 heart failure patients and concluded that CVP-guided fluid administration can safely and effectively reduce the risk of CIN in patients with CKD and CHF, while also reducing the adverse events in high risk patients. (44) This has been countered by Saraschandra, who indicated that the roles of static measures of fluid status (such as CVP and pulmonary capillary wedge pressure, PCWP) are increasingly being replaced by dynamic measures. (45) Daniel De Backer considered that most of the trials indicating unfavorable use of invasive hemodynamic monitoring in acute heart failure management are subject to selection bias, as these patients already have higher mortality rates, and thus invasive techniques may still have a place in selected patients with acute circulatory failure and, especially, in the most severe cases. (46) Hemodynamic assessment by CVP monitoring in a patient with pericardial diseases (constrictive pericarditis and pericardial tamponade) is useful in diagnosis and, more importantly, in differentiating pericardial from myocardial disease. (47)

Take-home points:

Fluid responsiveness: The presence of extreme values on CVP may be more useful than intermediate numbers in assessing fluid responsiveness. In a systemic review, the authors acknowledged a "gray-zone" approach to determine fluid responsiveness, i.e., a positive response was more likely to be observed when CVP was less than 6 mm Hg, and a response was unlikely when CVP was more than 15. (48)

Perioperative Use: CVP is important in major liver surgery and is correlated with better outcomes.

Cardiac Transplantation: CVP may be useful to assess right ventricular function in patients with acute pulmonary embolism, cardiac transplant or right ventricular infraction.

Constrictive Pericarditis: It can be used to differentiate constrictive pericarditis with cardiac tamponade.

Complete heart block: The waveform can assist in diagnosing complete heart block and assessment of pacing functions in atrio-ventricular sequential pacing.

SWAN GANZ CATHETER OR PULMONARY ARTERY CATHETER (PAC):

In the United States, use of PAC peaked in the 1990s to the extent that 1.5 million catheters were sold annually, with a utilization rate of 5.6 per 1000 hospital admissions.(49) PAC use is more common in the US than in Europe at present, with most utilization in cardiac surgery units and coronary care units.(49-53)

Historical perspective:

The current use of PAC for hemodynamic monitoring was introduced 1941, when pulmonologist Dr. Andre Cournand collaborated with a cardiovascular expert, Dr. Dickinson Richards, in Bellevue Hospital, New York. (54-58) They improvised the prior catheters and utilized PAC for the first time in collecting mixed venous blood and measuring cardiac output using Fick's principle. In 1949, the use of PAC to measure pulmonary capillary wedge pressure to estimate left atrial pressures was demonstrated by Lewis Dexter of Harvard Medical School. It was in 1970 when Dr. HJC Swan in Cedars-Sinai Hospital introduced PAC as a bedside tool to guide hemodynamic studies in critically ill patients. He was inspired by the spinnaker of a sail boat and used flow-guided PAC in the clinical setting. Subsequently, William Ganz applied the thermodilution method to measure cardiac output using fluoroscopic techniques. This culminated in the final design of the Swan-Ganz catheter, consisting of two lumens, one for balloon inflation and the other to record pressures. The design was ultimately modified by the addition of a thermistor to measure cardiac output for commercial use in a variety of medical fields. (54-58)

During the 1980s, PAC was considered an essential component of management in critically ill patients, and nearly one-third of intensive care patients were reported to undergo this procedure.(58) Its substantial role was first challenged by Eugene Robin, raising concerns about PAC safety, which was further supported by Connors and his colleagues in an observational multicenter study with 5000 patients in 1996.(59-60) The turning point in the success of PAC was a publication by Sandham et al in 2003, in which 1994 critical surgical patients were randomized to compare goal-directed therapy guided by PAC with standard care without using PAC. (61) They demonstrated no benefit in mortality or length of hospitalization with the use of PAC in high-risk surgical patients with increased risk of pulmonary embolism in the catheter group (8 events versus 0 events).

Subsequently, Harvey et al published an assessment of clinical effectiveness of PAC in critical care patients (n=1041) by doing an RCT in 64 UK-based medical centers, concluding no difference in mortality; instead, risk of complications was high with the use of PAC.(62) In the meanwhile, French researchers demonstrated no benefit of PAC in a selected cohort of ARDS patients, supported by Wheeler et al, who compared PAC with CVC to guide fluid therapy in ARDS patients, finding no benefit in mortality.(63-64) In heart failure patients, the ESCAPE trial randomized 433 patients and suggested PAC has no significant role in the management of this group of patients.(65)

Medical critical care patients:

The role of PAC in the medical ICU was challenged in 1994 by SURVIVOR investigators showing increased mortality, increased LOS in the ICU and risks of complications with the use of PAC. (66-68) In 1996, a survey from SCCM showed that 33% of the physicians were not able to identify the PAOP waveform, supported by Johnson et al's survey of ICU nurses, which found that fewer than half of the respondents characterized the tracing correctly. (69-71) In 2005, European investigators performed an observational study on 3147 patients and concluded that PAC use was not associated with increased mortality. (69-71) Thus, there had been many editorials published against the use of PAC, which led to the Cochrane study in 2013 that concluded, after a review of 13 studies including 5686 patients, that PAC did not alter the mortality, critical care length of stay or healthcare cost-effectiveness, and the authors demanded a specific protocol for its use in selected groups. (72)

Coronary care patients:

Forrester and his team used PAC for acute myocardial infarction (AMI) and described several physiologic parameters that intrigued clinicians.(73) In 2006, Finke et al generated novel hemodynamic parameters, such as cardiac power, using PAC in 541 patients who were in cardiogenic shock and showed that they were strongly correlated with mortality in this group.(74) Later, several studies across the globe showed that PAC is associated with more complications and perhaps increased mortality.(75-80) Zion et al assessed PAC use in 5841 AMI patients and found an elevated risk of mortality. (81) Most physicians use PAC in seriously ill cardiogenic shock patients and to differentiate between cardiogenic and noncardiogenic pulmonary edema. PAC is also the procedure of choice to diagnose pulmonary hypertension.

Surgical patients:

In 1984, Eisenberg et al demonstrated that PAC-guided management is both indicated and useful in the surgical intensive care unit. (82-85) Del Guercio utilized PAC-assessed parameters to reduce operative mortality in the elderly. (82-85) Shoemaker demonstrated a mortality benefit and decreases in length of hospital stay and ICU stay in surgical patients with the use of PAC-guided monitoring. (82-85) Later, in 2003, a randomized controlled trial was published on the use of pulmonary-artery catheters in high-risk surgical patients, which showed no benefit.(86) In 2008, Fellahi et al demonstrated increased mortality with PAC-guided use of dobutamine. (87)

In cardiac surgery patients, the use of PAC was supported by Pinsky et al in 2005 with the publication stating, 'Let us use the pulmonary artery catheter correctly and only when we need it.' (88) The idea was further supported by Marco in 2006, who agreed that PAC has a certain role in selected patients, especially those with depressed left ventricular function. (89)According to Marco, trans-esophageal echocardiography (TEE) seemed to be the biggest benefit of PAC, but with proper training, PAC has a role in real-time hemodynamic studies. (89)

Take-home points:

A review of literature from medical-surgical and cardiac ICUs shows that there have been considerable arguments and editorials regarding the use of PAC. Paul E Marik's review mentioned that PAC-generated data are not accurate, result in over treatment, are not useful in clinical practice and therefore can be associated with complications.(51) Steven Greenberg remarked that specific training is required to interpret PAC parameters and data for appropriate patients in timely manner. (50) Bobby et al reviewed 100 years of history of right heart catheterization and concluded that the use of PAC is a monitoring procedure rather than a treatment and can provide the physician the advantage of continuous hemodynamic monitoring for early therapeutic management before clinical decompensation. (52) Gidwani et al also commented that PAC remained a diagnostic intervention at the bedside with proven utility, but it requires higher skills for interpretation and selection of patients. (53)

Heart failure: PAC can be used in decompensated heart failure to guide management, to differentiate cardiogenic versus noncardiogenic pulmonary edema and to assess prognosis.

Complicated MI: It can help to differentiate cardiogenic versus hypovolemic shock and can help in guiding pharmacologic therapy with mechanical complications of MI until surgery is planned. With pulmonary edema refractory to diuretics and nitroglycerine, it can guide further management (Fig 1).

Pericardial tamponade: With PAC tracing, pericardial tamponade can be diagnosed if echocardiography is unyielding (Fig 1).

Perioperative use: It can be utilized in cardiothoracic surgeries to assess low cardiac output to guide management.

Pulmonary hypertension: It can assist in categorizing types of pulmonary hypertension and, with vasodilatation testing, can guide future therapy.

Transplant: It can help in evaluation and hemodynamic monitoring for heart and lung transplantation.

Congenital heart disease: Assessment of the magnitude and level of intracardiac shunt if echocardiography is nondiagnostic.

INFERIOR VENA CAVA PULSE VARIABILITY INDEX (IVCPVI):

In the recent era, much emphasis has been given to dynamic parameters of hemodynamic monitoring. With the use of point-of-care ultrasound (POCUS), clinicians are more drawn towards IVCPVI to assess the volume responsiveness, especially in critical care and emergency room settings. (90) (91) Focused assessed transthoracic echocardiography (FATE) was introduced to quickly screen the volume assessment and cardiac contractility. According to Muller et al, IVC variability of >40% is a predictor of fluid responsiveness in spontaneously breathing subjects, compared to <40%, which cannot rule out fluid requirements. (90) In mechanically ventilated patients, fluid responsiveness is likely if the IVC distensibility is > 18%. The diameter of the IVC is measured by transthoracic echocardiography in a subcostal view at end-expiration and end-diastole in the supine position.

Medical critical care patients:

There is considerable evidence supporting the use of IVCPVI as a bedside tool for volume assessment in mechanically ventilated critically ill patients.(90-92) In a meta-analysis by Huang et al, the authors concluded that the change in IVC diameter performed moderately well in predicting fluid responsiveness in patients with circulatory shock receiving mechanical ventilation, with a pooled area under the curve of 0.82 (95% CI, 0.79–0.85). Although the analysis had much strength, it did not include detailed clinical dynamics of subjects and was not applied in a surgical population. (91) Similarly, Barbier and his colleagues compared IVC variability with CVP in septic shock and remarked that baseline central venous pressure did not accurately predict fluid responsiveness. (92) The authors further concluded that IVCPVI predicts better in mechanically ventilated subjects than spontaneously breathing patients and in colloid-fluid resuscitation compared to crystalloid-fluid resuscitation. In a meta-analysis of 17 studies, it was concluded that in spontaneously breathing patients, IVC variability has a limited role and cannot be used to assess the preload. (93) The difference in spontaneous versus mechanically ventilated populations is explained by the fact that intrathoracic pressures and tidal volume vary in spontaneously breathing patients. (90) On the other hand, Mitaka et al explained that at higher PEEP, IVC collapsibility can give false information about volume assessment. (94) An interesting application of IVC variability was observed in hemodialysis patients, in whom it was proposed as a simple and reliable tool to predict dry weight in the dialysis population. (95)

In summary, IVCPVI is an easily available tool to assess preload in the ICU but has a controversial role in its prediction. It can be utilized to assess volume readiness if detailed clinical information is available. (95-98)

Coronary care patients:

In cardiac patients, IVC diameter is considered a surrogate marker for right atrial pressure. (99) In a small study enrolling 89 patients presenting to the ER, bedside measurement of the caval index (the percentage decrease in the IVC diameter with respiration) was considered a use full tool in diagnosing acute heart failure in situations with undifferentiated dyspnea.(100) In another study using handheld cardiac ultrasound assessment of IVC, it was shown that IVC variability can be utilized to guide diuretic therapy and has a significant impact on reducing readmissions in acute heart failure syndrome. Cardiac volume assessment has an important role in guiding the diagnosis and management of heart failure patients. (100) (101) Clinical assessment by bedside physical exam maneuvers lacks accuracy and varies with expertise. In one study comparing JVP assessment using traditional physical exam with IVC diameter variation measurement, it was evident that IVC diameter assessment was superior to JVP assessment in RAP prediction (71% versus 60%),(102) In a small study by Sascha et al, IVC diameter assessment at the time of admission and discharge along with BNP had predictive value to estimate CHF readmissions.(101) The importance of IVC diameter is overshadowed by the fact that valvular regurgitations and arrhythmias are common in these patients, which can lead to inaccurate assessment of volume by using IVC diameter. (102)

Similar to medical patients, IVC diameter itself lacks accuracy in coronary care patients but can be useful in conjunction with other hemodynamic parameters. Its role in cardiogenic shock and mechanical complications after myocardial infarction is still not clear.

Surgical patients:
Intravascular volume assessment during the peri-operative period relies on clinical examination and strict intake and output monitoring. (103-105) Fluid assessment intraoperatively can be estimated by IVC diameter, especially when using anesthesia. In a study by Zhang et al, preoperative IVC measurement was considered a reliable tool to predict hypovolemia during induction of anesthesia. (103) Go-guang et al proposed that in mechanically ventilated postoperative cardiac surgery patients, internal jugular and inferior vena cava variability are useful and noninvasive methods to assess fluid responsiveness. (104) On the other hand, the role of such variations in the intraoperative course is vaguely described and has been debated (104) (105) because intrathoracic and intra-abdominal pressures can vary depending on the type of surgery, which can affect IVC diameter. Several studies from the anesthesia literature have shown that adequate analgesia is required in the postoperative period to attain accurate volume assessment from IVC. (104) (105) In an observational study by Ayhan and colleagues, IVC diameter did not provide added information in the pre- or postoperative period in patients receiving standard fluid therapy. (106) Although the surgical world has limited data regarding the role of IVC in volume resuscitation, it has been observed that the surgeons and anesthesiologists do not seek IVC diameter as a preferred tool to predict volume assessment in surgical patients. (107)

Take-home points:
A review of literature from medical-surgical and cardiac ICUs suggests IVCPVI can be helpful in the following clinical circumstances:

Fluid responsiveness: IVCPVI can help assess fluid responsiveness in nonspontaneously breathing mechanically ventilated patients in medical, surgical and perioperative settings.

Heart failure: IVCPVI can help identify acute heart failure in patients presenting with undifferentiated dyspnea. It can also be utilized to guide diuretic therapy.

PASSIVE LEG RAISE (PLR):
The understanding of the physiologic mechanism associated with volume expansion led to the involvement of the Starling principle in fluid resuscitation. (108)(109)(110) The passive leg raise test is a noninvasive bedside method of volume assessment that is proposed to have reliable estimation in guiding fluid therapy. It should be performed in the semi recumbent position to mobilize 300 ml of pooled peripheral blood to the systemic circulation. The change in cardiac output can be directly assessed within 1 minute either by echocardiography or by the variation in arterial pulse pressure. A change in stroke volume of 10% is considered a positive response. An increase in end-tidal carbon dioxide is a unique noninvasive method of cardiac output assessment in mechanically ventilated patients. PLR has an advantage of being accurate in situations such as cardiac arrhythmias, nonventilated patients and variations in lung volumes. Its role in the setting of elevated PEEP and intra-abdominal hypertension is still controversial Medical critical care patients:

In the critical care setting, PLR is considered an ideal test in septic shock patients due to its utility in both mechanically ventilated and spontaneously breathing patients. Monnet et al emphasized the importance of PLR as a quick volume challenge in cases when other testing is physiologically not suitable. (108) Jabot et al indicated that PLR, if done in the semi recumbent position, provides better assessment than the supine position. (109) Lakhal and colleagues combined PLR with CVP measurement and described its usefulness, but the data had limited external validity.(110) Similarly, in a meta-analysis of 9 clinical studies, the author categorically stated that PLR-induced changes in cardiac output are more reliable than any other methods of fluid assessment in an ICU setting.(111) In contrast, Marik et al considered that although PLR provides more information of hemodynamics compared to static measures, its utility in spontaneous ventilation is limited. (112) Since then, meta-analyses and systematic reviews have showed the importance of PLR in critically ill patients. This is the reason that PLR is recommended in surviving sepsis patients and is promoted by many intensive care societies. (113)

Coronary care patients:
In the coronary care setting, the data regarding the utilization of PLR are limited. In a study by Xavier et al regarding role of PLR in fluid removal in critical care patients on renal replacement therapy, estimation of preload using PLR assisted in predicting hemodynamics in hemodialysis patients. (114) Although the importance of PLR has been reinforced in cardiac surgery cases, its role in heart failure and after myocardial infarction is yet to be explored. (115)

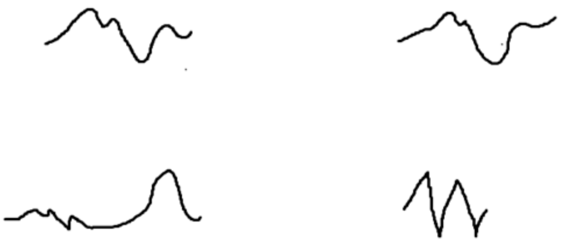
Surgical patients:
In perioperative care, PLR has received great interest to guide fluid management. (116) Zorko et al proposed the concept of the Trendelenburg position as a fast maneuver to attain fluid resuscitation in spinal anesthesia. (117) Later, Reuter and colleagues used the same concept in cardiac surgery patients, and they concluded that although the Trendelenburg position can change in preload, it does not have a beneficial effect on cardiac output. (118) Frost took a step forward and remarked that although PLR does not yield any change in cardiac output, it can provide a quick assessment of whether fluids are needed in the peri-operative period. (119) Finally, in a study of 120 cardiac surgery patients, the author asserted that PLR-based volume assessment is informative and can help to avoid anesthesia-related hypotension in adults undergoing cardiac surgery. (120) In conclusion, the use of PLR-based fluid resuscitation is not explored in all areas of the surgical world, and it needs to be studied in all operative settings. (121) Although its usefulness in abdominal surgeries is limited, being based on anecdotal data, it can provide basic information to guide advanced measures of resuscitation. (122)

Take-home points:
A review of literature from medical-surgical and cardiac patients suggests PLR can be helpful in the following clinical circumstances:

Fluid responsiveness: PLR can help assess fluid responsiveness in spontaneously breathing as well as nonspontaneously breathing mechanically ventilated patients in medical, surgical and perioperative settings.

CONCLUSION
In a nutshell, dynamic methods of hemodynamic monitoring are preferred over static measures in critically ill patients, though there is no single best assessment tool that can guide fluid resuscitation. Thus, the key is to utilize and correlate clinical acumen with available functional parameters. More study is warranted to guide volume estimation in conditions such as heart failure and acute respiratory distress syndrome and its validity in spontaneously breathing patients.

Figure 1:
Normal Waveform **Cardiac Tamponade**



Complete heart block **Constrictive pericarditis**

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