How Far Is the Sternal Angle from the Mid-right Atrium?

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BACKGROUND: The central venous pressure (CVP) is commonly estimated at the bedside by measuring the height of the jugular venous pressure (JVP) relative to the sternal angle. Determining the CVP from this measure requires that the distance from the sternal angle to the level of the mid-right atrium be known. Classical clinical teaching quotes this distance as 5 cm, variable between patients, and variable with changes in the elevation of the patient’s head. The validity of these JVP characteristics has been questioned.

OBJECTIVES: To measure the distance from the sternal angle to the level of the mid-right atrium (SA-RA) and determine if the SA-RA distance varies with patient position.

METHODS: Cross-sectional study conducted at a single-center teaching hospital on ambulatory patients undergoing computed tomography of the chest.

RESULTS: One hundred sixty patients were included. The median SA-RA distance with the patient lying supine was 5.4 cm (interquartile range, 4.7 to 6.1). Using geometric calculations to estimate the SA-RA distance when the patient’s torso was elevated above the supine position, the median SA-RA distance was calculated to be 8 cm, 9.7 cm, and 9.8 cm at 30, 45, and 60 degrees elevation respectively. The SA-RA distance varied extensively between patients and was independently associated with smoking, age, and antero-posterior chest diameter.

CONCLUSIONS: The distance from the sternal angle to the level of the mid-right atrium varies considerably between individuals and with patient position. When using the JVP to calculate the CVP, physicians need to consider specific patient factors and the patient’s position.

KEY WORDS: jugular venous pressure; physical examination.

The jugular venous pressure (JVP) is an important component of the bedside assessment of intravascular volume status. Clinicians use the JVP to quickly and noninvasively estimate a patient’s central venous pressure (CVP). The JVP is measured as the vertical distance from the top of the column of blood in the internal jugular vein to a zero point, most commonly taken to be the level of the right atrium.

There has been much controversy in the literature and among clinicians regarding the most appropriate method of examining the JVP as well as the utility of this bedside test. One of the most important elements in measuring the JVP and using it to estimate the CVP is identifying a uniform and easily reproducible external reference point that most reliably reflects the zero point. The mid-right atrium is assumed to be the zero point because it has the lowest fluctuations of hydrostatic pressure within the venous system. Therefore, the location of the mid-right atrium is essential for determining the CVP. Externally, the mid-right atrium is represented by the phleboptic axis, which is the junction of the fourth intercostal space and midpoint of the antero-posterior (AP) diameter. However, this has not been extensively corroborated.

The sternal angle has been the most widely used external reference point. It is the most easily and reproducibly identified external landmark, even though it may not be the most accurate. The CVP is most commonly estimated by measuring the vertical height from the top of the jugular venous pulsation to the sternal angle. This vertical height is then added to the distance from the sternal angle to the level of the mid-right atrium (SA-RA) to obtain CVP in cm H2O. The SA-RA distance has most widely been cited as 5 cm. In addition, many references claim that this distance does not vary when patients are elevated above the horizontal.

Clinicians have questioned these concepts regarding the SA-RA distance. Two studies, in which central veins were cannulated to permit accurate measurement of CVP relative to the sternal angle, found that measurements in the supine position differed significantly from those done with the subjects sitting at 45 degrees above the horizontal. Both Sapira and McGee geometrically argued that, contrary to common teaching, SA-RA distance should vary with patient position. Others have echoed this sentiment. Several studies that have compared the bedside assessment of the JVP with an internal jugular vein catheter in patients have consistently found that the former underestimates the CVP. McGee suggests that this underestimation is due to the exaggerated postural fall of the venous pressure when the patient is in the upright position.

To our knowledge, no study has rigorously assessed the SA-RA distance. The purpose of this cross-sectional study was to measure the SA-RA distance in a broad group of patients to determine if it indeed is 5 cm. Using geometric calculations, we explored whether the SA-RA distance changed with patient position. Finally, we wanted to determine which patient factors influenced the SA-RA distance.
METHODS

Choice of Imaging Technology

To calculate the distance from the sternal angle to the level of the mid-right atrium, we required an imaging technology that could reliably identify the sternal angle and the junction of the superior vena cava with the right atrium. We also needed to be able to measure the AP diameter as well as the vertical distance from the sternal angle to the level of the mid-right atrium in the supine position. These measurements had to be perpendicular to the horizontal plane for accuracy and for use in the proposed geometric model. Computed tomography (CT) met each of these requirements and was used for this study. Echocardiography could have been used to measure these distances, but we could not ensure that its measures were truly perpendicular to the horizontal plane.

Patient Recruitment

All ambulatory patients undergoing CT of the chest at the Ottawa Hospital–Civic Campus between 3 April 1998 and 30 September 1998 were invited to participate in the study. The hospital’s institutional review board approved the study. Patients were provided a 1-page summary that explained the study’s purpose, and informed consent was obtained. Patients who participated in the study completed a questionnaire that elicited their age, gender, height, weight, smoking status, and whether they had undergone previous thoracic surgery. Patients smoking >10 cigarettes/day for at least a 10-year period of time were classified as “smokers.” The ordering physician cited the indication for the CT on the requisition.

Patients were excluded if they declined to participate, were unable to complete the questionnaire (because of language barrier or illness), had their CT after regular working hours, or their large body size prohibited the identification of required landmarks on the CT image. Patients with severe chest abnormalities, such as previous complete pneumonectomy, severe kyphoscoliosis, or severe mediastinal shift, were also excluded, because these malformations decreased the accuracy of our measurements.

Measurements

All CT scans were performed on a General Electric High Speed Advantage scanner (General Electric, Fairfield, Conn) with patients lying supine and the head supported in a standard head holder. Scans were obtained with the patient supine during breath-hold at the end of a usual inspiration. All measurements were obtained by the same CT technologist. The SA-RA distance for supine patients (Fig. 1A, line c) and the SA-RA distance for patients at 90 degrees (Fig. 1A, line d) were measured from the appropriate cuts at the scanner’s work station. To identify the sternal angle on the CT, the level at which the second costal cartilage joined the sternum was located. The central portion of the sternal angle has a higher attenuation than the sternal body or manubrium, because it lacks bone marrow, thereby making the angle readily identifiable. The mid-right atrium was located as the midpoint between the anterior and posterior border of the right atrium 2 cm below the junction of the superior vena cava and the right atrium. Two centimeters was chosen because the average diameter of the right atrium is approximately 4 cm and the inferior border of the right atrium could not be reliably identified on CT imaging. Each patient’s antero-posterior and transverse chest diameters were measured directly from the CT.

The SA-RA distance at 0 and 90 degrees was measured directly from the CT scan. This, of course, was done with the patient supine. The SA-RA distance at 90 degrees, therefore, did not consider movement of the heart when the patient stands. We used geometric

![Figure 1](https://example.com/figure.png)

**FIGURE 1.** Distance from the sternal angle to the level of the mid-right atrium (SA-RA) at angle α. Patient is shown supine (A) and elevated to angle α (B). Lines a, b, and d were all measured directly from the CT scan. Line c was calculated as the difference of α and b. SA-RA is the distance from the sternal angle to the level of the mid-right atrium—the junction of L (A) and L (B). In A, SA-RA equals c. In B, SA-RA equals sin α * (d + c(tan(90-α))). This equation is valid in all situations, including when the sternal angle is not in the same vertical plane as the mid-right atrium.