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Brief Reports

THE USE OF INTERNAL JUGULAR VEIN ULTRASONOGRAPHY TO ANTICIPATE LOW OR HIGH CENTRAL VENOUS PRESSURE DURING MECHANICAL VENTILATION

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□ Abstract—Background: Critically low or high central venous pressure (CVP) values, together with systemic hypotension, can indicate hypovolemia or acute heart failure. However, measuring CVP requires the insertion of a central venous catheter, a time-consuming procedure that can be associated with severe complications. Objective: We sought to evaluate the use of ultrasonography of the internal jugular vein (IJV) to estimate low or high CVP values in patients who were on ventilation. Methods: Ultrasonography of IJV dimensions and the collection of hemodynamic data was performed in 47 patients, and the ratio between IJV diameter in the 30° and 0° position was calculated (ratio$_{30/0}$). The predictive value of ratio$_{30/0}$ for estimating low and high CVP levels was analyzed using receiver operating characteristic curves. Results: The median IJV diameter ratio$_{30/0}$ was 0.49. CVP ranged from 1 to 13 mm Hg (median 7 mm Hg). Seventeen patients had a CVP ≤ 5 mm Hg or lower (defined as "low"), and in 11 patients, values of ≥ 10 mm Hg were measured (defined as "high"). The corresponding IJV diameter ratios increased significantly from 0.34 (in the low CVP group) to 0.9 (in the high CVP group). Receiver operating characteristic analysis revealed a good predictive value of the ratio$_{30/0}$ for the prediction of low or high CVP values, respectively. A ratio$_{30/0}$ of < 0.45 optimally indicated a low CVP, while > 0.65 was the cutoff value to detect a CVP ≥ 10 mm Hg. Conclusion: The estimation of low or high CVP values by IJV ultrasonography in different patient positions can be a helpful instrument for the rapid hemodynamic assessment of the critically ill patient.

□ Keywords—central venous pressure; hemodynamics; jugular vein; thoracic surgery; ultrasonography

INTRODUCTION

Despite conflicting results about the diagnostic value of low central venous pressure (CVP) in recent years, there are a number of studies showing good correlation of CVP with surrogate markers of impaired tissue oxygenation caused by hypovolemia (1–4). On the other hand, the finding of an abnormally elevated CVP may signify pericardial tamponade or acute heart failure (5,6). Therefore, CVP is still part of the standard hemodynamic monitoring for critically ill patients. Moreover, it is a key parameter for the differential diagnosis of shock from unknown cause.

CVP measurement requires the presence of a central venous catheter (CVC), which may not be available in emergency situations or when a patient's condition is about to deteriorate rapidly. In addition, the insertion of a CVC may be time-consuming and, as an invasive procedure, can lead to severe complications (7). Therefore, techniques that allow for rapid and noninvasive hemodynamic assessment are needed.

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Recently, it has been shown that sonographic determination of the diameter of the inferior vena cava (IVC) is related to CVP and other hemodynamic parameters describing the patient's fluid state (8,9). Because of its compliance, changes of the intravascular volume state affect the venous pressure as well as the diameter of the vein. Guidelines by the American Society of Echocardiography support the use of evaluation of IVC size and collapsibility for the assessment of CVP (10). However, sonographic evaluation of the IVC may be challenging or even impossible (e.g., after major abdominal surgery or trauma or when subcostal midline chest drainage tubes have been inserted) (11). The internal jugular vein (IJV) is, compared to the IVC, much more easily accessible for sonographic visualization. Several authors described the estimation of CVP by ultrasonography of the IJV in spontaneously breathing patients (12–14). However, critically ill patients are often mechanically ventilated, and positive end-expiratory pressure may affect IJV geometry (15). Whether IJV diameter correlates with CVP in intubated and ventilated patients has not been investigated in detail. Our study aimed to establish a simple technique to anticipate low (≤5 mm Hg) versus high (≥10 mm Hg) CVP values by sonographic IJV measurements. To obtain valid results, ultrasonographic results as well as hemodynamic data were assessed in patients after coronary artery surgery (CAS) and left ventricular valve surgery (VS).

METHODS

This observational study was conducted at the cardiac surgery intensive care unit (ICU) of the University Hospital Bonn, Germany, in accordance with the principles expressed in the Declaration of Helsinki and after approval by the local ethics committee (protocol no. 206/14; date of approval: August 13, 2014). According to the approval, given that all measurements were considered to be part of routine practice, informed consent was waived. Inclusion criteria were as follows: 1) elective CAS or VS or combined procedures, and 2) age ≥ 18 years.

The following exclusion criteria were defined: 1) cardiac dysrhythmia (e.g., atrial fibrillation); 2) clinically relevant tricuspid or mitral regurgitation; 3) a history of radiotherapy or surgery of neck region; 4) thrombosis of large upper body veins; and 5) bilaterally inserted venous catheters (jugular or subclavian vein).

All patients were sedated and mechanically ventilated (airway pressure release ventilation [APRV]; V_T 6–8 mL/kg BW; $P_{peak} \leq 25$ cm H_2O; 10 cm $H_2O \leq$ positive airway pressure [PEEP] ≤ 13 cm H_2O; average I:E ratio 1:1.5; $S_aO_2 \geq 95\%$; and $pCO_2 \leq 45$ mm Hg). APRV is a pressure-controlled ventilation mode that allows for the definition of two levels of positive airway pressure (PEEP, P_{peak}), each being provided for a defined period of time. Depending on the ventilator settings, APRV is comparable to biphasic positive airway pressure mode. Sonographic measurement was performed using a HD15 ultrasound device (Philips Healthcare, Best, the Netherlands) equipped with a linear transducer (L12-3 Broadband Linear Array Transducer; Philips Healthcare). By default, patients arriving at the ICU after cardiac surgery had received a central venous line, usually inserted into the right IJV. To avoid any risk of infection of the puncture site, measurements were only carried out on the contralateral side. Examinations were performed by two Board-certified anesthesiologists, each with experience of > 100 ultrasound-guided IJV cannulations, and interobserver reliability was ensured in pilot tests by performing repeated measurements by the two involved ultrasound investigators in 10 patients. IJV was visualized by placing the transducer in a transverse plane on the patient's neck at the level of the cricoid cartilage. The vein was identified by compression and color Doppler imaging. To avoid any influence of external compression on the IJV diameter, enough ultrasound gel was used to allow the transducer to lose direct skin contact, thereby using the least possible pressure. A B-mode scan was recorded over an entire respiratory cycle, then the image was frozen and the diameter of the IJV was measured at the end of expiration.

CVP, systolic, diastolic, mean arterial pressure (MAP), and heart rate were collected using an Infinity C700 monitor (Dräger Medical GmbH, Lübeck, Germany) via indwelling central venous and arterial catheters. Ultrasonographic examinations and the collection of hemodynamic data were performed with the patient in a supine position with the upper body (head of the bed) elevated by 30° (semirecumbent). After changing to the 0° position, IJV ultrasonography was repeated and the ratio between the IJV diameter in the 30° and 0° position was calculated using the following formula: $ratio_{30/0}$ = diameter [30°]/diameter [0°].

Other recorded patient data included age, sex, Simplified Acute Physiology Score (SAPS) II, procedure, ventilation settings, and vasoactive drug infusion rates.

Statistical analysis was performed using PRISM software (GraphPad, La Jolla, CA). Unless otherwise stated, data are presented as median with interquartile range (IQR). Individual patients under varying conditions were compared using the Wilcoxon matched pairs test. The Mann–Whitney test was used to compare independent groups of samples. The ability of the IJV examination to identify low and high CVP values was determined using receiver operating characteristic (ROC) curve analysis. The alpha level was set at 5%.