A Comparison by Medicine Residents of Physical Examination Versus Hand-Carried Ultrasound for Estimation of Right Atrial Pressure

J. Matthew Brennan, MD, John E. Blair, MD, Sascha Goonewardena, MD, Adam Ronan, MD, Dipak Shah, MD, Samip Vasaiwala, MD, Erica Brooks, MD, Ari Levy, MD, James N. Kirkpatrick, MD, and Kirk T. Spencer, MD*

Physicians' ability to accurately estimate right atrial (RA) pressure from bedside evaluation of the jugular venous waveform is poor, particularly when performed by physicians in training. Conventional ultrasound measurement of the inferior vena cava (IVC) accurately predicts RA pressure, but the cost, lack of portability, and specialized training required to acquire and interpret the data render this modality impractical for routine clinical use. The objective of this study was to compare physical examination with hand-carried ultrasound (HCU) in the detection of elevated RA pressure (>10 mm Hg). After limited training (4 hours didactic and 20 studies), 4 internal medicine residents using an HCU device estimated RA pressure from images of the IVC in 40 consecutive patients <1 hour after right-sided cardiac catheterization. RA pressure was also estimated from examination of the jugular venous pulse (JVP) in 40 patients before right-sided cardiac catheterization. RA pressure was successfully estimated from HCU images of the IVC in 90% of patients, compared with 63% from JVP examination. The sensitivity for predicting RA pressure >10 mm Hg was 82% with HCU and 14% from JVP inspection. Specificities were similar between the techniques. Overall accuracies were 71% using HCU and 60% with JVP assessment. In conclusion, internal medicine residents with brief training in echocardiography can more frequently and more accurately predict elevated RA pressure using HCU measurements of the IVC than with physical examination of the JVP. **(Am J Cardiol 2007;99:1614–1616)**

In this study, we sought to compare the accuracies of physical examination and hand-carried ultrasound (HCU), performed by internal medicine residents with limited ultrasound training, for the estimation of right atrial (RA) pressure using right-sided cardiac catheterization as the gold standard for comparison.

Methods

The University of Chicago Institutional Review Board approved the protocol. Eighty-four consecutive patients referred for right-sided cardiac catheterization were enrolled. Right-sided cardiac catheterization was performed using a flow-directed pulmonary artery catheter. After obtaining central venous access, the catheter was advanced into the right atrium, where RA pressure was acquired after proper zeroing and calibration. Several cardiac cycles were recorded, and mean RA pressure was calculated using a hemodynamic software package (Mac-Lab, GE Medical Systems Information Technologies, Waukesha, Wisconsin).

Forty-four patients underwent brief echocardiographic examinations using an HCU device (Optigo, Philips Medical Systems, Andover, Massachusetts). This 6.6-pound device provides 2-dimensional images and has a limited number of controls for the adjustment of image depth and gain. Images can be frozen and scrolled for on-line review.

Internal medicine residents with minimal echocardiographic exposure and no previous formal training in ultrasonography performed the HCU studies. Each of the residents underwent 4 hours of formal didactic ultrasound training and performed 20 sonographer-supervised acquisitions and measurements of the inferior vena cava (IVC) from the subcostal approach. The IVC was assessed with the patient reclined in the supine position <1 hour before or after catheterization by a resident blinded to the results of the catheterization. IVC image quality was rated as poor, fair, or good on the basis of prespecified criterion. Poor quality images were omitted from the analysis.

After visualizing the IVC, 3 separate 2-dimensional imaging loops were acquired, taking care to maximize the IVC diameter throughout the respiratory cycle. Images were then frozen and reviewed to find the maximum IVC diameter ($IVCD_{max}$) during passive respiration within 2.0 cm of the junction of the IVC and the right atrium. Patients were then asked to perform a brief rapid inspiration or sniff, and additional loops were recorded. The minimum IVC diameter ($IVCD_{min}$) was then measured as the smallest IVC size recorded during the sniff. The IVC collapsibility index (IVCCI) was calculated using the

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*Corresponding author: Tel: 773-702-5836; fax: 773-702-1034.
E-mail address: kspencer@uchicago.edu (K.T. Spencer).

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formula $[(IVCD_{max} - IVCD_{min})/IVCD_{max}] \times 100$. All values were the average of 3 measurements.

Forty of the patients who underwent right-sided cardiac catheterization were studied to assess the residents' ability to evaluate RA pressure using the jugular venous pulse (JVP). A resident blinded to the right-sided cardiac catheterization results examined the JVP <1 hour before catheterization. The residents estimated mean RA pressure by examining the JVP using the technique they had learned during medical school and residency training. The physicians did not perform HCU examinations in these patients, because they could not have been blinded to their own JVP evaluations of RA pressure.

RA pressure ≥10 mm Hg was chosen to represent a clinically significant elevation in RA pressure. The sensitivity and specificity of the resident-performed HCU examinations were determined using traditional cutoffs for IVC size and collapsibility ($IVCD_{max}$ 2.0 cm and IVCCI 50%, respectively).[1] Likewise, the sensitivity and specificity of the residents' estimations of RA pressure from JVP examination were determined. Student's *t*-test was used to evaluate intergroup differences, and a weighted κ statistic was computed for agreement.

Results

Adequate ultrasound images were obtained in 90% of patients (60% good quality, 30% fair quality); the remaining 4 patients, who had poor image quality, were excluded from analysis. Eighty patients, with an average age of 50 ± 15 years (65% men, 35% women) and an average body surface area of 2.0 ± 0.3 m^2, were analyzed. Age and body surface area did not differ among patients with good, fair, and poor images ($p > 0.05$). The mean RA pressure was 7.4 ± 8.4 mm Hg.

In the hands of medical residents, HCU devices could be used to assess IVC size and collapsibility to estimate RA pressure in 90% of cases. An $IVCD_{max}$ >2 cm had fair to good sensitivity (70%), specificity (80%), and accuracy (78%) for predicting RA pressure >10 mm Hg. When an IVCCI <50% was used to predict RA pressure >10 mm Hg, the overall accuracy (68%) was comparable with that of IVC size, with somewhat better sensitivity (90%) but lower specificity (60%). IVCCI and IVC size had excellent negative predictive values of 89% and 95%, respectively, with somewhat poor positive predictive values (54% and 43%, respectively). By combining the criteria for IVC collapsibility and size, sensitivity (82%) and specificity (67%) were intermediate to those of either technique alone.

Medical residents failed to visualize the JVP in 37% of the 40 patients in whom it was attempted. In these patients, RA pressure was neither consistently high nor consistently low. RA pressure in subjects with nonvisualized JVPs was <5 mm Hg in 5 patients, >5 but <10 mm Hg in 7 patients, and >10 mm Hg in 3 patients. The average body surface area of patients in whom the JVP was visualized was not significantly different from those in whom it was not visualized (2.06 ± 0.29 vs 2.14 ± 0.30 m^2, $p = 0.42$). JVP assessment had an accuracy of 60% and specificity of 78% for predicting RA pressure >10 mm Hg in the 63% of patients in whom it was visualized (Table)1. The residents were particularly poor at distinguishing when the JVP was elevated, identifying this in only 1 of the 7 patients (sensitivity 14%). The negative and positive predictive values of JVP (70% and 20%, respectively) were likewise the poorest of all the parameters tested.

Table 1
Right atrial pressure classifications by hand-carried ultrasound and jugular venous pulse examination (percent of patients)

Variable	RA Pressure Classification by Invasive Catheterization (mm Hg)			
	≥15	10–15	5–10	<5
RA pressure estimation by HCU				
≥15	3	3	0	0
10–15	9	11	9	14
5–10	0	3	6	26
<5	0	3	3	11
RA pressure estimation by JVP examination				
≥15	0	0	0	0
10–15	0	4	8	8
5–10	4	20	20	20
<5	0	0	8	8

The patients were categorized into subgroups of RA pressure on the basis of a standard combination of IVCCI and IVCD cutoffs.[2] When the patients were grouped into RA pressure ranges by the residents' HCU measurements as well as their estimations of JVP (Table 1), the agreement for RA pressure classification was identical for HCU and JVP estimation (32%). However, the weighted κ statistic, which takes into account the degree of mismatch, was superior for HCU (0.42 vs 0.07).

The most common misgrouping of RA pressure using HCU was overestimating RA pressure in patients who actually had RA pressures <5 mm Hg. This increased the number of false-positive elevated RA pressure estimations, contributing to the somewhat low positive predictive value for HCU. Conversely, the most common misgrouping of RA pressure by JVP estimation was to assign patients to the 5 to 10 mm Hg group whose RA pressures were either higher (10 to 15 mm Hg) or lower (<5 mm Hg). The residents placed 64% of their JVP estimates in the 5 to 10 mm Hg range, whereas only 36% were actually in that range. These false-negative classifications led to the poor sensitivity for JVP.

Discussion

Examination of the JVP is the mainstay of the bedside estimation of RA pressure and a cornerstone of the cardiovascular physical examination. The detection of elevated JVPs in patients with heart failure predicts elevated pulmonary capillary wedge pressures and portends poorer prognoses.[3–5] However, the JVP is often difficult to accurately ascertain because of patients' body habitus, the presence of jugular catheters, an inability to position patients, and poor patient cooperation. This limitation of JVP assessment was confirmed in this study, in which medical residents failed to ascertain the JVP in 37% of subjects.

Even when the JVP is assessed by experienced examiners, the results are suboptimal.[4,6–8] In inexperienced hands,

the results of JVP examination are even less accurate.[9] A recent abstract compared JVP and central venous pressure measurements in 64 patients in an intensive care unit after a training session designed to instruct physicians in the proper method for JVP assessment.[9] These investigators found a poor correlation between invasive and physical examination estimation of RA pressure ($r = 0.30$). Without a specific training session, the correlation between RA pressure and JVP estimation in this study was similarly poor at 0.17. The JVP results do not suggest a systematic error in the technique used to inspect the JVP but rather that residents tended to classify most patients into the "safe" normal range of 5 to 10 mm Hg.

Using size and collapsibility, ultrasound examination of the IVC has proved to be a robust surrogate marker of RA pressure.[1,10,11] Unfortunately, the size, complexity, and cost of a standard-platform ultrasound machine make their use at the point of care difficult. Many of these limitations are readily addressed with HCU technology.[12–16] The substantially lower cost of HCU devices as well as their increased portability and ease of use greatly increase their utility at the point of care. Not all cardiac findings can be evaluated with these limited devices; more subtle abnormalities, such as left ventricular wall motion, are more difficult to discern.[17] However, HCU assessment of the IVC by ultrasound technicians has recently been shown to be similar to that of a standard platform (96% agreement, $\kappa = 0.87$).[16] In addition, these devices are significantly simpler to operate, and their diagnostic utility by personnel with limited ultrasound training has been proved in multiple clinical settings.[17–25]

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