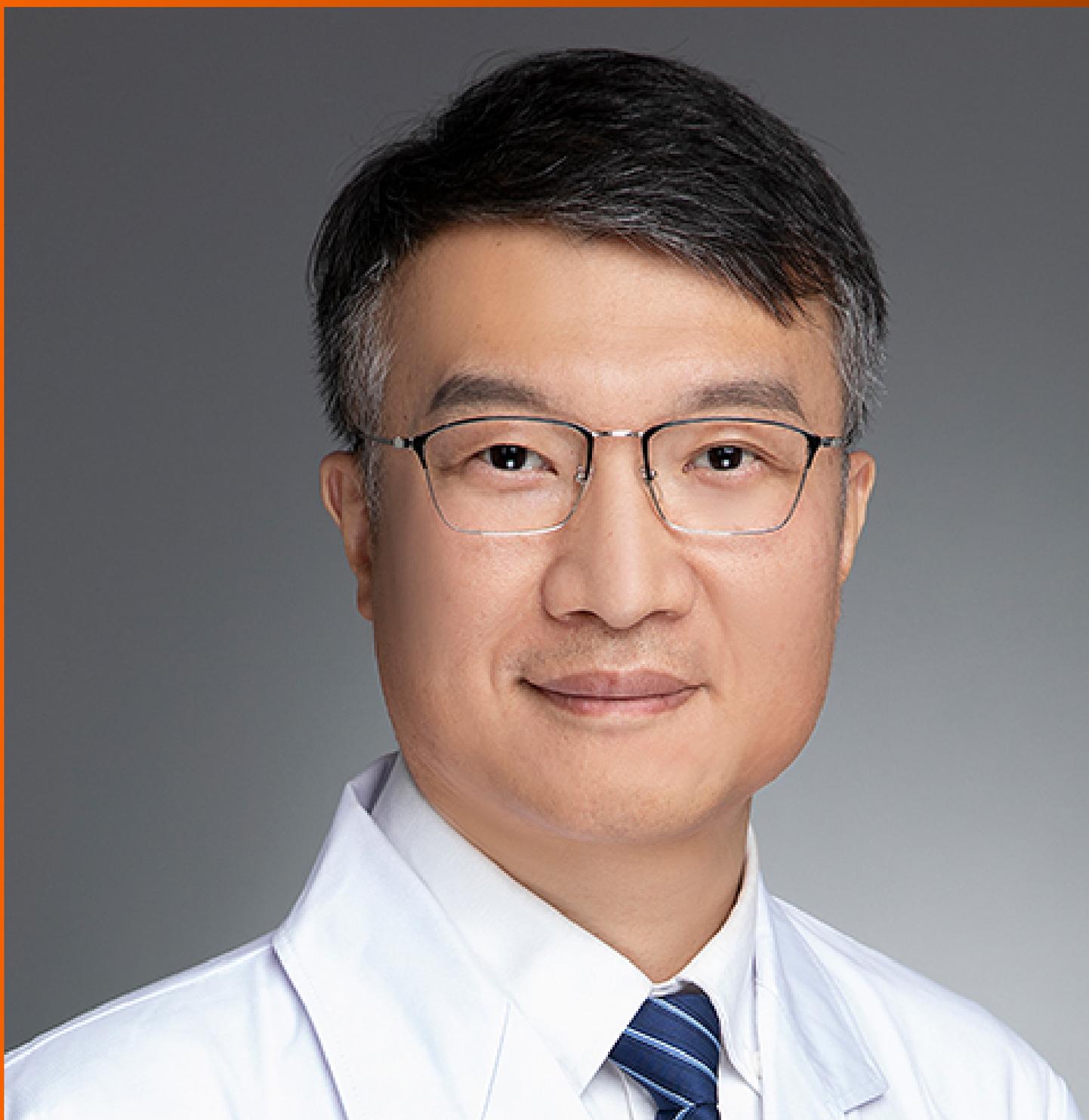


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**RESPONSIBLE EDITORS FOR THIS ISSUE**

Production Editor: Si Zhao; Production Department Director: Xiang Li; Editorial Office Director: Yun-Xiaojiao Wu.

**NAME OF JOURNAL**

*World Journal of Cardiology*

**ISSN**

ISSN 1949-8462 (online)

**LAUNCH DATE**

December 31, 2009

**FREQUENCY**

Monthly

**EDITORS-IN-CHIEF**

Ramdas G Pai, Dimitrios Tousoulis, Marco Matteo Ciccone, Pal Pacher

**EDITORIAL BOARD MEMBERS**

<https://www.wjnet.com/1949-8462/editorialboard.htm>

**PUBLICATION DATE**

February 26, 2024

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<https://www.wjnet.com/bpg/gerinfo/242>

**STEPS FOR SUBMITTING MANUSCRIPTS**

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## Seeing beneath the surface: Harnessing point-of-care ultrasound for internal jugular vein evaluation

Vichayut Chayapinun, Abhilash Koratala, Taweevat Assavapokee

**Specialty type:** Medicine, general and internal

**Provenance and peer review:** Invited article; Externally peer reviewed.

**Peer-review model:** Single blind

**Peer-review report's scientific quality classification**

Grade A (Excellent): 0  
Grade B (Very good): 0  
Grade C (Good): C  
Grade D (Fair): 0  
Grade E (Poor): 0

**P-Reviewer:** Uz Zaman M, Pakistan

**Received:** December 20, 2023

**Peer-review started:** December 20, 2023

**First decision:** January 11, 2024

**Revised:** January 16, 2024

**Accepted:** February 1, 2024

**Article in press:** February 1, 2024

**Published online:** February 26, 2024



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### Abstract

Point-of-care ultrasound (POCUS) of the internal jugular vein (IJV) offers a non-invasive means of estimating right atrial pressure (RAP), especially in cases where the inferior vena cava is inaccessible or unreliable due to conditions such as liver disease or abdominal surgery. While many clinicians are familiar with visually assessing jugular venous pressure through the internal jugular vein, this method lacks sensitivity. The utilization of POCUS significantly enhances the visualization of the vein, leading to a more accurate identification. It has been demonstrated that combining IJV POCUS with physical examination enhances the specificity of RAP estimation. This review aims to provide a comprehensive summary of the various sonographic techniques available for estimating RAP from the internal jugular vein, drawing upon existing data.

**Key Words:** Point-of-care ultrasound; Bedside ultrasound; Internal jugular vein; Right atrial pressure; Central venous pressure

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**Core Tip:** Point of care ultrasound of the internal jugular vein serves as a non-invasive tool to evaluate right atrial pressure. This is particularly useful when neck vein inspection is challenging, or inferior vena cava sonography lacks reliability. When combined with the physical examination and other sonographic parameters, it becomes a valuable component of bedside hemodynamic evaluation.

**Citation:** Chayapinun V, Koratala A, Assavapokee T. Seeing beneath the surface: Harnessing point-of-care ultrasound for internal jugular vein evaluation. *World J Cardiol* 2024; 16(2): 73-79

**URL:** <https://www.wjgnet.com/1949-8462/full/v16/i2/73.htm>

**DOI:** <https://dx.doi.org/10.4330/wjc.v16.i2.73>

## INTRODUCTION

An accurate assessment of hemodynamic status at the bedside is of utmost importance in guiding proper management through altering blood volume and cardiac output, especially in critically ill patients. Central venous pressure (CVP) is a physiologic parameter that is used to assess cardiac preload within this evaluation. CVP is identical to right atrial pressure (RAP) in the absence of vena caval obstruction, and these terms are often used interchangeably. Assessing CVP clinically by performing a neck veins examination can be challenging at times and yield low sensitivity, especially in the elderly, obese, and short-necked patients[1-4]. The gold standard for measuring CVP is *via* inserting a central venous catheter (CVC) into the superior vena cava, however, this method is invasive, time-consuming, and can cause serious complications[4-6]. With the help of point-of-care ultrasound (POCUS), RAP can be non-invasively measured through various methods including using compression ultrasound on the forearm vein[7], evaluation of the inferior vena cava (IVC), and evaluation of the internal jugular vein (IJV). The most common method is the evaluation of IVC diameter and collapsibility[8,9] (Figure 1). However, the association between IVC parameters and RAP is moderate and lacks reliability in mechanically ventilated individuals or those with abdominal compartment syndrome[10]. Moreover, imaging the IVC can be challenging in situations like morbidly obese individuals, those unable to recline, patients with cirrhosis, ascites, or those who have undergone recent abdominal surgery[11]. Owing to its location and convenient accessibility, IJV POCUS presents a viable alternative in such instances. Unlike visual inspection, where identifying the vein can be difficult in many cases, POCUS makes the IJV easily visible, saving time for physicians and improving the accuracy of the examination[12,13].



IVC diameter (cm)	% Collapse with a sniff	Estimated RAP (mmHg)
≤ 2.1	>50	3 (0-5)
>2.1	<50	15 (10-20)
≤2.1	<50	8 (5-10)
>2.1	>50	8 (5-10)

**Figure 1** Estimation of right atrial pressure by inferior vena cava ultrasound in spontaneously breathing patients, based on current guidelines[8]. IVC: Inferior vena cava; RA: Right atrium; HV: Hepatic vein; RAP: Right atrial pressure.

## SONOGRAPHIC METHODS OF IJV ASSESSMENT

Multiple techniques have been described to assess CVP by IJV ultrasound. Based on available data, these methods encompass measuring the vertical height of the blood column in the IJV[13-16], utilizing the IJV height-to-width ratio (aspect ratio)[17,18], IJV collapsibility index (IJV-CI)[13,17,19-22], IJV distensibility index[23], measuring the maximal anteroposterior diameter of the IJV (AP-IJV Dmax)[18,24], calculating the difference in the percentage of the IJV cross-sectional area (IJV-CSA) or diameter before and after the Valsalva maneuver[25,26], and combining IJV vertical height with right atrial depth measured with echocardiography[27,28].

The first technique, pioneered by Lipton[14], uses POCUS to visualize the height of the blood column in the IJV above the sternal angle of Louis where a venous collapse is seen (the ‘wine bottle’ or ‘paint brush’ appearance), thereby being able to measure the height of the IJV more accurately than compared to only performing neck veins examination (Figure 2). The height is then added to the hypothesized right atrial depth below the sternum of 5 cm to calculate the RAP, abiding by the doctrine of Sir Thomas Lewis, who first proposed the use of neck veins examination in 1930. This method’s accuracy is questionable, owing to the presumed right atrial depth of 5 cm, which is proven to be inaccurate[27, 29]. In a study by Deol *et al*[30] ultrasound-assisted assessment of the column height underestimated CVP by 4.7 cm H<sub>2</sub>O, whereas visual inspection underestimated it by 6.1 cm H<sub>2</sub>O. Moreover, this approach can be time consuming as it requires two tools to assess the height of the column from the sternal angle (*e.g.*, two rulers, a pen and a ruler, or a tongue depressor and a ruler or tape, commonly employed by physicians at the bedside), further compromising measurement

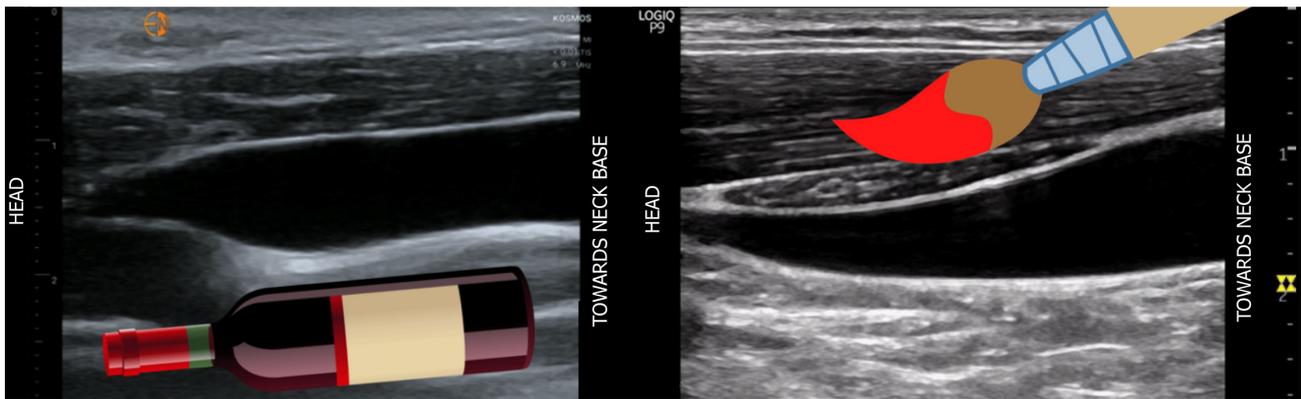


Figure 2 Internal jugular vein collapse point compared to a wine bottle and paint brush. Figures adapted from NephroPOCUS.com with permission.

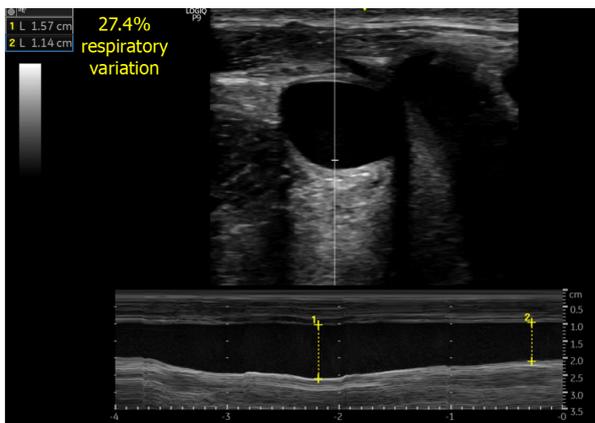


Figure 3 Anteroposterior diameter of the internal jugular vein. M-mode tracing depicts respiratory variation in the diameter.

accuracy[31].

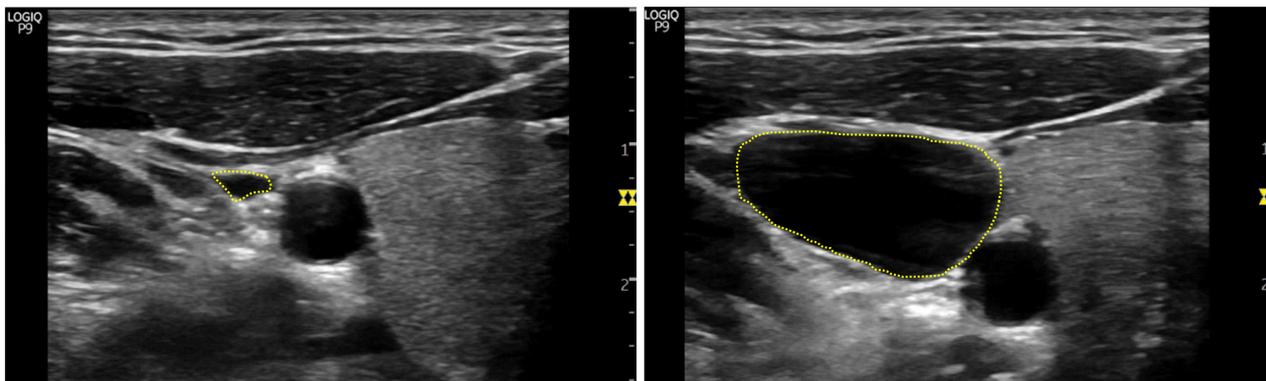
The second technique uses the height-to-width ratio (aspect ratio) to estimate the CVP as a binary variable (*e.g.*,  $</> 10$  mmHg), without precisely quantifying it. The transducer is positioned at the level of the cricoid cartilage in the transverse plane, then the height (anteroposterior diameter) and the width (transverse diameter) are measured to obtain the aspect ratio. A ratio of  $< 0.75$  has shown to correlate with RAP of  $< 10$  mmHg with a sensitivity and specificity of 62% and 67% respectively in one study[17]. This method yields mixed results, and its utility is currently not well-demonstrated[18].

The third technique uses the collapsibility index of IJV (IJV-CI) to estimate RAP. The IJV-CI is calculated by its respiratory variation,  $(IJV_{max} - IJV_{min})/IJV_{max}$  expressed in percentage (Figure 3). The actual RAP cannot be quantified, but studies[13,21,22] have shown that an IJV-CI of approximately  $\leq 30\%$  signifies an elevated CVP of  $\geq 8$  mmHg, demonstrating good sensitivity and specificity. Worthy of particular mention, in a study by Leal-villarreal *et al* [21] in patients with cirrhosis, IJV-CI (anteroposterior diameter 2 cm above the sternoclavicular joint)  $\leq 24.8\%$  was better at predicting a CVP  $\geq 8$  mmHg with 100% sensitivity and 97.1% specificity outperforming IVC POCUS. In this cohort, IVC POCUS was unattainable in 18% of the cases correlating with our real-life experience in cirrhotic patients.

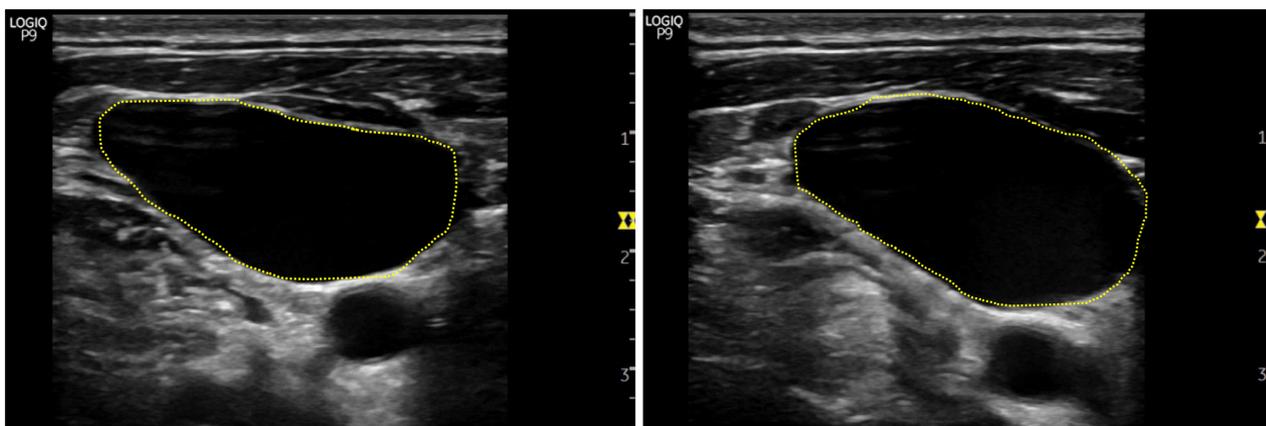
The fourth technique uses the IJV distensibility index to predict the fluid responsiveness in patients undergoing mechanical ventilation. IJV is imaged at the cricoid cartilage level in the transverse plane and the distensibility index is calculated by  $(IJV_{max} - IJV_{min})/IJV_{min}$ , expressed in percentage. In one study, an IJV distensibility index of  $> 18\%$  before volume challenge (7 mL/kg crystalloid) had an 80% sensitivity and 85% specificity to predict fluid responsiveness [23]. While this technique does not quantify the RAP, it could be a valuable adjunct to other hemodynamic parameters in assessing fluid status in mechanically ventilated patients.

The fifth technique uses the IJV maximal anteroposterior diameter (AP-IJV Dmax) to predict the RAP whether it is low ( $< 8$  mmHg) or high. Similar to the second technique of acquiring the aspect ratio, the transducer is positioned transversely 2 cm above the clavicle, at end-expiration and the diameter is collected to correlate with RAP. It has been shown that AP-IJV Dmax has the best correlation with RAP, the best validity in predicting its values, and a very good inter-rater reliability[24] along with its accuracy in predicting low RAP of  $< 8$  mmHg[18].

The sixth technique uses the difference in the percentage of the IJV cross-sectional area (IJV-CSA) before and after the Valsalva maneuver to assess for RAP. The Valsalva maneuver increases the IJV-CSA by about 20%-30% in patients with normal RAP, and it is assumed that in volume-overloaded patients with a decrease in venous compliance, the increase in IJV-CSA will be blunted. This technique measures the patient's IJV-CSA at the vertical column height where a venous collapse is seen and re-measures that same parameter while the patient performs the Valsalva maneuver, then calculates



**Figure 4** Increase in the size of internal jugular vein with Valsalva maneuver by several folds in a spontaneously breathing person with normal right atrial pressure.



**Figure 5** Minimal increase in the size of internal jugular vein with Valsalva maneuver in a spontaneously breathing heart failure patient with elevated right atrial pressure.

the difference in the percentage of the IJV-CSA (Figures 4 and 5). One study[25] found that a  $< 17\%$  increase in IJV-CSA with Valsalva predicted elevated RAP ( $\geq 12$  mmHg) with 90% sensitivity, 74% specificity, and a 94% negative predictive value. Alternatively, the ratio between maximum IJV diameter during Valsalva maneuver and diameter at rest (JVD ratio)  $< 4$  has also shown to predict elevated RAP[26].

Another recently described technique uses the IJV vertical height combined with right atrial depth measured with echocardiography to quantify the RAP. While similar to the first technique in principle, this approach enhances accuracy by directly measuring the right atrial depth instead of relying on the assumed 5 cm. It involves marking the highest point of the venous collapse (wine bottle sign) and then performing a focused cardiac ultrasound to visualize the heart in long axis (parasternal long axis view). Right atrial depth is measured from the surface to the location of the non-coronary cusp of the aortic valve attachment to the posterior left ventricular outflow tract (Figure 6). The two parameters, the column height, and the right atrial depth, are then added together for an estimation of the RAP in cm H<sub>2</sub>O, later converted to mmHg. This method predicted actual RAP within 3 mmHg 74% of the time when compared to cardiac catheterization-derived value[27].

In an alternative technique described by Xing *et al*[28], the initial step of measuring the height of collapse point is the same but the right atrial depth is calculated using an adjusted apical 4-chamber view with the right atrium in the center of the view, where distance between the transducer contact point and the center of the right atrium is recorded. A pencil and a ruler are then used in relation to the transducer to derive the surface projection of the center of the right atrium. The RAP is then estimated by adding the IJV column height to the right atrial depth. This technique demonstrates a substantial correlation and high accuracy, with a mean difference of 0.22 mmHg in RAP compared to CVC. Nevertheless, it lacks practicality in a clinical setting where swift assessment is essential, as it involves multiple operators and the use of various measuring instruments.

With respect to estimation of RAP using IJV POCUS in mechanically ventilated patients, there is limited data. One noteworthy study is by Hilbert *et al*[32] in a cohort of 47 patients, where they evaluated the ratio between IJV diameter in the 30° and 0° head position (30/0 ratio). A 30/0 ratio of  $< 0.45$  indicated a low CVP, whereas a cutoff of  $> 0.65$  predicted a CVP  $\geq 10$  mmHg with reasonable accuracy.



## FOOTNOTES

**Author contributions:** Chayapinun V drafted the initial version of the manuscript; Assavapokee T and Koratala A have designed the manuscript; Assavapokee T and Koratala A have revised the manuscript for critical intellectual content.

**Conflict-of-interest statement:** All authors have no conflicts of interest to declare.

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**S-Editor:** Gong ZM

**L-Editor:** A

**P-Editor:** Zhao S

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