Usefulness of the External Jugular Vein Examination in Detecting Abnormal Central Venous Pressure in Critically Ill Patients

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Background: Central venous pressure (CVP) provides important information for the management of critically ill patients. The external jugular vein (EJV) is easier to visualize than the internal jugular vein and may give a reliable estimate of CVP.

Methods: To determine the usefulness of the EJV examination in detecting abnormal CVP values, we performed a prospective blinded evaluation comparing it with CVP measured using an indwelling catheter in critically ill patients with central venous catheters. Blinded EJV examinations were performed by clinicians with 3 experience levels (attending physicians, residents and fellows, and interns and fourth-year medical students) to estimate CVP (categorized as low [≤5 cm of water] or high [≥10 cm of water]). The usefulness of the EJV examination in discriminating low vs high CVP was measured using receiver operating characteristic curve analysis.

Results: One hundred eighteen observations were recorded among 35 patients. The range of CVP values was 2 to 20 cm of water. The EJV was easier to visualize than the internal jugular vein (mean visual analog scale score, 8 vs 5; $P<.001$). The reliability for determining low and high CVP was excellent, with areas under the curve of 0.95 (95% confidence interval [CI], 0.88-1.00) and 0.97 (95% CI, 0.92-1.00), respectively, for attending physicians and 0.86 (95% CI, 0.78-0.95) and 0.90 (95% CI, 0.84-0.96), respectively, for all examiners.

Conclusion: The EJV examination correlates well with catheter-measured CVP and is a reliable means of identifying low and high CVP values.

Trial Registration: clinicaltrials.gov Identifier: NCT00303355

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THE PRINCIPAL ROLE OF THE neck examination in critically ill patients is an assessment of jugular venous pulse magnitude and waveform contour. This procedure can be done quickly at the bedside without cost or patient discomfort before using invasive hemodynamic instrumentation. Information obtained from the jugular vein examination can be used to assess central venous pressure (CVP), which may provide useful data about intravascular volume status, adequacy of fluid resuscitation, presence of congestive heart failure, or other abnormal conditions, such as the Kussmaul sign in pericardial tamponade.[1]

Reported limitations of the CVP assessment by the physical examination in critically ill patients include decreased reliability during mechanical ventilatory assistance, reduced accuracy of the physical examination at very low CVP values, and poor correlation with invasive measurements in obese patients.[2] The examination of the internal jugular vein (IJV) is difficult for many clinicians, and previous studies[3-6] assessing the correlation between the IJV examination and CVP measured by central venous catheter showed poor accuracy and nonimprovement with increased experience. The IJV may be difficult to examine because of its deep position, a feature that may impair visualization, especially in obese patients or patients with tissue edema. In addition, the IJV is anatomically adjacent to the carotid artery, and pulsations from this artery may obscure the subtler venous waveform of the IJV.

Recent attention in medical education seems to be focused on technological advances in diagnosis and treatment at the expense of fundamentals of the physical examination. As such, concern has been raised about the erosion of physical examination skills among current and future trainees.[7-11] These concerns notwithstanding, CVP elevations observed on physical examinations have served as warning signs of conditions associated with increased morbidity and mortality.[12,13] Furthermore, the use of an algorithm for resuscitation in the intensive care unit (ICU), which in part used invasive CVP measures to guide therapy, led to improved survival among patients with se-

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vere sepsis and septic shock.[14] In addition, a large multicenter study[15] comparing fluid management in patients with acute respiratory distress syndrome demonstrated that maintaining a low CVP was associated with fewer days of mechanical ventilatory assistance and intensive care. Accordingly, a reliable noninvasive means of assessing CVP would be attractive and would have widespread applicability across a broad range of patient care.

The external jugular vein (EJV) is an appealing alternative to the IJV, because it is easy to visualize. However, the usefulness of the EJV in the assessment of CVP is unclear. Purported obstacles include the circuitry of the route of the EJV to the right atrium, the effect of neck fascial planes on the EJV, the smaller caliber of the EJV relative to the IJV, and the presence of venous valves.[1,2] Nevertheless, a reliable assessment of CVP measurements via the EJV has been demonstrated in patients undergoing surgery with external jugular and internal jugular catheters in place.[16,17]

To date, no rigorous attempts have been made to correlate EJV measurements by the physical examination with invasively measured CVP, to our knowledge. We conducted a prospective blinded study to evaluate the assessment reliability of abnormally low or high CVP by the EJV examination performed by clinicians with various levels of experience in ICU patients with indwelling central venous catheters.

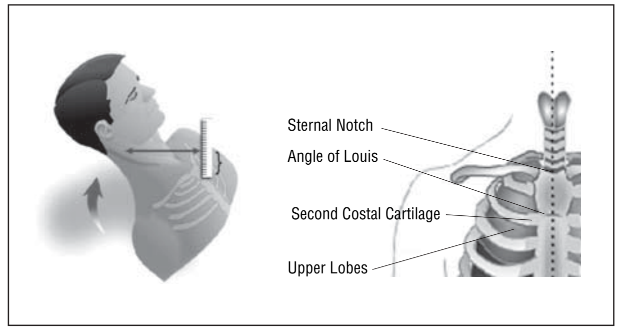

Figure 1. Instructions given for the external jugular vein (EJV) examination (an online eVideo is available). 1, Position the patient as you would for the internal jugular vein examination, at an angle usually between 30° and 45° from the horizontal. For extremely low central venous pressure (CVP), you may need to lower this angle, and conversely you may need to seat the patient more upright to evaluate high CVP. 2, Check the left and right sides of the neck. Tangential light may help identify pulsating EJVs. If the veins are not apparent, you may ask the patient to perform a Valsalva maneuver, or place your finger at the base of the neck to distend the veins temporarily. These maneuvers will identify the course of the EJV but should not be used during measurement. 3, If the vein is readily visible and distended, locate the apex of the pulsating meniscus. (Some patients will have distended veins, but the jugular venous pressure is assessed at the top of the venous pulsation, not at the maximal height of distension. Stripping the vein will help locate the pulsations if the vein is already distended.) 4, Stripping is performed as follows: A, Place 2 adjacent fingertips over the area of interest along the EJV. B, Spread your fingers apart along the course of the EJV. C, Remove the lower finger, and leave the upper finger in place. The vein should fill from below (retrograde), and you may be able to appreciate the point of pulsation more clearly. Curved arrow indicates the head of the bed being raised upward; straight arrow, horizontal line from UC to ruler to where indicated to measure; bracket, distance on the ruler; and vertical dotted line, center of the sternum.

METHODS

The study was performed prospectively in medical and surgical ICUs and included patients receiving mechanical ventilatory assistance and spontaneously breathing patients, all of whom had preexisting central venous catheters. All patients were eligible for the study, regardless of diagnosis, neck size, or catheter location (patients with only a femoral venous catheter were excluded). Measurements from the catheters were read in millimeters of mercury and were converted to centimeters of water (1 mm Hg = 1.36 cm of water). Because the jugular venous pulse wave cannot be seen at extremely high CVP levels, patients whose CVP measurement by the indwelling catheter exceeded 20 cm of water were excluded. Demographic data (age, sex, weight, body mass index, ICU admission diagnosis, and severity of illness as measured by the Acute Physiology and Chronic Health Evaluation II [APACHE II] score[18]) were recorded for all patients. A daily screen of all consecutive patients admitted to the ICUs was performed. All eligible subjects were approached, and informed consent was obtained as soon as possible after ICU admission. The study was approved by the Institutional Review Board at the University of Chicago. Informed consent was obtained directly from the patient or from a surrogate decision maker for patients who were unable to make informed decisions.

PARTICIPANTS

Participants in the trial were delineated into the following 3 levels of experience: attendings (pulmonary and critical care attending physicians), intermediates (second-year and third-year medical residents and pulmonary and critical care fellows), and novices (internal medicine interns and senior medical students). All first-time examiners were given a brief didactic lecture and written instructions on measuring CVP using the EJV (**Figure 1**). Observers were given 2 short rulers to estimate venous pulsation height. The specific approach to the examination of the EJV, including proper patient positioning, is shown in Figure 1 and is available in an online video.

MEASUREMENTS

Before patient examinations, participants reported the emphasis that had been placed on the EJV examination during their medical school physical diagnosis training. This was done using a visual analog scale from 0 to 10, with 0 indicating no emphasis and 10 indicating total emphasis on the EJV. All catheter measurements were rounded to the nearest whole number. Participants recorded the vertical distance of the EJV waveform above the angle of Louis (sternomanubrial angle) as per the approach shown in Figure 1 and in the online video (eVideo; available at: http://www.archinternmed.com). Five centimeters of water were added to this vertical distance to account for the distance of the right atrium below the angle of Louis (assuming a constant distance over a wide range of patient positions).[19] After the examination, participants were asked to grade the ease of visualization of IJVs and EJVs using the visual analog scale.

A single investigator (A.G.V.) made central venous catheter measurements, which served as the "gold standard" measure of CVP. This was done immediately before each observer's evaluation. Airway pressure monitoring was used to ensure that invasively measured CVP readings were done at end expiration.[20] Central venous pressure transducers were leveled using a spirit level at a position that was 5 cm vertically below the angle of Louis and were then zeroed before each measurement. Patient clinical information was withheld from observers, and all central line readings were removed from view on the bedside monitor, so that each examiner was blinded to the central venous catheter value.

Table 1. Characteristics of 35 Examined Patients and Catheter Central Venous Pressure (CVP) Readings*

Demographic	Value
Age, y	64.2 ± 19.3
Male/female ratio	18:17
Acute Physiology and Chronic Health Evaluation II score	18.8 ± 4.1
Weight, kg	75.4 ± 18.5
Body mass index†	26.3 ± 6.6
Heart rate, beats/min	105 (90-115)
Arterial pressure, mm Hg	83 (70-90)
Intensive care unit diagnoses, No.	
Acute respiratory distress syndrome	8
Sepsis	8
Gastrointestinal bleed	4
Congestive heart failure	11
Miscellaneous	4
Catheter CVP reading, mean ± SD (interquartile range), cm H_2O	9.9 ± 5.2 (2-20)
Right internal jugular catheterization, No.	20
Mechanical ventilatory assistance, No.	16

*Data are given as mean ± SD or as median (interquartile range) unless otherwise indicated.

†Calculated as weight in kilograms divided by the square of height in meters.

ANALYSIS

Central venous pressure values were divided a priori into low (≤5 cm of water), reference range (6-9 cm of water), and high (≥10 cm of water) categories, using values identical to those used in previous prospective assessments of the IJV vs a central venous catheter.[2,5] We evaluated 35 patients. No formal sample size calculation was performed. The primary end point of the study was the ability of the EJV examination to identify low and high CVP categories using area under the receiver operating characteristic (ROC) curve analysis.[21] Secondary analyses included a comparison of the ease of visualization of the IJVs vs the EJVs among observers, as well as the Bland-Altman graphical comparisons of EJV estimates and central venous catheter measurements of CVP.[22]

Data were analyzed using GraphPad Prism (GraphPad Software, San Diego, Calif) and Analyze-it (Analyze-it Software Ltd, Leeds, England) software. The means ± SDs are reported for normally distributed data. Medians (with interquartile range) are given for comparisons of nongaussian results. *t* Test or Mann-Whitney test was used to assess differences between continuous variables as appropriate. To estimate between-observer and between-subject variance, we fit a random-effects model with CVP as measured by the EJV examination as the dependent variable and with type of observer (novice, intermediate, or attending) and subject as the random effects. A comparison of nonparametric data obtained by multiple groups was analyzed using Kruskal-Wallis test with post hoc Dunn test comparison. The correlation between 2 variables was also assessed using Pearson product moment correlation determination. Sensitivity, specificity, likelihood ratios, and positive and negative predictive values for the EJV examination assessments were calculated.

RESULTS

Of 36 patients who provided informed consent, 1 patient was excluded for having a central venous catheter CVP of 28 cm of water. Of the remaining 35 patients, 16 were orally intubated and were receiving mechanical ventilatory assistance. One patient had a tracheostomy. Patient characteristics are given in **Table 1**. Thirty-four observations were recorded among patients with low CVP, 50 observations were recorded among patients with high CVP, and 34 observations were recorded among patients with normal CVP (6-9 cm of water).

The observations were based on 118 examinations comprising 38 examinations performed by 6 different attending examiners, 33 examinations performed by 15 different intermediate examiners, and 47 examinations performed by 24 different novice examiners. Sixty of 118 examinations were performed in patients who were receiving mechanical ventilatory assistance. Seventy-six of the examinations were performed in patients with internal jugular catheters, with the remaining patients having subclavian catheters. In patients with internal jugular catheters, examiners evaluated the side of the neck opposite the catheter. There were no differences between the right and left sides with regard to the perception of the difficulty or the reliability of readings (data not shown). Using the random-effects model with CVP as measured by the EJV examination as the dependent variable and with type of observer (novice, intermediate, or attending) and subject as the random effects, between-observer variance was estimated to be 0.053, and between-subject variance was estimated to be 6.54. From this, it can be concluded that most of the variance in the model is attributable to variance across subjects and not to variance across types of observers.

Attending physicians demonstrated the best performance, with areas under the ROC curve of 0.95 (95% confidence interval [CI], 0.88-1.00) among patients with low CVP and 0.97 (95% CI, 0.92-1.00) among patients with high CVP. Although junior examiners did not perform as well, areas under the ROC curve remained excellent except for novice examiners in the low CVP and high CVP categories. The ROC curve analysis results are shown in **Figure 2**. **Table 2** gives the sensitivity, specificity, likelihood ratio, and positive and negative predictive value of the EJV examination in estimating low and high CVP. When comparing patients who received mechanical ventilatory assistance with spontaneously breathing patients, there were no appreciable differences in the results (data not shown).

The Bland-Altman graphical comparison of methods technique[22] was used to compare observations and central venous catheter readings for all examinations and for each group of examiners. A visual assessment of the Bland-Altman plots suggests that novice and intermediate examiners seem to underestimate CVP by larger amounts at higher catheter readings of CVP compared with attending examiners (**Figure 3**). The bias (95% confidence limits) and corresponding Pearson product moment correlation coefficients are given in **Table 3**.

The ease of visualization was significantly better for the EJV compared with the IJV for all examiners (mean visual analog scale score, 8 [95% CI, 6-9] vs 5 [95% CI, 3-7]; $P<.001$). The median reported emphasis during training on EJV use as part of the physical examination was 3.0 (95% CI, 0.0-7.0) for all observers.

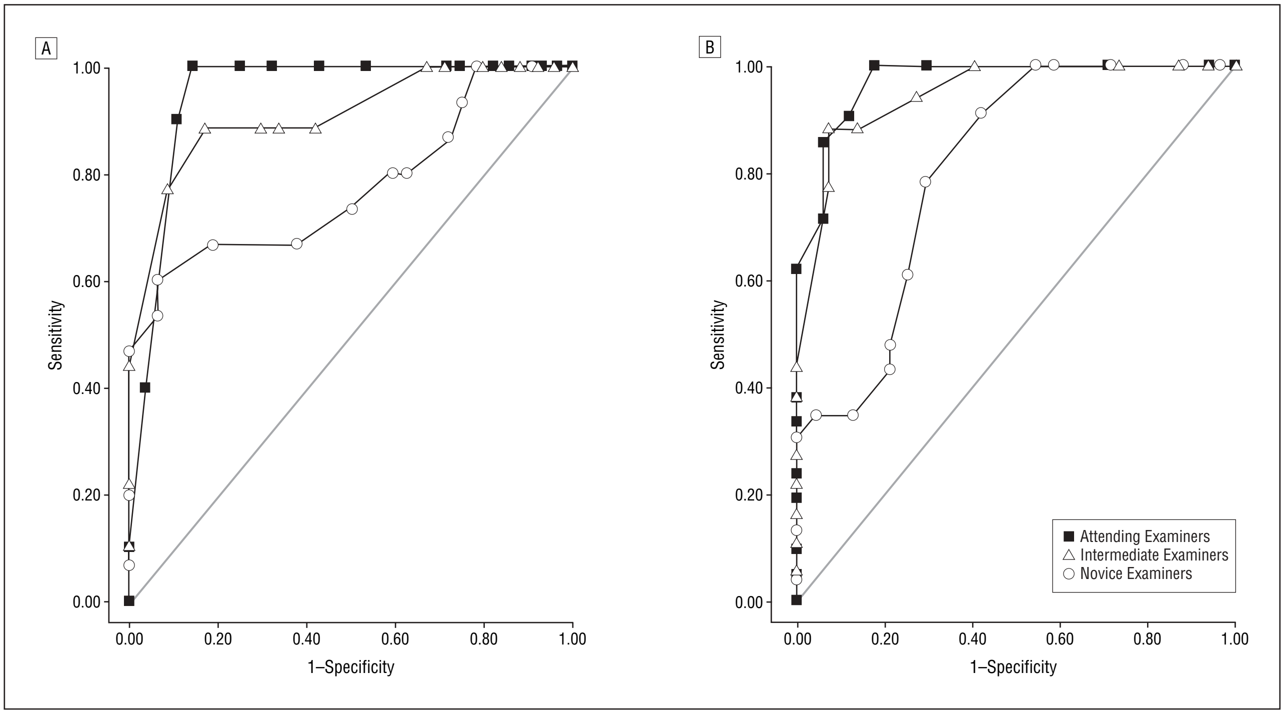

Figure 2. Receiver operating characteristic curves for discrimination of low (A) and high (B) central venous pressure. A, Receiver operating characteristic curves for discrimination of low central venous pressure (≤ 5 cm H_2O). Area under the curve was 0.95 (95% confidence interval [CI], 0.88-1.00) for attending examiners, 0.91 (95% CI, 0.79-1.00) for intermediate examiners, 0.78 (95% CI, 0.61-0.94) for novice examiners, and 0.86 (95% CI, 0.78-0.95) for all examiners. B, Receiver operating characteristic curves for discrimination of high central venous pressure (≥10 cm H_2O). Area under the curve was 0.97 (95% confidence interval [CI], 0.92-1.00) for attending examiners, 0.95 (95% CI, 0.88-1.00) for intermediate examiners, 0.81 (95% CI, 0.69-0.93) for novice examiners, and 0.90 (95% CI, 0.84-0.96) for all examiners.

Table 2. Predictive Value of the External Jugular Vein (EJV) Examination in Estimating Low and High Central Venous Pressure (CVP)

	Low CVP Examinations				High CVP Examinations			
Variable	Novice	Intermediate	Attending	All	Novice	Intermediate	Attending	All
No. of examinations	47	33	38	**118**	47	33	38	**118**
Prevalence of low and high values	15	9	10	**34**	23	18	17	**58**
Sensitivity	0.47	0.78	0.90	0.68	0.61	0.78	0.71	0.69
Specificity	1.00	0.92	0.89	0.94	0.75	0.93	0.94	0.86
Likelihood ratio								
Positive	∞	9.80	8.20	11.30	2.40	11.10	11.80	4.90
Negative	0.50	0.20	0.11	0.34	0.50	0.20	0.30	0.40
Predictive value								
Positive	1.00	0.78	0.75	0.82	0.70	0.93	0.94	0.84
Negative	0.80	0.92	0.96	0.88	0.67	0.78	0.73	0.72

COMMENT

We performed a prospective blinded assessment of the EJV examination of CVP compared with CVP measured by a central venous catheter in the ICU setting. Our results confirm the assertion that the EJV is easier to visualize than the IJV and depicts abnormally low and high CVP with remarkable precision. Our findings are strengthened by the fact that the EJV examination was compared with an established standard (CVP by central venous catheter measurement) in a blinded fashion. Furthermore, by withholding clinical information, examiners were unbiased by anticipated diagnoses or by awareness of therapeutic interventions (eg, diuresis or fluid administration). The ability to discriminate CVP in any patient, particularly one who is critically ill, into categories with such fidelity has tremendous implications for bedside care.

A critical question for many patients is whether CVP is too low or too high. Whether the goal of measuring CVP is to determine the cause of dyspnea,[23] the reason for pulmonary edema (low vs high CVP cause), or the intravascular volume status in a hypotensive patient, CVP is an important data point.[24] The results of our study suggest that the EJV examination is a powerful tool in such assessments.

Central venous pressure is an important end point in the resuscitation of patients with severe sepsis and septic shock. Rivers et al[14] used an algorithm targeting CVP of 8 to 12 mm Hg or higher to guide therapy in such patients. A practical impediment to the accomplishment of early goal-

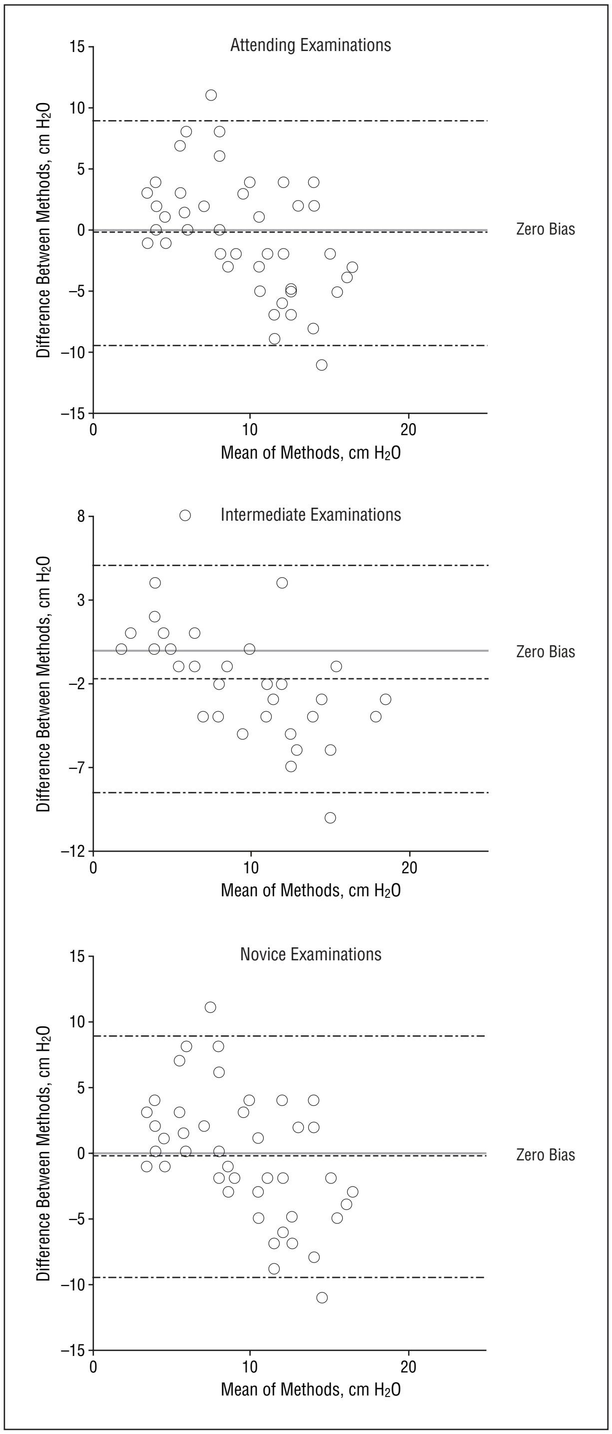

Figure 3. The Bland-Altman plots[22] of the correlation between the external jugular vein examination and catheter-measured central venous pressure values.

directed therapy is the timeliness of placing a central venous catheter, particularly in busy centers with limited clinical staff. The EJV examination may permit immediate estimation of CVP, even before central venous access is accomplished. This could guide clinicians to initiate intravenous fluid bolus therapy before the catheter is placed if CVP is low by the EJV examination.

Contrary to previously suggested limitations of the physical examination of jugular veins,[2,5] we found no difference in the reliability of the EJV examination whether

Table 3. Data Summary of the Examinations Shown in Figure 3*

Examiners	No.	Bias (95% Confidence Limits of Agreement), cm of Water	*R* Value†
Novice	47	−0.3 (−9.6 to 8.9)	0.51
Intermediate	33	−1.7 (−8.6 to 5.2)	0.81
Attending	38	−1.0 (−6.8 to 4.8)	0.82
All	**118**	−1.0 (−8.6 to 6.7)	0.69

*Based on the Bland-Altman plots[22] of the correlation between the external jugular vein examination and catheter-measured central venous pressures values.
†Pearson product moment correlation.

or not the patient received mechanical ventilatory assistance. A recent study[15] of patients who received mechanical ventilatory assistance with acute lung injury found benefits to reducing CVP with diuretic therapy. As such, it may be possible to use the EJV examination in lieu of central venous catheterization for ongoing management of volume status in some patients with acute lung injury or acute respiratory distress syndrome. Further research will be needed to confirm this hypothesis.

Performance of the EJV examination improved with physician experience but was comparable among attendings, residents, and fellows. Previous studies[4-6] of CVP measurement did not report the degree of reliable discrimination of abnormal values as that noted in our trial. Given the remarkable performance of the EJV examination, we believe that it should be used as the preferred approach to estimation of CVP.

In previous studies[3-6] of jugular vein examinations, categorization among low, normal, and high CVP groups varied. We chose the cutoff points of 5 cm of water or lower and 10 cm of water or higher to allow comparison with previous work evaluating the IJV examination.[2,5] In the most comprehensive published evaluations of jugular vein examinations that delineated CVP into categories, Cook et al[2,5] noted that the bedside IJV assessment using these cutoffs was poor. Based on the technique outlined to examiners in our study, the assessment of CVP lower than 5 cm or lower of water required placing patients in the Trendelenburg position. This extra step did not seem to affect the reliability of the low CVP assessments. On the contrary, the need to use the Trendelenburg position to see the EJV pulse may be a reliable way of confirming that CVP is indeed low.

This study confirms previously published work suggesting that invasive CVP measurement cannot be replaced entirely by the bedside examination if the goal is achieving the exact CVP value.[2,5,6] The physical examination is imperfect with regard to achieving this degree of reliability. Nevertheless, the usefulness of the EJV assessment is promising to categorize whether CVP is low or high. Arguably, these classifications may be much more useful clinically than determination of the exact CVP value.

Our trial has several limitations. Our observations were not all truly independent, because more than 1 observation typically was made on the same patient. Nevertheless, our random-effects model analysis suggests that most of the variance in the model was attributable to variance across subjects rather than across types of observers. Because of our sample size, we were unable to evaluate all outliers systematically. However, outliers such as mechanically ventilated patients and those with low CVP had good results with the EJV examination. Obese patients may be outliers because of the difficulty in visualizing their neck veins. However, as already discussed, the ROC curves for obese and nonobese patients were similar. Other outliers (eg, other neck anatomic abnormalities) were not studied in our protocol and cannot be commented on. The presence of a tracheostomy may limit the ability to accurately examine the jugular veins. Because our trial included only 1 patient who had a tracheostomy, the conclusions we can draw about such patients are limited. Our exclusion of patients with high CVP (>20 cm of water) is another limitation. Given that most patients' neck lengths would not allow visualization of the jugular venous pulse even in the upright position, this is an inherent limitation of the examination, regardless of whether the IJV or EJV is used. It seems logical to expect that patients with CVP this high would have other clinical signs and symptoms that would suggest volume overload, although we did not evaluate this end point in our study. The jugular vein examination cannot be relied on to guide critical therapy in patients with very high CVP. Another limitation is the necessary time lag between catheter placement and attainment of informed consent inherent to this study. Such a time lag limits our ability to comment on the usefulness of the EJV examination in the earliest periods of ICU presentation.

Although our results represent the experience at a single center, it is clear that the use of the EJV examination is easy and accurate. Given the excellent performance in the ICU, it seems reasonable to speculate that the EJV examination can be used in other settings (eg, hospitals, emergency departments, and outpatient clinics) to recognize abnormal CVP levels with a high degree of reliability. Further studies will be needed to confirm this supposition. The greatest strength of the EJV examination is the ability to easily identify low and high CVP levels. Given the prior poor correlation between the IJV examination and CVP, the deterioration of examination skills among trainees, and the significant value of CVP measures in a wide range of clinical conditions, routine EJV examination training should be conducted, and the examination should be readily used to detect abnormal CVP in critically ill patients.

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Author Contributions: Drs Vinayak, Gehlbach, and Kress had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Vinayak, Hall, and Kress. *Acquisition of data:* Vinayak, Levitt, Gehlbach, Pohlman, and Kress. *Analysis and interpretation of data:* Vinayak, Levitt, Hall, and Kress. *Drafting of the manuscript:* Vinayak, Pohlman, and Kress. *Critical revision of the manuscript for important intellectual content*: Vinayak, Levitt, Gehlbach, Hall, and Kress. *Statistical analysis:* Vinayak and Kress. *Administrative, technical, and material support:* Vinayak, Pohlman, Hall, and Kress. *Study supervision:* Kress.

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