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EDITORIAL COMMENT

Empowering Physical Examination

The "Laying On" of Ultrasound*

Bruce J. Kimura, MD, FACC,†‡ Anthony N. DeMaria, MD, MACC†
San Diego, California

The estimation of central venous pressure (CVP) by inspection of the neck veins is regarded as a quintessential example of effective bedside cardiovascular examination because it is virtually cost-free and requires minimal time and no equipment. In the upright position, venous drainage from the head occurs primarily through the vertebral veins, allowing the jugular vein to act as a manometer, "collapsing" at a level indicative of the CVP. Sir Thomas Lewis (1) described the examination of the external jugular veins as a method to estimate CVP in 1930 and, since that time, elevated jugular venous pressure (JVP) has demonstrated prognostic importance in heart failure. However, attempts to validate the accuracy of the technique have been fraught with inconsistency (2), and one study even suggested that no difference in the accuracy of estimating the JVP exists between attending physicians and medical students (3). Validation studies performed in critically ill patients and have reported accuracies of only 50% to 60%, with interobserver differences of up to 7 mm Hg (3). The success of this technique recently may have been further reduced by a variety of factors, including a more obese population with JVPs that are difficult to ascertain, reliance on invasive monitoring, and less emphasis on training in the technique.

See page 595

In 1980, the measurement of the inferior vena cava (IVC) diameter was found to correlate with CVP (4) and soon became a component of the standard echocardiogram. Unlike the arterial circulation, the venous system has highly variable capacitance, making it difficult to define an upper limit of body-size-indexed IVC diameter under normal CVP. Instead, vessel collapsibility with respiration has become the preferred measure. Although somewhat dependent upon site of measurement and force of inspiration, the results of validation studies in which the investigators used patients who were not in respiratory distress generally agree that a "sniff" that results in IVC "collapse" of more than 50% of the original diameter likely represents a normal CVP—with 80% to 90% accuracy (5). Studies in critically ill patients have demonstrated the clinical utility of IVC measures in septic shock, tamponade, and acute right heart failure.

Unlike the jugular vein, which acts as an isolated manometer, the IVC is under constant filling from lower-extremity and splanchnic veins and under constant compression by the overlying liver. Therefore, IVC diameter relates to CVP through the complex interaction of venous return with intra-abdominal, thoracic, and right atrial pressures. Vasoparesis, as in sepsis, could pool blood peripherally, reducing pre-load and IVC size, whereas sympathetic venoconstriction could shunt blood centrally to the IVC, as in heart failure. Few data exist on the relative effect of nitrates, antiadrenergics, and vasodilator therapies on the size of the IVC. Further confounding matters, intra-abdominal pressure can compress the IVC and reduce lower-extremity venous return and vessel diameter. The Valsalva maneuver, paradoxic breathing, and abdominal adiposity can cause differential changes in pressure within the superior and inferior vena cavae, affecting their relative diameters and flows. This complex interaction of venous return has been manifest in the failing heart by such physical examination signs

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From the †Department of Cardiology, University of California, San Diego, California; and the ‡Department of Cardiology, Scripps Mercy Hospital, San Diego, California.

as Kussmaul's and abdominal-jugular reflux but has not been well-studied with the use of ultrasound.

The IVC is readily seen and can be easily measured from a single subcostal longitudinal ultrasound view, even by physicians without formal training in echocardiography. Arguably, the IVC is easier to recognize than the JVP and is a more sensitive indicator of increased CVP, particularly in obese or critically ill patients. Analogous to differentiating the carotid and jugular pulsations in the neck on physical, mistaking the intra-abdominal aorta for the IVC represents a serious pitfall in interpretation of ultrasound images by the novice. The novice user must also understand IVC dynamics during positive pressure ventilation, where IVC "collapse" is the result of the competing influences of intra-abdominal and intrathoracic pressures varying within the respiratory cycle. Although limited by the aforementioned physiologic caveats and technical pitfalls, measurement of the IVC diameter is well-suited for bedside, hand-carried ultrasound (HCU) examination because of its ease of application.

In this issue of *iJACC (JACC: Cardiovascular Imaging)*, Goonewardena et al. (6) demonstrate the clinical utility of IVC measurement by using HCU. The investigators followed 75 patients admitted to their hospital with decompensated heart failure primarily from systolic dysfunction and evaluated the prognostic value of IVC parameters at hospital discharge in the subsequent 30-day readmission rate of 31 patients. Through logistic regression analysis of patient variables at discharge, the authors find maximum IVC diameter and collapsibility, serum sodium, and log-transformed brain natriuretic peptide as significant predictors of readmission, performing better than patient age, weight, net diuresis, length of stay, or renal function. The authors, who are experts in echocardiography, IVC dynamics, and HCU use, demonstrate the predictive value of the IVC parameter by having novice examiners use an older HCU device. This setting enhances the findings, highlighting the feasibility of physician-applied HCU as a routine bedside technique. The alternative solution of ordering daily "limited" echocardiograms from the echo laboratory for all heart failure patients nearing discharge was not tested but appears overly labor-intensive and costly in comparison.

The study makes a valuable contribution to the developing field of HCU and less so to heart failure physiology and echocardiography. Because the decision to discharge a patient is influenced by many medical and nonmedical factors, this small study requires large-scale validation with patients of varying ventricular function and etiologies (ischemic vs. nonischemic) and by multiple types of physicians (cardiologist vs. noncardiologist) using HCU. The reader cannot be certain of the number of residents using HCU, their relative accuracies, interobserver error, discordance with physical examination findings, or involvement in the patient's care. It is important to note that this study did not test treatment strategies directed at the IVC dilation, nor did it examine the additive benefit of the HCU findings to a clinical prognostic evaluation by the treating physician. The treatment implications of "a more prolonged inpatient diuresis" before discharge are speculative and may be an overly simplistic approach to the IVC dilation, especially before the effects of vasodilators and antiadrenergics on the IVC diameter are understood.

Refractory sympathetic activation of advanced heart failure may maintain IVC plethora, characterizing some patients who simply cannot tolerate further reduction in CVP before discharge because of hemodynamic limits, pre-load dependency of a failing right ventricle, or pre-renal azotemia. Such a refractory patient may have been obvious by history, hospital course, and physical examination to the treating physician and would have been at a known risk for readmission. The study leaves unanswered whether the treating physician discharged the patient prematurely because of an inability to recognize the JVP elevation, as the authors suggest, or whether the increase in CVP was simply a sign of intractable disease.

Nonetheless, despite the documented uncertainties of clinical JVP estimation and many caveats to IVC diameter use, it is not unreasonable to envy the simplicity of a seemingly effortless "quick look" at the patient's IVC or jugular veins with the use of ultrasound during morning rounds. Ultimately, the role of the current investigation may be to highlight the need for further study of venous tone as a predictor of mortality in heart failure and the IVC's response to heart failure therapies. In the short term, it validates the use of a simple bedside ultrasonic sign for prognosis in a frequently hospitalized population and likely has similar implications in outpatient care.

Ultrasound-assisted physical examination, a concept enabled by the advent of small, portable HCU devices and studies such as Goonewardena et al. (6), offers a blend of the immediate and personal nature of the enhanced bedside diagnosis afforded by a

JACC: CARDIOVASCULAR IMAGING, VOL. 1, NO. 5, 2008
SEPTEMBER 2008:602–4

brief application of ultrasound. Although challenging traditional notions of the complexity of ultrasound use and ease of the physical examination, HCU falls far short of echocardiography while still enhancing bedside diagnosis. The clinician can use the HCU examination to find signs of systemic disease and is not confined to an arbitrary radiologic or organ "border."

Preliminary studies suggest that simplified limited imaging protocols can have clinical impact (7) and can be performed by briefly trained nonechocardiographers to improve their bedside diagnostic accuracy (8). The creation of a brief cardiovascular-limited ultrasound examination (CLUE) will require thoughtful adaptation of the standard echocardiographic techniques to general medical application during bedside physical examination. Given the aforementioned discussion on the limitations of an apparently simple IVC parameter, it is clear that expert knowledge of echocardiography, cardiac physiology, disease prevalence, and clinical practice will be necessary to formulate and validate each potential component of CLUE. Evidence-based targets for inclusion in CLUE could include carotid atheroma, left ventricular systolic dysfunction, left atrial enlargement, abdominal aortic aneurysm and now, potentially, IVC plethora.

In the future, it might be anticipated that medicine will formulate an entire HCU-assisted physical examination that will incorporate CLUE as its cardiovascular component. Such an examination would detect disease at earlier stages, assist clinical diagnosis and management, and empower the process of physical examination. With the current trend toward centralization of large expensive imaging modalities in tertiary medical centers, the use of a technique that is inexpensive and performed during a patient visit endorses face-to-face, "hands-on" diagnosis as a paradigm worth preserving, and the doctor-patient relationship as the most important diagnostic interaction from which all other referrals are based. In essence, cardiac ultrasound has come full circle, using a recent technologic advancement to preserve what initiated development of the field itself—the limitations of bedside diagnosis.

Reprint requests and correspondence: Dr. Bruce J. Kimura, MD, FACC, Medical Director, Noninvasive Cardiology, Scripps Mercy Hospital, 4060 Fourth Avenue, #206, San Diego, California 92103. *E-mail: kimura.bruce@scrippshealth.org.*

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