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ORIGINAL ARTICLE

Central venous line (CVL): Importance of its use in the Cardiac ICU and its complications

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Abstract:

A key concept of management of the patients in the intensive care unit (ICU) during immediate postoperative period is optimization of cardiovascular function including provision of an adequate circulating volume and titration of cardiac preload to improve cardiac function. Monitoring circulatory filling as well as cardiac preload is done by measuring the central venous pressure (CVP) with the use of a central venous line (CVL). So, all patients undergoing open heart surgery cannot go without CVP monitoring.

In the department of Cardiac Surgery CVL serves many other purposes in the management of peri-operative patients, particularly those in the ICU, in addition to CVP monitoring. These may include massive blood or fluid transfusion, administering multiple drugs simultaneously for prolonged period, giving medicines that affect heart, especially if quick response is required, taking frequent blood samples etc.

But placement of CVL is a highly technical job that is usually performed by anesthetists and is associated with some complications. These complications are not common but may cause significant morbidity and possibly even mortality even when CVL access is obtained by experienced staff.

Our study period was from January 2010 to January 2015 and our study sample was randomly selected 3000 patients. All patients underwent open heart surgery and all patients underwent CVL insertion. To manage ICU patients, we monitored CVP of all patients. Measured CVP helped management of ICU patients, determined outcome and prognosis. Patients with CVP remaining equal to or less than preoperative CVP with no or single inotropic support required minimum ICU stay (1-2 days) 1583(52.77%). Patients with CVP remaining equal to or less than preoperative CVP with multiple inotrope required 2-4 days ICU stay 1144(38.13%). But those whose CVP remained greater than preoperative CVP or CVP greater than 15 cm of water had ICU stay greater than 4 days 273(9.1%) and mortality was greatest in this group of patients.

Key Words: *Central Venous Line, Central venous pressure, Internal jugular vein, Subclavian Vein, External Jugular Vein, Right Atrium*

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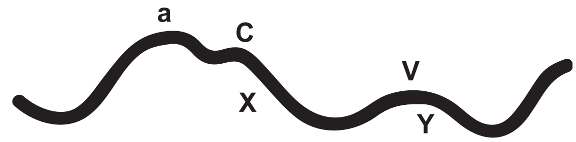
Introduction:

Inspite of the appearences of several newer monitoring technologies, central venous pressure monitoring remains in common use as an index of circulatory filling . [1] Central venous access is achieved through various routes such as internal jugular vein (IJV), sub clavian vein (SCV), external jugular vein (EJV) etc. But in NICVD and all other cardiac centers of Bangladesh, IJV is used commonly via anterior approach. Less frequently and when access through IJV is failed, SCV and EJV route is used. Through these routes central venous catheter tip reaches into superior vena cava (SVC) or into Right Atrium (RA)[2]. Central veins are those great veins that open into RA without any intervening valves. [3] Monitoring circulatory filling as well as cardiac preload is done by measuring the central venous pressure with the use of a central venous line keeping the patient in supine position in a point over the right atrium at the intersection of 4th intercostals space with the mid axillary line.[4]

Normal value of CVP ranges from 0 to 6 cm of water. CVP is the index of circulatory filling and cardiac preload. It actually measures right atrial pressure. CVP is commonly measured by means of fluid filled cannula (CVP catheter) with its tip into SVC or RA, connected to either a fluid filled manometer or more commonly to an electronic pressure transducer linked to a monitor which will display a continuous pressure wave.[3]

Central venous waveform has three ascending waves (a, c & v) and two descending waves (x & y). a wave is due to atrial systole. a wave is followed by x descent which corresponds to atrial relaxation. x descent is punctuated by c (+ve) wave. c wave is caused by closure and bulging back into RA of the tricuspid valve leaflet during ventricular systole. v wave is caused by build up of pressure into atria due to continued venous return into atria when tricuspid valve (TV) is closed as a result of ongoing ventricular systole and early diastole. y descent is due to opening of tricuspid valve and rapid passive flow of atrial blood into ventricle. But in the department of Cardiac Surgery, we use only average baseline CVP.[5]



Central Venous Trace

CVP is influenced by volume of blood in the central venous compartment and compliance of that compartment. There is definite relationship between venous return and CVP, and, CVP and cardiac output.[1,6] Increasing CVP (i.e. preload) by infusing fluid or blood increases cardiac output proportionately.[6] But this occurs up to a point beyond which further increase in CVP will not increase cardiac output. Moreover it will carry the risk of fluid overload. This is the minimum CVP for maximum cardiac output. [7]

There are some factors that affect measured CVP.[4] They are as follows;

1. Central venous blood volume:
   - Venous return
   - Total blood volume
   - Regional vascular tone
2. Compliance of central compartment:
   - Vascular tone
   - Right ventricular compliance
     - Myocardial disease
     - Pericardial disease
     - Tamponade
3. TV disease :
   - Stenosis
   - Regurgitation
4. Cardiac rhythm:
   - Junctional rhythm
   - Atrial fibrillation (AF)
   - Atrioventricular rhythm
5. Reference level of transducer
6. Intra-thoracic pressure:
   - Respiration
   - Intermittent positive pressure ventilation (IPPV)
   - Positive end expiratory pressure (PEEP)
   - Tension pneumothorax

But the CVP of the patients in the ICU who underwent open heart surgery is little affected by vasomotor reflexes which have been blocked pharmacologically by the anesthetic agents. Other cardiac organic factors that might affect measured CVP are absent in our patients because they have been surgically corrected. Moreover intra-thoracic pressure [eg respiration, Intermittent positive pressure ventilation(IPPV), Peak end expiratory pressure(PEEP) etc] will not affect CVP because we measure CVP at the end of expiration in the absence of PEEP.

Potential uses of CVL:

Measurement of CVP:

Measurement of CVP is extremely important for management of patients in the ICU during immediate post operative period following open heart surgery. CVP which is an index of preload is a common essential invasive monitoring system of these patients for proper fluid management. For optimum fluid therapy, we record preoperative CVP in the operation theater just before starting operation. This preoperative CVP acts as a guide for fluid therapy.[8] After completion of surgery, we maintain CVP equal to or below preoperative CVP which is associated with good outcome.

Higher CVP or very low CVP is associated with cardiac dysfunction which may culminate to death of the patient if not intervened in time. There is a special relationship between measured CVP and outcome of the patients. After initial optimization and fluid restriction (zero balance) patients whose CVP does not cross preoperative CVP and who maintain satisfactory cardiac output with minimum inotropic support show better outcome in terms of shorter period of ICU stay. CVP higher than 15 mm Hg with multiple inotropes in higher doses is associated with poor outcome.[9]

Sometimes we utilize CVP measurement to predict fluid responsiveness of the patient. Despite CVP around preoperative CVP when we see cardiac output is not satisfactory, we give a bolus of fluid, usually 200 ml, very rapidly to raise CVP. If the rise of CVP is associated with increase in cardiac output and rise of BP, then we maintain the higher CVP. Dynamic change in CVP with respiration i.e. fall in CVP e" 1 mm Hg during inspiration is highly predictive of fluid responsive cardiac index (CI).[10,11]

Other uses of CVL (Besides CVP measurement) :

Besides CVP measurement CVL has many other important uses in the department of Cardiac Surgery[12]:

- To give multiple inotrope and vasoactive drugs simultaneously for prolonged period.
- To give medicine that affect heart specially if quick response of the medicine is required.
- To give medicine which is very irritant for the vein and tissue if given through a peripheral line, eg K^+
- To give large amount of blood or fluid quickly.
- To take frequent blood samples.
- To give parenteral nutrition occasionally when required (eg. during prolonged ventilation).

Despite its important use in the department of Cardiac surgery, the CVL is associated with some hazards or complications, a few of which may be life threatening.[13,14] A list of complications is given below:

1. Arterial puncture
2. Blood stream infection
3. Hemothorax
4. Pneumothorax
5. Hemopneumothorax
6. Vessel occlusion
7. Catheter malposition
8. Catheter induced thrombosis
9. Arrythmia
10. Venous air embolism
11. Hematoma
12. Endocarditis
13. Multiple punctures & change of route of access
14. Thrombosis

But the benefits of the use of CVL in the department of Cardiac Surgery is indispensible and life saving and it greatly outweighs the danger of the complications associated with its placement.

Materials and methods:

This study was conducted at the department of Cardiac Surgery, NICVD, Dhaka, Bangladesh.

The period of study was from January, 2007 to January, 2016. A retrospective observational study was performed. In this study all adult patients (18^+ years) who underwent open heart surgery were included. The patients were randomly selected. We enrolled 3,000 patients in our study.

After the patient has been shifted from operation theater (OT) to ICU, we connect the patient with monitor and ventilator. We revise fluid, blood, inotrope to optimize hemodynamic condition. Then we send blood sample for arterial blood gas (ABG), electrolytes and random blood sugar (RBS) and urgent requisition for chest X-ray. We analyze the reports and correct accordingly if any derangement was noted and reset ventilator if required. This optimized state is the study point of CVP monitoring. We record CVP every one hour and half hourly in some patients if deemed appropriate. We restrict fluid and try to keep in a state of zero balance. We classify our patients in three categories:

1. Whose CVP remain equal to or below preoperative CVP and requires no or minimum inotropic support (eg. single inotrope) to maintain satisfactory hemodynamic condition.
2. Whose CVP tends to rise above preoperative CVP but be kept equal to or below preoperative CVP with moderate dose of single or multiple inotrope to maintain satisfactory cardiac output.
3. Whose CVP remains above preoperative CVP or above 15 mm Hg despite high doses of multiple inotropes.

We assessed their outcomes in terms of period of ICU stay. We also analyzed the CVP of patients who died in ICU during early post operative period. Other uses of CVL & its complications were also recoded and analyzed.

But placement of CVL is a highly technical job that is usually performed by anesthetists and is associated with some complications. These complications are not common but may cause significant morbidity and possibly even mortality even when CVL access is obtained by experienced staff.

Results:

Demographic data analysis shows that male: female is about 3:2.Distribution of number of patients in different age groups shows small variations with maximum concentration in 56-65 years and minimum in >65 years age. (Table l)

The patients (52.77%) whose CVP remains equal or less than preoperative CVP with no inotrope or single inotrope are associated with excellent outcome of surgery in terms ICU stay (1-2 days).But those (91% of patients) whose CVP tends to remain higher than preoperative CVP or higher than 15 mm of Hg. despite the support of higher doses of multiple inotropes are associated with worst outcome (> 4 days).An intermediate group of patients (38.13%)whose CVP was kept equal or

Table-I

Age and sex distribution of patients.(n=3000)

SL	Age(yrs)	male	female	total	Percentage (%)
1	18-25	210	302	512	17
2	26-35	252	238	490	16
3	36-45	356	242	598	20
4	46-55	218	187	405	13.5
5	56-65	432	183	615	20.5
6	>65	258	122	380	13
total				3000	100

Table-Il

Relationship between CVP with inotropes and length of ICU stay (n=3000)

Category	CVP with inotrope	No. of patients	ICU stay	Percentage
1	CVP ≤ preoperative CVP with single or no inotrope	1583	1-2 days	52.77%
2	CVP ≤ preoperative CVP with multiple inotropes	1144	2-4 days	38.13%
3	CVP Ã preoperative CVP or > 15 mm Hg with high dose of multiple inotropes	273	> 4 days	9.1%

less than pre operative CVP with moderate dose of multiple inotropes have also satisfactory outcome (2-4 days).(Table ll)

There is strong relation between CVP and mortality following cardiac surgery.90.67% mortality is associated with very high CVP (>15 mm of Hg).Mortality is very low (9.33%) seen in patients with CVP equal or less than preoperative CVP. (Table lll)

CVL has multiple essential uses in cardiac ICU and used to take frequent blood sample from all patients (100%).But its most important common uses are to monitor CVP (100%) and to give multiple inotropes, other vasoactive medications and antibiotics for prolong period (99%).Other common and important uses of CVL are rapid infusion of large volume of blood and fluid (93.13%) and rapid optimization of serum potassium through CVL (60.43%).Parental nutrition (1.73%) and medication other than inotrope (5.03%) are less frequent uses of CVL.(Table IV)

Complications due to CVL insertion and in situ position are uncommon and most are amenable

Table-IIl

Relationship between CVP and mortality (total mortality n=150)

SL	CVP	No. of death	Percentage
1	CVP ≥ 15 mm Hg	136	90,67%
2	CVP ≤ preoperative CVP	14	9.33%

Table-IV

Uses of CVL in cardiac ICU (n=3000)

SL	Use	No. of patients	Percentage
1	Monitoring of CVP	3000	100%
2	To give multiple inotropes and vasoactive medications and antibiotics for prolonged period	2970	99%
3	To give K^+(irritant, if given peripherally)	1813	60.43%
4	Rapid infusion of large amount of blood and fluid	2794	93.13%
5	To take frequent blood samples	3000	100%
6	To give parenteral nutrition	52	1.73%
7	To give medicines (other than inotropes) whose quick response is essential (eg. amiodarone, sodi-bi-carb, lignocaine, dessication therapy etc.)	151	5.03%

Table-V

Complications of CVL (insertion and in situ position): n=3000

SL	Complications	No. of patients who sustained the complication	Percentage
1	Arterial puncture	63	2.1%
2	Blood stream infection	46	1.53%
3	Hemothorax	12	0.4%
5	Pneumothorax	18	0.6%
4	Catheter malposition	14	0.47%
5	Arrythmia	7	0.23%
6	Hematoma	87	2.9%
7	Endocarditis	1	0.03%
8	Haemopneumothorax	4	0.13%
9	Multiple puncture & change of route of access	122	4.07%

to minor intervention. Hemothorax (0.4%), blood stream infections (1.53%) and endocarditis (0.03%) are also seen and these may be very dangerous and life threatening. (Table V)

Discussion:

In the department of cardiac surgery, CVL is inserted in all patients undergoing open heart surgery. CVL insertion is mandatory because of its indispensable uses in peri-operative patients. CVL is inserted in OT before starting operation and preoperative CVP is recorded.

CVL is used to measure CVP in ICU. It is a common essential monitoring system to manage postoperative patients in ICU. It is useful for judicious use of fluid management and determination of appropriate inotropic support. After initial stabilization measured CVP reflects outcome and prognosis of the patients. It is obvious from this study (Table ll) that if patients' CVP remains d" preoperative CVP with minimal or no inotropic support, patients' recovery is good and associated with shorter period of ICU stay. If the patients need multiple support and higher doses, ICU stay period is seen to increase parallely. If the patients' CVP remains higher despite high doses of multiple inotropes, the prognosis is poor and mortality is higher in this group. This observation correlates well with the work of Rady MY, Ryan T et al in 1998.[9]

We analyzed CVP of the patients who died in immediate and late postoperative period and could establish a clear cut relationship between measured CVP and mortality. Most death cases had high CVP (> preoperative) and high doses of multiple inotropes.[9]

We studied other uses of CVL. In most patients (100%) CVL is used to give multiple medications simultaneously (inotropes, vasoactive and cardioselective medications). In 93.13% patients CVL is used to give large amount of blood and fluid transfusion. All patients required frequent blood sampling through CVL. Frequent electrolyte monitoring and correction is a common procedure in immediate postoperative cardiac patients and many patients require K^+ infusion which is irritant if infused through peripheral lines. In our study, 60.43% patient required K^+ infusion through CVL. 52 (1.73%) patients required parenteral nutrition through CVL for prolonged ICU stay due to complications. CVL is also used to give medicines (other than inotropes) where quick response was essential such as amiodarone, sodibicarb etc. in about 5.03% of patients. Almost similar uses have been shown in the study of Boon, J.M., Van Schoor et al. 2008.[12]

CVL related complications were not common (6%).[5] Arterial (carotid>subclavian>femoral artery) puncture occurred in 63 (2.1%) patients. Blood stream infection noted most commonly in those patients whose CVL remained in situ for longer period and occurred in 1.53% cases. Haemothorax occurred in 12 (0.4%) cases, two of which developed instability before opening chest due to gross concealed hemorrhage into right pleural cavity. Although no other studies found hemothorax while doing CVL insertion through internal jugular vein. Local hematoma was the commonest complication and occurred in 87 (2.9%) patients. Catheter related arrhythmia and endocarditis were two less frequent complications. One (0.03%) patient developed CVL related prosthetic valve endocarditis. Same organism was isolated from blood C/S and CVL tip C/S. This patient died due to failure to control infection. Although this was a very very rare CVL related complication, it was life threatening. The complication rate of our study is closely related to the work of Sznajder Ji et al. 1986.[15]

Conclusion:

To manage ICU patients following open heart surgery, CVP measuring is essential for judicial fluid management and selection of inotropes and vasoactive drugs. Measured CVP can reflect outcome and prognosis of these patients. CVL has many other valuable uses in ICU patients, which cannot be replaced by peripheral lines. But there are some CVL related complications, a few of them, if occur, are very dangerous. In spite of this, use of CVL in cardiac ICU is so indispensable and life saving for each patient that it greatly outweighs its potential risks of complications. All doctors and nurses managing postoperative cardiac patients should have adequate knowledge regarding the use and importance of CVL.

Reference:

1. Patterson SW, Piper H and Starling EH. The regulation of the heart beat. *The Journal of physiology*. 1914;*48*(6):465-513.
2. Bannon MP, Heller SF, Rivera M. Anatomic considerations for central venous cannulation. *Risk management and healthcare policy*. 2011; *4*:27.
3. Reems MM, Aumann M. Central venous pressure: principles, measurement, and interpretation. *Compend Contin Educ Vet. 2012;34*(1):E1.
4. Godje O, Peyerl M, Seebauer T. Central venous pressure, Pulmonary capillary wedge pressure and intrathoracic blood volume as preload indicators in cardiac surgery patients. *European Journal of Cardio-Thoracic Surgery. 1998;* 13: 533-540.
5. Vincent JL ED. Updates in Intensive Care & Emergency Medicine. Functional hemodynamic monitoring. Brussels. Springer. 2017; Vol 42: 99.
6. Patterson SW, Starling EH. On the mechanical factors which determine the output of the ventricles. *The Journal of physiology*. 1914;*48*(5):357-379.
7. Kuhtz-Buschbeck JP, Lie RK, Schaefer J, Wilder N. Reassessing diagrams of cardiac mechanics: from Otto Frank and Ernest Starling to Hiroyuki Suga. *Perspectives in biology and medicine*.2016;*59*(4):471-490.
8. Venn, R., Steele, A., Richardson, P., Poloniecki, J., Grounds, M. and Newman, P., 2002. Randomized controlled trial to investigate influence of the fluid challenge on duration of hospital stay and perioperative morbidity in patients with hip fractures. *British journal of anaesthesia*, *88*(1), pp.65-71.
9. Rady MY, Ryan T, Starr NJ. Perioperative determinants of morbidity and mortality in elderly patients undergoing cardiac surgery. *Critical care medicine*. 1998;*26*(2):225-235.
10. Magder S, Georgiadis G, Cheong T. Respiratory variations in right atrial pressure predict the response to fluid challenge. *Journal of Critical Care*. 1992;*7*(2):76-85.
11. Magder S, Lagonidis D. Effectiveness of albumin versus normal saline as a test of volume responsiveness in post-cardiac surgery patients. *Journal of critical care*. 1999;*14*(4):164-171.
12. Boon JM, Van Schoor AN, Abrahams PH, Meiring JH, Welch T. Central venous catheterization—An anatomical review of a clinical skill, Part 2: Internal jugular vein via the supraclavicular approach. *Clinical Anatomy*. 2008;*21*(1):15-22.
13. Smith RN, Nolan JP. Central venous catheters. *Bmj*,2013;347:f6570.
14. McGee DC, Gould MK. Preventing complications of central venous catheterization. *New England journal of medicine*. 2003;*348*(12):1123-1133.
15. Sznajder JI, Zveibil FR, Bitterman H, Weiner P, Bursztein S. Central vein catheterization: failure and complication rates by three percutaneous approaches. *Archives of internal medicine*. 1986;*146*(2):259-261.