Prospects of Jugular Venous Pulse Assessment

Bhattarai MD[1]

[1]General Medicine Unit with Diabetes and Endocrinology Service, Bir Hospital, National Academy of Medical Sciences, Kathmandu, Nepal.

ABSTRACT

There is no controversy regarding the current clinical method of examination of waveform of jugular vein pulse. However there are limitations of clinical assessment of central venous pressure by jugular vein pressure measurement from the level of sternal angle. There are variations in the reported distances from sternal angle to right atrium as well as to upper limit of JVP. In erect position, anterior end of fourth intercostal space is at about the level of mid-right atrium. In patients with visible JVP at neck in erect position, measurement of CVP can be done more accurately directly from the anterior end of fourth intercostal space. For others, the position of mid-right atrium can be marked in lateral chest wall first in erect position at the mid-point of an anteroposterior line from anterior end of fourth intercostal space to back. Subsequently in reclining position, the vertical height of venous pressure can be measured from the horizontal plane of the midpoint marked at lateral chest wall to visible upper limit of JVP. Such measurement can be done in a more reliable way with venous pressure (VP) manometer with its indicator rod at the horizontal plane of mid-right atrium and with its horizontal surface at upper limit of JVP. The venous pressure manometer can also be used to measure relatively less reliable upper limb venous pressure (ULVP), as indicated by the vertical distance at which veins of upper limb collapse, especially when JVP is not visualized due to subnormal CVP as in hypovolemia.

Keywords: *CVP, JVP, right atrium, sternal angle, upper limp venous pressure, venous pressure, venous pressure manometer*

INTRODUCTION

Non-communicable diseases like cardiovascular diseases, chronic respiratory diseases, diabetes and others account for 60% of all deaths worldwide.[1] Glucose intolerance is one of the major predisposing factors for deaths due to cardiovascular disease and is rapidly emerging as a global health care problem that threatens to reach pandemic levels by 2030.[2-8] Cardiovascular disease alone now accounts for nearly 30% of all deaths worldwide and 27% in low-income and middle-income countries.[9,10] Thus both left-sided and right-sided heart failure is becoming increasingly common all over the world.

Clinical method of assessment of JVP is the standard way to provide important information concerning the dynamics of the right side of the heart because the jugular system is in direct continuity with the right atrium.[11-6] The abbreviation 'JVP' may be used for jugular venous pulse or jugular venous pressure.[17] The two main objectives

Correspondence:
Dr. Madhur Dev Bhattarai
General Medicine Unit with Diabetes and Endocrinology Service, Bir Hospital, National Academy of Medical Sciences, Kathmandu, Nepal.
Email: mdb@ntc.net.np
Phone: 4230710

of the examination of the neck veins are inspection of their waveform and estimation of the central venous pressure (CVP).[18] Without the assessment of both jugular venous pressure and waveform, the examination of cardiovascular examination is incomplete.

Jugular venous pressure and waveform

Usefulness of examination of jugular venous pressure

Measurement of jugular venous pressure (JVP) provides information about central venous pressure.[11,17-20] The causes of the raised jugular venous pressure from the management point of view to consider (Table 1). In cirrhosis, the venous pressure above the hepatic vein, including the jugular veins and right atrium, is usually reduced or normal.[21-3] One exception to this general rule can occur in patients with tense ascites in whom upward pressure on the diaphragm can increase the intrathoracic pressure. Although elevated initially in this setting, the central venous pressure rapidly falls to normal following the removal of a small amount of ascitic fluid, which substantially reduces the intraperitoneal pressure.[22] Similarly, in some patients, chronic heart failure can lead to cirrhosis (due to chronic passive congestion of the liver) and hemodynamically-mediated proteinuria, which on rare occasions approaches the nephrotic range.[24] Jugular venous pressure measurement can help in such situations for diagnosis. The presence of an elevated jugular venous pressure also has prognostic significance, being associated with a higher risk of progression to symptomatic heart failure in those with asymptomatic left ventricular dysfunction and a higher risk of hospitalization for heart failure or death from left ventricular dysfunction.[14,25]

Absence of raised jugular venous pressure: Absence of raised jugular venous pressure may not rule out heart failure, cardiac tamponade, constrictive pericarditis or other conditions. This could be due to

- associated hypovolemia due to fluid loss, diuretic use or bleeding,
- associated vasodilatation due to septicemia or anesthesia,
- different stages or manifestations of diseases, for example localized constriction or compression of left ventricle or inlet of inferior vena cava,
- improper technique of examination, or
- limitations of measurement of JVP from the level of sternal angle (see below).

The cardiac tamponade without elevated jugular venous pressure is also called as low pressure tamponade.[26]

Usefulness of assessment of jugular venous waveform

The normal jugular venous pulse wave or right atrial pressure wave recordings usually consist of three positive waves, a, c and v, and two negative waves, x and y.[27,28] To the naked eye, the two descents, x and y, are the most obvious events. The jugular venous pulse is abnormal in a number of disease states (Table 2).

Kussmaul's sign: Kussmaul sign is a paradoxical rise in the height of the jugular venous pressure, instead of normal "inspiratory collapse", during inspiration because the increased venous return cannot be accommodated within the right side of the heart due to the various causes. It is most often caused by severe right-sided heart failure and is a frequent finding in patients with constrictive pericarditis, right ventricular infarction, massive pulmonary embolism and tricuspid stenosis and less commonly in pericardial tamponade.[11,14,18,29-31] In patients with inferior or inferoposterior acute myocardial infarction, the presence of Kussmaul's sign almost invariably indicates predominant right ventricular infarction.[14,31-3]

Abdominal-jugular (or hepato-jugular) reflux: Pressure on the anterior abdomen raises the intrathoracic pressure and hence the pressure in the vena cava and jugular veins. Diagnostic value of distensions of jugular veins with abdominal compression in heart failure as compared to normal and its mechanisms have been a matter of interest since long.[34-41] It may be the earliest sign to appear in right ventricle dysfunction due to left heart failure or other causes, occult constrictive pericarditis or tricuspid stenosis.[18,26] In the absence of these conditions, a positive abdominal-jugular reflux suggests an elevated pulmonary artery wedge or central venous pressure.[11,12,42,43] The mechanism for this phenomenon has not been clearly elucidated.[14] The increased central venous pressure could result from increased vasoconstriction or venous tone.[34,44] Pressure on the abdomen is considered to raise the intrathoracic pressure and hence the pressure in the vena cava and jugular veins and to produce a transient increase in venous return to the heart.[19,29,45] Abnormal elevation of systemic venous pressure may, thus, be the consequence of volume expansion and a raised diaphragm during abdominal compression.[14,46] Normally, the right ventricle readily accommodates to such rises and translates it as more output into the lungs and there is only a transient rise in pressure. If it is only due to increased venous return to the heart, even the normal response would be absent in complete supra-hepatic inferior vena cava obstruction. The study in patients with supra-hepatic inferior vena cava obstruction may help to clarify the mechanisms of abdominal-jugular reflux.

Method of examination of jugular venous pressure and waveform

There is no controversy regarding the current clinical method of examination of waveform of jugular venous pulsations. However there are limitations of clinical assessment of CVP by jugular vein pressure measurement from the level of sternal angle. Normal central venous or right atrial mean pressure does not exceed 7 mm mercury or 9 cm blood or water. The jugular venous pressure is taken as the highest point at which a pulsation can be seen, measured vertically above the manubriosternal or sternal angle. The right atrium is generally considered to be below 5 cm and JVP is considered elevated or abnormal if it is more than 4 cm above the sternal angle. But there are individual variations in the distances from the sternal angle to the right atrium as well as to the upper limit of JVP. Though for clinical purpose it is not considered limiting, as in the majority of patients, the main value comes from determining whether the right atrial pressure is low or high, and how it changes over time or in response to medical therapy.[14] But this limitation makes the clinical measurement of central venous pressure from sternal angle arbitrary. It is, thus, even considered that there is tremendous inaccuracy in attempting to determine the pressure in the right atrium by the clinical examination of jugular venous pressure from sternal angle and the sensitivity and specificity of this test are low, thus rendering it inaccurate in predicting elevated pressures.[20] There are further possible areas to make the measurement of JVP more accurate and simplified for day to day use.

Measurement of JVP directly from the level of mid-right atrium

Limitations of JVP measurement from sternal angle

The upper limit of normal JVP is considered differently by different authors as 3 cm,[18,47,48] or 4 cm,[11,19,29] above the sternal angle. In fact, it is even mentioned that at 45°, the upper limit of normal JVP is 4 to 5 cm above the sternal angle; if the patient is at 30°, the upper limit of normal is 6 cm.[20] Similarly, apart from the such variations of the distances from the right atrium to the upper limit of JVP, there are variations in the reported distances below to right atrium from it. The sternal angle is used as the reference point because the center of the right atrium is considered to lie approximately 5 cm below the sternal angle in the average patient, regardless of body position.[11,18-20] But such assumptions may lead to underestimation of right atrial pressure.[14] The sternal angle is also assumed by others to be approximately usually 6 cm above the atrium in most positions.[49,50] A careful clinical study used CT scan measurements in 160 patients to determine the distance between the sternal angle and the level of the right atrium.[50] The median value for the vertical distance was 5.4 cm in the supine position. However, when the CT images of the torso were rotated to 30º, 45º and 60º, the median vertical distance was 8, 9.7, and 9.8 cm, respectively. Furthermore, there was wide range of values among patients (for example 5 to 13 cm at 30º). It is recommended that 10 cm should be added rather than 5 cm if the torso is elevated greater than 45 degrees.[51] These observations illustrate the difficulties in accurately determining the right atrial pressure by measurement from sternal angle.[14]

JVP measurement in erect position: The vertical height from the fourth intercostal space

The right atrium is located at the midpoint of an anteroposterior line from the anterior end of fourth intercostal space to the back. In any posture, a horizontal plane through this midpoint is the "phlebostatic" or "zero level".[49] In erect position, fourth intercostal space is at about the mid-right atrium in the surface marking.[52] So if the JVP is raised and seen at the base of neck in erect position, the measurement of vertical height made from the fourth intercostal space to the level of JVP in sitting or standing gives directly the most approximate value of central venous pressure, the normal value of which is 9 cm. Thus in such patients with visible JVP, the measurement of vertical height can be done relatively easily and more accurately in sitting or standing position directly from the fourth intercostal space. This would indeed embrace most patients with elevated JVP.

JVP measurement in reclining position: The vertical height from the horizontal level of midpoint of the anterior end of fourth intercostal space to back

In most adults, the upper border of the clavicles is from 13 to 18 cm above the right atrium and in erect position, the distance is similar from the anterior end of fourth space.[49] Thus in some individual patients even with central venous pressure more than 9 cm, JVP may not be seen in the neck in erect position. In such individuals, as well as in patients with normal or less venous pressure, jugular vein pressure has to be measured in reclining position. But in reclining position the vertical height to upper limit of JVP from anterior end of the fourth intercostal space will decrease as compared to that from horizontal level of the mid-right atrium. Because in reclining position, the anterior end of the fourth intercostal space will be relatively higher in position as compared to the horizontal plane passing through the mid-right atrium (Figure 1). Thus the midpoint of anteroposterior line from fourth intercostal space to back has to be marked in the lateral chest wall in erect position of the patient with the help of long centimeter scale (or indicator rod of the venous

Table 1. **Causes of the raised jugular venous pressure**

Mechanisms	Causes
Left- and right-sided heart failure	Heart failure, cor pulmonale, right ventricular infarction
Mechanical obstruction	Causes from superior vena cava (SVC) forward: SVC obstruction, tricuspid stenosis, pulmonary stenosis, pulmonary embolism, mitral stenosis, pericardial tamponade, constrictive pericarditis
Other specific cardiac conditions	Tricuspid valve incompetence Right ventricular infarction Atrial septal defect with mitral valve disease
Fluid overload	Renal failure, iatrogenic fluid overload

Table 2. **Abnormalities of the jugular venous pulsations**

Abnormalities	Causes
Absent 'a' wave if there is no contraction of right atrium	Atrial fibrillation (rarely a double venous pulsation is seen due to the presence of 'c' wave transmitted from the carotid artery[45]
Tall 'a' wave (sometimes described as 'flicking') due to increased resistance to right atrial contraction	Right ventricular hypertrophy due to (causes from left ventricular backward) left ventricular hypertrophy, pulmonary hypertension, pulmonary stenosis, tricuspid stenosis or atresia, right atrial myxoma[11,45]
'Cannon' ('a') wave when atrium contracts against a closed tricuspid valve	**Irregular:** complete heart block, multiple extrasystoles, ventricular tachycardia, ventricular pacing **Regular:** 2:1 AV block, junctional rhythm, ventricular tachycardia with 1:1 retrograde conduction
'Systolic' or 'cv' or giant 'v' wave due to fusion of the c and v waves in the absence or attenuation of an x descent	Tricuspid regurgitation due to right ventricular failure or tricuspid valve disease
Prominent 'a' and 'v' waves	Right ventricular failure and sinus rhythm[11] Atrial septal defect[11]
Prominent 'x' descent	Cardiac tamponade In conditions with large 'a' waves Right ventricular volume overload like in atrial septal defect
Prominent 'y' descent	Constrictive pericarditis, tricuspid regurgitation, myocardial dysfunction, ventricular dilatation
Slow 'y' descent due to obstruction to right ventricular filling	Tricuspid stenosis Right atrial myxoma[18]
Non-pulsatile raised JVP	Superior vena cava obstruction Occasionally in severe cardiac tamponade, severe constrictive pericarditis[26] Rarely in markedly elevated jugular vein pressure without associated tricuspid regurgitation[26]

pressure manometer as discussed below). Later on in reclining position, the measurement of vertical height made from the horizontal plane passing through the midpoint marked in the lateral chest wall to upper level of JVP directly gives the most approximate value of central venous pressure. Such measurements can be relatively easily and reliably measured with the help of venous pressure (VP) manometer, as discussed below.

Venous pressure (VP) manometer

Conventional method of clinical assessment of jugular vein pressure requires the measurement of vertical height of JVP from the reference point like sternal angle ideally with the help of two centimeter scales. But most clinicians may not carry two centimeter scales with them. So generally it may be measured arbitrarily as the length of any straight material, like a centimeter scale,

pen or even finger, kept vertically from the sternal angle to the horizontal plane of upper limit of JVP by bringing the observer's eyes to the same level. Such actual steps of measuring the vertical height of JVP are in general also not described clearly in the standard textbooks.[11,17-9,29,48,49] Thus it is not surprising that the measurement value of JVP is often mentioned just arbitrarily. The venous pressure manometer can measure the vertical distance of the upper limit of jugular venous pressure in more standard way. The indigenously developed one by the author is shown in Figure 2. The central frame of the manometer has two portions upper horizontal surface to show the upper limit of jugular venous pressure and an indicator rod below to indicate the approximate level of the mid-right atrium, which can be considered at the horizontal level of the anterior end of fourth intercostal space for erect position and of the midpoint marked in the lateral chest wall as discussed above for reclining position. The central frame with its two portions can be moved up and down as a whole and by tightening the screw behind can be fixed at the required position as indicated by the indicator rod. The horizontal surface, unlike indicator rod, can be moved up and down on the central frame independently and be fixed at the required position by the screw behind. The vertical distances between the horizontal surface and the indicator rod are calibrated in centimeter in the central frame of the manometer making it easier to measure directly. The indicator rod also has levels in centimeter scales, so that, after arranging anterior and posterior points, the midpoint of the anteroposterior line from the fourth intercostal space to the back can be marked in the lateral chest wall in the erect position of the patient. The indicator rod can be made horizontal, as shown in the figure, with the help of a chain. In the resting position, when not in use, the indicator rod can be freed from the chain and just hung below.

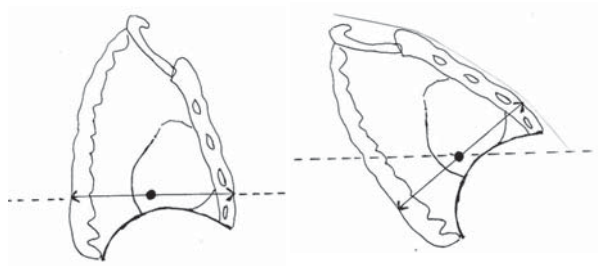

Figure 1. The relation of the anterior end of the fourth intercostal space with the horizontal plane passing through the mid-right atrium in erect and reclining positions

Double arrowhead line (↔) is the anteriorposterior line from the anterior end of the fourth intercostal space to the back with right atrium at the midpoint shown by a central dot.

Dotted line (----) is the horizontal plane parallel to the ground passing through the mid-right atrium.

For the measurement of JVP, the central frame is adjusted at the horizontal level of the mid-right atrium as indicated by the indicator rod. The horizontal surface of the venous pressure manometer is brought to the level of the upper limit of jugular vein pulsations and fixed at that point. The central venous pressure can be directly read in the central frame as the vertical distance from the indicator rod to the upper horizontal surface. The manometer can also measure the upper limb venous pressure, this is discussed below. Preliminary observation of measurements of jugular venous pressure as well as of upper limb venous pressure by VP manometer from the mid-right atrium plane is quite encouraging. Larger study is required to establish its value.

Upper limb venous pressure (ULVP) measurement

Examination of the upper limb veins

With normal venous pressure in the erect position, a column of blood distends the superior vena cava up to a height of 9 cm above the right atrium. Any peripheral veins anatomically below this level are normally filled with blood; those above are collapsed. The visible veins in the dependent arms and forearms are distended with blood up to the same level as in the vena cava.[49] In the horizontal position, all peripheral veins are filled. If the arm is raised slowly, the distal portions of the veins collapse as they attain the height of central venous pressure above the level of the right atrium. The vertical distance, at which the veins of the upper limb collapse, gives the alternate indirect measurement of central venous pressure.[49]

Limitations

The major limitation of the examination of the arm vein is that central venous pulsations can not be assessed as in case of JVP. It gives the indirect measurement of central venous pressure, but the waveforms can

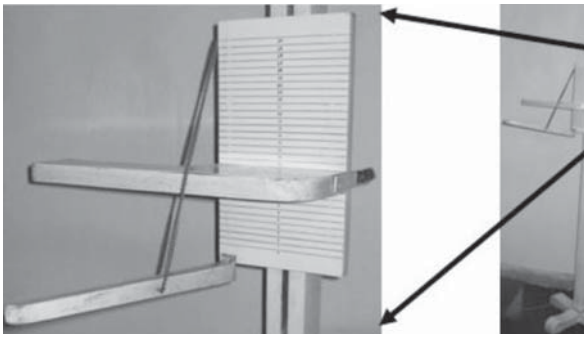

Figure 2. Indigenously developed venous pressure manometer

not be examined or analyzed. The other limitation is that there is great individual variation in the caliber and superficiality of the veins of the arms. In such situations, the observations need to be correlated with veins as close to the heart as possible so as to exclude blockage by valves; this is less likely in the cephalic, basilic, or median basilic veins.[49]

Upper limb venous pressure measurement with the help of venous pressure (VP) manometer

Upper limb venous pressure can be measured relatively easily by venous pressure (VP) manometer. As most patients can sit, the upper limb venous pressure can be directly measured with its indicator rod at the anterior end of fourth intercostal space for any, e.g. low, normal or high, level of venous pressure. If the patient can not sit, then venous pressure is measured with its indicator rode at the horizontal level of the midpoint of the anterior-posterior line, marked in the lateral chest wall, from anterior end of fourth intercostal space to back. Thus, for measurement of JVP, the central frame is adjusted at the appropriate horizontal level of the mid-right atrium as indicated by the indicator rod. The hand is then rested flat on the horizontal surface and the horizontal surface is moved from the lower most point in the central frame till the veins in the upper limb just collapse. The horizontal surface is fixed at that point and the vertical distance from the indicator is measured in centimeter directly from the central frame.

Advantages of upper limb venous pressure (ULVP) measurement

In general upper limb venous pressure measurement is less reliable than measurement of venous pressure from jugular vein. But, as most patients can sit, it can be rather easily measured from the anterior end of fourth intercostal space for any, e.g. low, normal or high, level of venous pressure. The other advantage is that if even in the minimum possible reclining position it is difficult to visualize the JVP due to the subnormal central venous pressure like due to hypovolemia, the upper limb venous pressure can still be measured indicating the central venous pressure. In case of JVP, in the horizontal position, the venous pulsation is usually visible in the neck when the right atrial pressure is normal and if the neck veins collapse in the horizontal position, subnormal right atrial pressure is suspected.[14] The other possible advantage of upper limb venous pressure measurement is that it would encourage the practice of the venous pressure assessment in health care settings. As the upper limb venous pressure can be measured from anterior end of fourth intercostal space in sitting position in most patients, it can be easily measured by the nurses and paramedics regularly with the help of venous pressure manometer and venous pressure measurement values could be available routinely in the ward like other vitals measurements. While this will have to be correlated with measurement from jugular vein by physicians, it will in this process encourage physicians to pay appropriate attention to jugular venous pressure. The jugular vein pressure and upper limb venous pressure measurements would, thus, be complementary to each other.

CONCLUSIONS

The two main objectives of the examination of the neck veins are inspection of their waveform and estimation of the central venous pressure. There is no controversy regarding the clinical method of examination of waveform of jugular venous pulse. However there are limitations of clinical assessment of central venous pressure by jugular vein pressure measurement from the level of sternal angle. In these backgrounds, making venous pressure assessment by non-invasive methods more reliable and convenient will be quite useful. In patients with visible JVP at the neck, measurement of central venous pressure can be done more accurately and quite easily from the anterior end of fourth intercostal space. Considering the relative variations in the distance both below and above from the sternal angle, there is no obvious reason why JVP should still now be continued to measure from the sternal angle in patients with visible jugular vein pulsations in sitting position, rather than directly and more reliable measuring from the anterior end of the fourth intercostal space. If jugular vein pulsations are not seen in sitting positing, venous pressure can be measured from the horizontal plane of the midpoint (marked at the lateral chest wall in erect position) of the anteroposterior line from the fourth intercostal space to back, particularly with the help of VP manometer. Similarly upper limb venous pressure measurements with the help of VP manometer can make such measurements convenient and common in health care settings, as the measurements could be made routinely by the nurses and paramedics as well. There is, thus, need of studies in these areas of measuring venous pressure noninvasively to make it more standard and convenient.

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