ÖZGÜN ARAŞTIRMA ORIGINAL RESEARCH

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COMPARISON OF NONINVASIVE CENTRAL VENOUS PRESSURE MEASUREMENT METHODS: INTERNAL JUGULAR VEIN VERSUS VENA CAVA INFERIOR

NONİNVAZİV SANTRAL VENÖZ BASINÇ ÖLÇÜMÜ YÖNTEMLERİNİN KIYASLANMASI: İNTERNAL JUGULER VEN VE VENA CAVA İNFERİOR

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Öz

Amaç
Santral venöz basınç ölçümü hastaların hacim durumunu tespit etmek için etkili bir yöntemdir. Bununla birlikte, pnömotoraks gibi hayatı tehdit eden komplikasyonlar ortaya çıkabilir. Ultrasonografik ölçümlerin invaziv santral venöz basıncın bir göstergesi olarak kullanılabileceğini düşünmekteyiz.

Gereç ve Yöntem
Çalışmamız, Ocak 2015-Ocak 2016 tarihleri arasında, 18 yaşın üzerinde olan ve Acil Yoğun Bakım Ünitemizde internal juguler vene (IJV) santral venöz kateter yerleştirilen 81 hasta üzerinde gerçekleştirildi. İnternal juguler vendeki kanın yüksekliği, internal juguler ven kollapsibilite indeksi (IJV-Kİ) ve kaval indeks (Kİ) ultrasonografi ile ölçüldü. Daha sonra invaziv santral venöz basınç (SVB) ölçüldü ve hastalar düşük SVB ve normal SVB grupları olarak iki gruba ayrıldı ve bu üç yöntem açısından gruplar arasında istatistiksel olarak anlamlılık arandı.

Bulgular
Yaş ortalaması 68,58 ± 13,33 idi. Hastaların 54'ü (% 66,6) erkekti. Kırk altı hasta (% 56,8) mekanik ventilasyon altındaydı. Düşük SVB grubu 62 hastadan (% 76,5) oluştu. Ortalama invaziv SVB 4,83 ± 4,26 mmHg idi. IJV-Kİ ve invaziv SVB ile Kİ (r= 0,267, p=0,016 ve r=0,319, p=0,04), IJV yükseklik yöntemi ve Kİ ile invaziv SVB ölçümü arasında anlamlı korelasyonlar vardı (r=-0,231, p=0,03 ve r=0,357, p=0,01). Kİ ile invaziv SVB ölçümü arasında herhangi bir korelasyon izlenmedi (r = -0,010, p = 0,368).

Sonuç
Noninvaziv santral venöz basınç ölçüm yöntemleri invaziv santral venöz basınç düzeyleri için bir gösterge olarak kullanılabilir. IJV-Kİ, SVB'ı tahmin etmek için yararlı bir araç olabilir. IJV ölçümleri, özellikle hipovolemik hastalarda vena cava inferior ölçümlerinden daha iyi sonuç vermektedir.

Anahtar Kelimeler: Santral venöz basınç, İnternal juguler ven, Kollapsibilite İndeksi, Vena cava inferior, Ultrason, Korelasyon

Abstract

Objective
Central venous pressure measurement is an effective method to detect the volume status of the patients. However, life-threatening complications such as pneumothorax may occur. We assume that ultrasonographic measurements may be used as a surrogate of invasive central venous pressure.

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Materials and Methods
Our study has been conducted between January 2015-January 2016 on 81 patients who were over the age of 18 and to whom a central venous catheter has been placed in the internal jugular vein (IJV) in our Emergency Intensive Care Unit. The height of the blood column in the internal jugular vein, internal jugular vein collapsibility index (IJV-CI) and the caval index (CI) of vena cava inferior have been measured by ultrasound. Then, invasive central venous pressure (CVP) has been measured and the patients were separated into two groups as low CVP and normal CVP groups and statistically significance was sought between groups in regard of these three methods.

Results
The mean age was 68.58±13.33 years. Fifty-four of the patients (66.6%) were male. Forty-six patients (56.8%) were mechanically ventilated. Low CVP group consisted of 62 patients (76.5%). Mean invasive CVP was 4.83±4.26 mmHg. There were significant correlations between IJV-CI and invasive CVP along with the CI (r=-0.267, p=0.016 and r=0.319, p=0.04, respectively), IJV height method and CI as well as invasive CVP measurement (r=-0.231, p=0.03 and r=0.357, p=0.01, respectively). The CI did not yield any correlation between invasive CVP measurement (r=-0.010, p=0.368).

Conclusion
Noninvasive central venous pressure measurement methods may be used as a surrogate for invasive central venous pressure levels. The IJV-CI may be a useful tool to estimate CVP. Measurements of IJV yields better results than the measurements from vena cava inferior (VCI) especially in volume depleted patients.

Keywords: Central venous pressure, internal jugular vein, collapsibility index, vena cava inferior, ultrasound, correlation

Introduction

Central venous pressure (CVP) is still being used in the intensive care unit and emergency department settings to evaluate the volume status of critically ill patients. As well as it is an invasive measurement method with risks of major complications such as pneumothorax, noninvasive measurement methods of CVP with bedside ultrasonography has gained popularity lately. Internal jugular vein (IJV) height, diameter and area measurement, vena cava inferior (VCI) diameter measurement and calculation of caval index (percentage of the relative decrease in vena cava inferior diameter with deep inspiration) can be mentioned among these methods.

Although it is proven that these methods correlate with invasive CVP values, none of them has become a part of the routine in the assessment of the critically ill. Noninvasive CVP measurement is first described in 1930 by Sir Thomas Lewis employing physical examination and measurement of the height of the blood column which provides the intraluminal distention of the IJV (1). Unfortunately, this method did not achieve the desired accurate results, especially in obese and elder patients because of the dependency on the physical examination (2). Despite the technological advancements and the variety of noninvasive CVP measurement methods, invasive CVP measurement is still used in clinics where these technologies are not readily available.

This study aimed to seek a correlation between invasive CVP and noninvasive CVP values which are estimated by bedside ultrasonographic methods which are a noninvasive estimation of CVP according to the height of the blood column in the IJV (IJV height estimation method) and, IJV collapsibility and caval indexes.

Materials and Methods

This prospective cohort study was performed between January 2015 and January 2016 in the emergency intensive care unit of a tertiary medical center with 450 admittances annually. Eighty-one patients older than 18 years, to whom were placed a central venous catheter in their IJV with various indications were enrolled. This study was approved by the local ethics committee (Adnan Menderes University School of Medicine Ethics Committee of Non-interventional Clinical Researches, 2014/419) and written consent was obtained from the patients or first degree relatives or their legal representatives when the patient is unable to cooperate. Age, sex, respiratory status (spontaneous or mechanically ventilated), the height of the blood column in the IJV, diameters of IJV, and VCI at both inspiration and expiration and invasive CVP values were recorded for all patients.

Inclusion criteria were as follows: Patients older 18 years old and patients who already have central venous catheters in IJV. The exclusion criteria were defined as: Patients younger than 18 years old, patients with pregnancy, known tricuspid valve regurgitation, cor pulmonale, elevated cardiac enzymes, and history of radiotherapy or surgery to the neck region.

The IJV measurements were performed in two steps. An adequate amount of ultrasound gel has been used to minimize the effect of the compression by preventing the transducer from contacting the skin. First, a 4-13 MHz linear transducer was used to obtain the diameter of the IJV both at the end of the inspiration and the expiration at the level of cricothyroid membrane while the patients were in the supine position. The largest and the smallest diameters of the IJV were measured and then an IJV-CI was calculated according to this formula: (Maximum diameter of IJV-Minimum Diameter of IJV/Maximum diameter of IJVx100%) (3). Then, the patient was brought to the semi-recumbent position with the patient's head elevated at the angle of 45 degrees. The transducer was then placed on IJV in the longitudinal plane and the vein was identified with compression and color Doppler imaging. The height of the IJV was measured as the vertical distance between the narrowing point of the vein and the sternal angle. The CVP was estimated by adding 5cm to this height.

Caval index measurement was performed in the well acknowledged, conventional fashion with a 1-5 MHz convex transducer while the patients were in the supine position. The largest and smallest diameters of VCI was recorded. The caval index then was calculated as follows: (Maximum Diameter-Minimum Diameter)/Maximum Diameter x %100. With all data obtained, an estimation of noninvasive CVP was made according to the collapsibility of VCI (4).

Positive end-expiratory pressure (PEEP) was set to 5 cmH_2O in patients who were mechanically ventilated during measurements to ensure achieving the physiological state as possible (5). Following the completion of the ultrasonographic measurements, the caval index has been calculated and recorded. Then the catheter was connected to the monitor (LifeScope BSM-3763, Nihon Kohden Corp., Tokyo, Japan) and an invasive CVP value was obtained.

All ultrasonographic measurements were performed by the first author of this study who has a country-wide certification on Emergency Ultrasonography using Hitachi Aloka Prosound Alpha 6 ultrasound device (Hitachi Aloka Medical America Inc., CT, USA), blinded in invasive CVP value.

According to the invasive CVP values, a threshold of CVP lower than 8 cmH_2O was determined as low CVP. This value was selected based on the Surviving Sepsis Campaign 2012 Guidelines (6). Thus, the patients were divided into two groups. Statistical relationships between the two groups and a correlation between noninvasive CVP estimation methods and the invasive CVP levels were investigated.

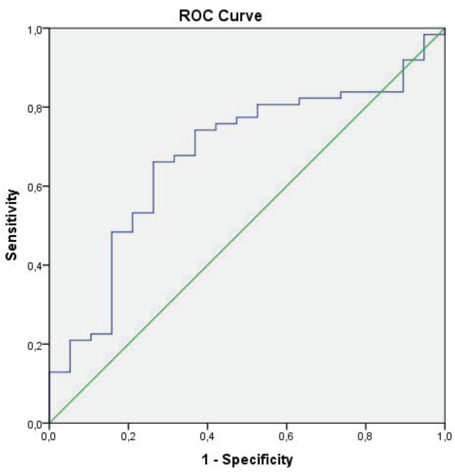
Statistical Analysis

All statistical calculations were made using SPSS 20.0 (IBM Corp. Released 2011. IBM SPSS Statistics for Windows. Version 20.0. Armonk, NY: IBM Corp.). The statistical significance level was determined as 0.05. A Chi-square test was performed to analyze the statistical similarity between groups. Mann-Whitney U was used to investigate significant difference between groups among all measurement methods. Spearman correlation test was performed to detect the correlation between estimated and invasive CVP values.

Results

Eighty-one patients (27 females and 54 males) with the mean age of 68.58±13.33 were included in the study. An overview of the patient characteristics is given in (Table-1). Of the 81 patients, 35 patients were breathing spontaneously while 46 of them were intubated and mechanically ventilated. Besides, 62 of them had an invasive CVP value under 8 mmHg (76.5%). The mean invasive CVP level was 4.83±4.26 mmHg in all groups. This value was 3.00±2.38 in the low CVP group and 10.84±3.45 in the normal CVP group (p=0.000).

The mean IJV collapsibility index was 29.02±23.53 in the low CVP group and 16.32±13.61 in the normal CVP group (p=0.02). With a cut-off level of 13.09% according to the ROC curve analysis, this method detected low CVP with a sensitivity of 74.2% and a specificity of 63.2% (AUC=0.677, p=0.02) (Graphic 1). The IJV



Graphic 1
ROC Curve analysis for the Internal Jugular Vein Collapsibility Index (AUC=0.677, p=0.02)

height method estimated a mean CVP of 5.03±4.29 and 8.57±2.65 mmHg in the low and normal CVP groups, respectively (p=0.00). The caval index measurement was 32.60±25.91 in the low CVP group and 25.42±27.24 in the normal CVP group (p=0.61). Chi-square test did not yield significant differences between the two groups (χ^2=6.98, p=0.08) (Table-2).

Spearman's rho test showed a negative correlation between IJV-CI and invasive CVP measurements (r=-0.267, p=0.016). We found a positive correlation between IJV height method and invasive CVP values (r=0.357, p=0.01). Besides, the measurements with the IJV height method were negatively correlated with the IJV-CI measurements (r=-0.231, p=0.03). Also, there was a significant correlation between IJV-CI and caval index (r=0.319, p=0.04). On the other hand, the caval index method did not show any correlation between the invasive CVP measurements (p=0.36) (Table-3).

Table 1 Demographic and Diagnostic Characteristics of the Patients

	Overall	Low CVP Group	Normal CVP Group	p
Age (years)	68.5±13.3	68.9±12.1	67.4±16.9	0.95
Sex (male/female) (n)	54/27	42/20	12/7	0.71
Respiratory Status (spontaneously breathing/mechanically ventilated) (n)	35/46	27/34	8/11	0.91
Mean Invasive CVP (mmHg)	4.83±4.26	3±2.38	10.84±3.45	0.00

Table 2 Bedside ultrasound measurements of the internal jugular vein and inferior vena cava

Measurement Method	Low CVP Group (SD)	Normal CVP Group (SD)	p
IJV Collapsibility Index (%)	29.02±23.53	16.32±13.61	0.02
IJV Height (Estimated CVP as mmHg)	5.03±4.29	8.57±2.65	0.00
Caval Index (%)	32.60±25.91	25.42±27.24	0.61

Table 3 Spearman correlation coefficients between ultrasound measurements and the invasive central venous pressure.

Comparison Between Measurement Methods	r	p
IJV Collapsibility Index and Invasive CVP	-0,267	0,016
IJV Height Method and Invasive CVP	0,357	0,01
IJV Height Method and Caval Index	-0,231	0,03
IJV Collapsibility Index and Caval Index	0,319	0,04
Caval Index and Invasive CVP	-0,101	0,368

Discussion

Central venous pressure is still being used in the determination of the volume status of the critically ill. Alongside the technological advancements in medicine, it is now almost a necessity to measure CVP noninvasively due to major complication risks despite the routine use of ultrasound in catheter placement. With the integration of the ultrasound in clinical practice, particularly in central venous catheter placement, this procedure has become safer (7). Nevertheless, risks of life-threatening complications and rates of long-term morbidities (e.g. catheter-related bloodstream infections) should not be underestimated. In a recent Cochrane systematic review (8), total complication rates of IJV cannulation, arterial puncture, and mechanical complications were 13.5%, 9.4%, and 3% respectively. Besides, the use of ultrasound yielded a decrease in the rates of total complications, arterial puncture, and mechanical complications 71%, 72%, and 73% respectively (8). We believe that this is another reason to be in search of a noninvasive volume estimation method.

In a recent study, Haliloğlu et al reported that the IJV-CI detected the volume depletion in non-ventilated patients with sepsis with a sensitivity of 78% and a specificity of 85% (9). However, their study was conducted in non-mechanically ventilated patients and the mean age of the study population was lower than ours which the absence of PEEP might have influenced the right atrial pressures. Also, the competency of the regulatory mechanisms of the vascular tone according to age might have had played a role dissimilarly to our study. In 2019, Parikh et al (10) reported that IJV-CI correlates with the right atrial pressures that they measured invasively which represents quite a similarity to our study. In a recent review, Pourmand et al (11) reported that the cut-off value of IJV-CI is 39% to use for the detection of the volume depletion but the basis of this value is unclear. In our study, this value was lower than Pourmand's. We assume that this might be originated from the unequal distribution of the patients with sepsis in our study population. Considering these two reports,

In 80 healthy volunteered patients, Ünlüer et al (12), compared the height of the IJV before and after a blood donation of 450 ml. Additionally, they investigated the IJV collapsibility index, and they detected a significant decrease in the height of the IJV after the donation. Thus, they proposed that this finding can be used to detect the early phase of hypovolemia. Likewise, Nik Muhamad (13) et al suggested that the measurement of the height of the IJV might correlate well with the invasive CVP values. Parallel to these reports, we also found a correlation between the IJV height method and the invasive CVP values (p=0,01). On the other hand, IJV measurement method can be time-consuming especially in the emergency settings, the patient should be placed in a semi-recumbent position exactly, the tapering portion of the blood column in the IJV must be marked correctly, the horizontal line from this point should be parallel to the surface, and the vertical measurement to the sternum should be performed accurately.

Another noninvasive volume estimation method in our study was measuring the collapsibility index of VCI. However, there are controversies regarding the utility of the caval index in the literature. A decade ago, Nagdev et al (14) suggested that in patients with more than 50% collapse in VCI, CVP was ≤8 mmHg, thus, showing a strong correlation with low CVP values. This was coherent with the well-known clinical approach of the volume estimation with the caval index. Also, Orso et al (15) investigated whether caval ultrasound could detect low volume status in dehydrated elderly patients with elevated BUN/Creatinine levels and found that a caval index is a reliable tool for the detection of the volume depletion. Additionally, Aydın et al (16) particularly claimed that the end-expiratory diameter of VCI shows a strong correlation with invasive CVP values. Discrepantly, our findings of the caval index were different than these studies. When literature is reviewed, it is acknowledged that more recent studies question the value of VCI measurements. Although in a relatively small group of critically ill patients, Govender et al (17) found no correlation between caval index and CVP.

In a study, where Kent et al (18) suggested that the correlation between IJV-CI and the caval index is questionable, we found a significant correlation between IJV-CI and the caval index. However, we must admit that this correlation is not as strong as expected due to the low level of a correlation coefficient. We assume that this relationship may be better understood with additional studies containing a larger number of participants.

When all ultrasonographic methods of this study are reviewed together, we may suggest that the methods involved with the internal jugular vein yields better results. Furthermore, IJV-CI is a better tool to estimate a noninvasive CVP than CI especially in the patients with low CVP, in another words the volume depleted patients.

Our study has several limitations. First, our sample size consisted of intensive care unit patients, and most of them were diagnosed with sepsis (42%) which they were mostly volume-depleted and in need of aggressive fluid resuscitation and inotropic agents. We think this is the main reason why the mean invasively measured CVP was 4.4 mmHg in our sample size. Additionally, 62 of our patients (76.5%) had an invasive CVP value of <8 mmHg. This hampered us to make a comparison with an adequate number of patients who had an invasive CVP value of ≥8 mmHg. Second, we enrolled both spontaneously and mechanically ventilated patients into our study. This may have influenced the calculation of the caval index and other ultrasound parameters. Third, we did not stratify for the use of vasopressors or the use of sedatives that could affect the measurements, and fourth our measurements were accomplished by only one ultrasonographer, thus we did not compare inter- or intra-rater reliability of the ultrasound techniques.

Conclusion

Noninvasive CVP estimation methods with bedside ultrasonography can be useful and used instead of invasive CVP measurement. Among these methods, although it may be time-consuming methods involving IJV may be more accurate than CI when investigating volume depleted patients. In particular, IJV-CI, with a cut-off level of 13.09%, a low CVP state can be estimated with a sensitivity of 67.7% and a specificity of 63.2%.

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