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Research Article

Is There an Optimal Positive End-Expiratory Pressure to Measure the Internal Jugular Vein Collapsibility Index? A Pilot Study in Mechanically Ventilated Patients

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ABSTRACT

Background: Hemodynamic monitoring its early stabilization is very important in critically ill patients. Evaluating the Internal jugular vein diameter during respiratory cycles by the means of Point-of care ultrasound provides an important, easily available and precise index for monitoring hemodynamic status; a new method which is called Internal Jugular Vein Collapsibility Index (IJV-CI). Any events that alters intrathoracic volumes and pressures may affect this index. In this study we investigate the effects of various levels of positive end-expiratory pressure on this index.

Methods: Thirty mechanically ventilated patients were studied. We used three different PEEP levels (0, 5 and 10 cmH2o) and point-of-care ultrasound evaluation of IJV (Internal Jugular Vein) diameter to determine the IJV-CI. The analysis were performed using SPSS V.25.0.

Results: Patients were included men (76.6%) and women (33.3%). The mean age of patients was 39.65±3.4 for men and 42.71± 9.34 for women. The IJV-CI were 20.71±11.77 and 24.25±11.46 in PEEP=0 and PEEP=10 cmH20 groups respectively. In 5cmH20-PEEP group median and interquartile range were 16.45(14.8). The IJV-CI in three different PEEP levels were not statistically significantly different.

Conclusion: According to the finding of this study, we found no evidence of an optimal PEEP level to measure The IJV-CI.

It is very important to diagnose hypovolemia as one of the most important life-threatening physiologic conditions, especially for patients admitted to the ICU. However, rapid assessment of intra-vascular volume and diagnosis of hypovolemia has always been difficult and challenging, especially when the patient's physiologic findings and clinical signs are used for this assessment [1-3]. Moreover, there are also accurate methods available that are either as invasive and complicated as the use of a central venous catheter, or rely on the use of echocardiography, which is expensive and requires specialized staff. Therefore, other methods have been introduced to estimate intravascular volume, for instance, measuring the respiratory changes of the diameter of the inferior vena cava (IVC) using ultrasound is one of these methods [4-5]. Nevertheless, this method cannot be used in 10 to 15% of patients (obese patients, ascites and abdominal distension) [6]. The use of the internal jugular vein to estimate central venous pressure (CVP), a measure that is called Internal Jugular vein collapsibility index (IJV-CI), due to being more technically accessible than abdominal IVC is suggested and thus has been studied in several studies [4-11]. It has been shown that an internal jugular collapse index of more than 39% may indicate hypovolemia in patients admitted to the ICU [2]. Increasing the airway pressure in

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mechanical ventilation leads to an increase in right atrial pressure and reduces venous return [12]. Moreover, one of the contributors to an increased intrathoracic pressure in patients under mechanical ventilation is positive end expiratory pressure (PEEP) [13]. In other words, the positive end-expiratory pressure decreases venous return by increasing the intrathoracic pressure and consequently reduces the internal jugular vein collapse, and thus can interfere with IJV-CI as a measure of hypovolemia. Several studies have already shown a direct relationship between PEEP and CVP [13-15]. However, no study has yet been conducted to investigate the relationship between PEEP changes and IJV-CI. In this study, we investigated the effect of PEEP changes on IJV-CI.

Methods

The present study was conducted as a pilot quasi-experimental study in 30 patients under mechanical ventilation admitted to the ICU of Ayatollah Mousavi Hospital in Zanjan, Iran, and has been evaluated and approved by the Research Ethics Committee of Zanjan University of Medical Sciences in July 2019. Prior to participating in the study, due to the inability of patients, written informed consent was obtained from their relatives. Patients older than 18 years, without any cardiac disease and without sepsis were included in the study. Exclusion criteria were inability to find the internal jugular vein due to a cervical collar or neck dressing, technical problems such as inability to position the patient properly and contraindication to use the considered PEEPs due to some medical conditions (e.g. increased Intra cranial pressure).

Measurements

Patients' information was recorded in a questionnaire that included age, sex, cause of hospitalization, case number, date of hospitalization, Approximate weight and respiratory parameters such as PEEP and vein diameter measured in each condition. Patients were deeply sedated with midazolam (1-2 mg Iv/stat) and fentanyl (50-100 µg Iv/stat) then injected with a muscle relaxant (atracurium 0.5 mg/kg). Intervention measures began about 3-5 minutes after the muscle relaxant injection. All patients underwent the following ventilator settings: Mode: SIMV, Tidal volume = 8 cc/Kg, Respiratory Rate = 10, PEEP = 0, Fio2 = 50%. Then, the anterior–posterior (AP) diameter of the internal jugular vein at the end of Inspiration and expiration were measured to calculate the Internal Jugular collapsibility index. The diameter of the internal jugular vein was measured by the same person and in supine position as follows:

1. The patient's head was elevated 30°.
2. The head was rotated slightly 30° to expose the right/ left IJV.
3. A linear probe was placed transversely lateral to the level of cricoid cartilage.
4. Minimum pressure was applied on the patient's skin to obtain a visible ultrasound image. The IJV was identified based on its compressibility and pulse wave Doppler.
5. The ultrasound probe was rotated to obtain the most circular cross-sectional image of the vein.
6. The image of the patient's respiratory cycle was stored and AP diameter of IJV was measured.
7. The maximum and minimum AP diameter of the IJV were measured during inspiration and expiration respectively in B mode.
8. The IJV-CI was calculated using the following formula [2]:

$$IJV-CI=[\frac{\text{Max}\,Diameter-MinDiameter}{Max\ Diameter}]\times 100$$

Then 5 and 10 cm H2O PEEP was applied to each patient respectively for 5 minutes and IJV-CI were measured. The eZono 3000 portable ultrasound (Jena, Thuringia, Germany) with a linear

transducer and the frequency of 3-12 MHz was used for Ultrasound measurements.

Statistical Analysis

In descriptive statistics, numerical variables were reported as mean ± standard deviation (SD) or median (inter-quartile range, IQR) as appropriate. A Kolmogorov–Smirnov test was used to test the distribution of numerical variable. Because the data were not normally distributed, Friedman test was examined to compare the response to the three PEEPs. Analyzes were performed using SPSS V.25. The significance level for all analyzes was considered 0.05.

Results

Thirty patients consisted of 23 males (mean age: 65.39± 4.3 years) and 7 females (mean age: 71.42± 34.9 years) in a range of 18 to 84 years were enrolled in the study. Twenty-five patients were diagnosed with multiple trauma and 5 patients were admitted to the intensive care unit for other reasons. The IJV-CI calculated in 5cm H2O PEEP did not have a normal distribution. There was no statistically significant difference between the IJV-CI mean at different PEEP levels (Table 1). In addition, no statistically significant difference was observed at different PEEP levels by gender (Friedman P Value= 0.26 in males and Friedman P Value = 0.8 in females).

Table 1. Relationship between different positive end-expiratory pressures (PEEP) and IJV-CI

PEEP (cmH2O)	IJV-CI	P value
PEEP 0	20.71±11.77	
PEEP 5	16.45 (14.8)	0.29
PEEP 10	24.25±11.46	

Values are expressed as mean ± SD or median (IQR).
PEEP, positive end expiratory pressure; IJV-CI, Internal Jugular collapsibility index.

Discussion

Thirty mechanically ventilated patients were studied to investigate the relationship between PEEP changes and the IJV-CI. To our knowledge, this study is the first study to discover this relationship. As a result of this study, no statistically significant difference was observed between the three different PEEP levels. In other words, no optimum level of PEEP can be suggested to measure this hemodynamic monitoring index. Due to the balance forces acting on the collapse of the jugular veins, it was expected that due to increase in intrathoracic pressure after increasing PEEP, the increase in intrathoracic venous pressure would be transferred to the outside of thorax (jugular veins / IVC) and cause the extra-thoracic veins dilate more, thus interferes with the estimation of intra-vascular volume by affecting the IJV-CI [12]. In a study led by Jassim et al. In ICU patients with spontaneous breathing those with high CVP (>10) had a lower IJV-CI and vice versa in patients with low CVP (<10) The IJV-CI was higher [7]. In another study in which patients under mechanical ventilation also participated, the mean IJV-CI in hypovolemic patients was 52.9% and this number was 21% in euvolemic patients [2]. Studies have been conducted to examine the relationship between PEEP and CVP in which Shojaee et al. [13], Kim et al. [14], Cao et al. [15], and Yang et al. [16] have shown a specific rate of increase in CVP with increase in PEEP. In this study, the mean value of the IJV-CI increased with increasing PEEP. However, this relationship is not statistically significant. Numerous studies have shown that the IJV-CI can be a reliable indicator for estimating intravascular volume and CVP; either in patients with Spontaneous breathing or in mechanically ventilated patients on PEEP or vasopressor support [2, 4, 11, 17, 18]. Moreover, some studies have shown that the association between the IJV-CI and inferior vena cava collapsibility index (IVC-CI) is seen only in patients with spontaneous breathing thus, this association does not exist in conditions of increased intrathoracic or intra-abdominal pressure [19]. Given that this is a pilot study and due to the lack of similar studies on the relationship between PEEP changes and the IJV-CI, It is not possible to compare the findings of this study with other studies. 5cmH2O PEEP is considered the physiological level [20]. Under physiological conditions the change in pulmonary vascular resistance is very small (<15%) [21]. Therefore, they have a wider collapsibility and the venous pressure is at a minimum normal level in balance with arterial elasticity, thoracic wall and diaphragm. Thus, a low external pressure on the skin can also compress the veins. Although, in order to measure venous diameter each time, five minutes was allocated for adapting to new PEEP level, the probe pressure on the skin surface is not the same in the different measurements. This factor might have caused a measurement error that could justify non normal distribution. Another factor that should be considered in such measurements is the type of ultrasound. The ultrasound machine used in this study was the eZono 3000 portable ultrasound. In B Mode, this device is only able to record 84 frames of the respiratory cycle. This device has a 3-12 MHz probe according to the catalog, but no information was obtained from its frame rate. Patients were paralyzed and were given only 10 breaths per minute, and if we consider that creating a moving image requires at least 18 frames per second. Therefore, this number of frames records only 4.6 seconds. According to the settings of the ventilator, the respiratory cycle is about 6 seconds, thus the minimum and maximum diameter of the vein during the respiratory cycle may not have been recorded properly. Thus, the calculated index may have encountered an error. In addition, this may affect determining the minimum and maximum diameter of the vein by the observer. Therefore, it may be more accurate to perform all measurements by M mode to determine the minimum and maximum venous diameter. If the patient is mechanically ventilated by Lung-protective methods with low tidal volumes because the elastic forces of the thorax are not opposed to the airway pressure, the calculated the IJV-CI will not be a measure of the patient's hemodynamic status [22-23]. Nevertheless, in this study, the tidal volume was set at 8 CC/kg and no patient requiring such ventilation (e.g. ARDS) was included in the patient list.

Conclusion

In Conclusion, since no statistically significant difference was found between the IJV-CI mean at the three different PEEP levels, the results of this study do not suggest any optimal PEEP level to measure this index.

The authors of the present study have some recommendation. First, to use a larger sample size in order to better determine the data distribution. Second, to use M mode to increase the measurement accuracy. Third, to decrease the likelihood of human error, consecutive measurements should be performed without moving the probe.

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