Journal of Advances in Medical and Biomedical Research | ISSN:2676-6264

Evaluation of the Effect of Three Different Tidal Volumes on Internal Jugular Vein Collapsibility Index in Hypovolemic Mechanically-Ventilated Patients Before and After Fluid Therapy

Alireza Zeraatchi[1], Fatemeh Safavi[2], Taraneh Naghibi[2*]

1. *Dept. of Emergency Medicine, School of Medicine, Zanjan University of Medical Sciences, Zanjan, Iran*
2. *Dept. of Anesthesiology and Critical Care Medicine, School of Medicine, Zanjan University of Medical Sciences, Zanjan, Iran*

Article Info

10.30699/jambs.31.147.342

Received: 2022/11/16;
Accepted: 2023/02/28;
Published Online: 27 Sep 2023;

Use your device to scan and read the article online

Corresponding Information:
Taraneh Naghibi,
Dept. of Anesthesiology and Critical Care Medicine, School of Medicine, Zanjan University of Medical Sciences, Zanjan, Iran

E-Mail: tnaghibi@zums.ac.ir

ABSTRACT

Background & Objective: The diameter of the internal jugular vein changes with variations in intrathoracic pressure during inhalation and exhalation and this difference increases during hypovolemia. One of the causes of increased intrathoracic pressure in patients under mechanical ventilation is the tidal volume, which can affect the diameter of the internal jugular vein. On this basis, the present study was designed to investigate the effect of tidal volume on the internal jugular collapsibility index.

Materials & Methods: In this clinical trial, 30 hypovolemic patients under mechanical ventilation were studied and three tidal volumes of 8, 10, and 12 cc/kg were applied to the patients. Subsequently, patients received fluid therapy and the measurements were repeated. Finally, the internal jugular vein diameters and the indices before and after the fluid therapy were measured in the three mentioned tidal volumes. A repeated measures t- test was used to compare the data.

Results: The means of the internal jugular collapsibility index in the three tidal volumes of 8, 10, and 12 cc/kg were 27.78 ±8.87, 28.11±10.24, and 29.67±11.72(p=0.577) respectively before fluid therapy. These values were 27.78±8.87, 28.11±10.24, and 29.67±11.72 (p= 0.288) respectively, after fluid therapy.

Conclusion: The results of this study showed that the internal jugular collapsibility index does not correlate with the tidal volume in hypovolemic patients and after fluid therapy.

Keywords: Internal Jugular Vein, Collapsibility Index, Tidal Volume, Hypovolemia, Ventilator

Introduction

The application of ultrasound on the patient's bed in the Intensive Care Unit (ICU) has been widespread for the past two decades, and several guidelines are presented for use by the Emergency Medicine Association (1) and the American Care Society (2, 3). Ultrasonography is the widely-used method for early hypovolemia diagnosis and intravascular volume assessment (4-6). In this regard, numerous studies have been conducted on different organs to evaluate vascular volume. Among these cases are the volume and contraction of the right and left cavities of the heart (7), the amount of inferior vena cava vein collapsibility, and the internal jugular vein indices (8-10). The internal jugular vein indices are easily measurable due to the accessibility of this vein (4). Internal jugular collapsibility is one of the most widely-used indices to examine the intravascular volume in patients undergoing mechanical ventilation (11). In these patients, there is a positive pressure inside the chest during the inhalation, which can reduce the intravenous return and increase the diameter of the artery outside of the chest, including the external and internal jugular veins. At the time of exhalation, this mode is reversed (12). On this basis, an internal jugular collapsibility index was created. Previous studies have shown that the internal jugular collapsibility index of more than 18% is a sign of hypovolemia (13).

Previous studies have shown that an increase in airway pressure following mechanical ventilation increases the right atrial pressure (RAP), which results in reduced intravenous return (14). One of the factors in increasing intra-chest pressure in patients undergoing mechanical ventilation is the tidal volume. Therefore, we decided to examine the impact of the amount of tidal volume on the internal jugular collapsibility index in the present study.

Materials and Methods

This study was a single-center clinical trial. The project was approved by the ethics committee of Zanjan University of Medical Science, Zanjan, Iran (IR. ZUMS.REC.1396.208).The study was started after receiving the IRCT code with the number IRCT20101211005363N11.

Due to the lack of a similar study, a pilot form of the study was performed on 30 patients. This study was conducted on patients who were admitted to Mousavi Hospital of Zanjan University of Medical Sciences.

The inclusion criteria were as follows:

1. Hypotensive patients (systolic pressure less than 90 mm Hg or decreased by more than 50 mm Hg in patients with high blood pressure)
2. Urine less than 0.5 cc/Kg for more than two hours
3. Heart rate over 100 beats/ min and central venous pressure less than 10 Cm H_2o
4. Age over 18 years
5. Absence of heart and lung diseases

6. Patient's relative satisfaction to participate in the study

The exclusion criteria were as follows:

1- Jugular Collapsibility index Less than 18%

2- Failure to find the internal jugular vein due to technical problems, including the inability of the patient's position

Patients entered the study when the intensivist decided to administer fluids based on the hypovolemia criterion. A central venous line was inserted for patients through the right internal jugular at the beginning of the study. Then a chest X-ray was taken. The tip of the catheter should be placed at the junction of the atrium with the superior vena cava. After confirming the location of the catheter, patients were under sedation with Midazolam (Exir pharmaceutical company) 0.15 mg /kg of body weight and Fentanyl (**C**aspian Company) 0.25 mg/kg of body weight. Three minutes later, Pancuronium (Caspian Company) was injected with a dosage of 0.06 mg/kg. Five minutes after the prescription of Pancuronium, patients were placed in the following settings of mechanical ventilation.

SIMV: Tidal Volume= 8 cc/Kg, Respiratory Rate=10, Positive end-expiratory pressure (PEEP) =5, Fio2=50%

Five minutes after the mechanical ventilation with the above settings, the diameter of the internal jugular vein was measured at the end of the inspiration, and the expiration, then the internal jugular collapsibility index was calculated.

These parameters were measured by the following method:

1-The patient's head was elevated 30 degrees and moved 30 degrees to the left

2. The linear ultrasound probe model eZono 3000 with a frequency of 7.5 MHz was placed in the transverse section in the margins of the cricoid cartilage.

3. Minimum pressure was applied on the patient's skin.

The maximum diameter of the internal jugular vein was measured at the end of the inhalation and its minimum was measured at the end of the exhalation with B Mode. Then, the Jugular Collapsibility index was calculated from the following formula:

IJV collapsibility index = [(Max diameter − Min diameter)/ (Max diameter)] × 100%

It should be noted that in this situation if the internal jugular vein collapsibility index was less than 18 %, the patient was excluded from the study. Then Tidal Volume = 10, 12 cc/kg was applied for 5 minutes. After this period, all variables including the diameters of the internal jugular vein at the end of inhalation and exhalation, and the internal jugular vein collapsibility indices were measured in different tidal volumes.

After completing the measurement of the variables, the patient was again placed on Tidal Volume = 8 cc/Kg. After 5 minutes, the central venous pressure was measured and 10 cc/kg of normal saline was prescribed. The prescription of normal saline continued so that the central venous pressure increased by more than 2 cm H_2o. However, it should not be increased more than 5 cm H_2o (according to law 5-2). In this case, the response to the liquid was considered. All the above steps were repeated after liquid therapy. The diameters of the internal jugular vein at the end of the inhalation and exhalation and internal jugular vein collapsibility indices were measured in all three tidal volumes after fluid therapy.

Statistics

The data were analyzed with SPSS version 20 software. To compare the variables between tidal volumes of 8 and 10 and 12 cc/kg, according to the normal distribution of data, the REPEATED MEASURED test was conducted.

Then, their significance level was compared using the Greenhouse-Geisser test. The significance level of the p-value in the present study was less than 0.05.

Results

Demographic characteristics

In this study, the mean age of the population was 50.1 ± 24.9 with a minimum of 18 and a maximum of 93 years. 60% of patients (18 people) were male and 40% (12 people) were female.

Among the three different tidal volumes, a significant difference was observed in the diameter of the internal jugular vein at the end of inhalation ($p = 0.001$) and exhalation ($p = 0.001$) before the fluid therapy. However,

there was no obvious difference in the internal jugular vein collapsibility index between the three tidal volumes, before the fluid therapy, (P = 0.577) (Table 1).

Table 1. The averages and standard deviations of the jugular collapsibility index and the diameters of the internal jugular vein at the end of the inhalation and the exhalation before the fluid therapy.

Consequences	8 cc/kg	10 cc/kg	12 cc/kg	P value
The diameter of the internal jugular vein at the end of the inhalation	15.36±4.95	16.87±5.11	18.31±4.51	0.001*
The diameter of the internal jugular vein at the end of the exhalation	11.17±4.57	12.11±4.24	12.95±4.09	0.001*
Internal jugular collapsibility index	27.78±8.87	28/11±10/24	29/67±11/72	0.577

*** The significance level of the P-value is less than 0.05. The *REPEATED MEASURED TEST has* been used. In each group, the mean value is ± SD.**

After fluid therapy, the diameters of the internal jugular vein at the end of inhalation (p=0.001) and exhalation (p=0.001) were statistically significant between the three different tidal volumes, but in the internal jugular vein collapsibility index, no statistical difference was observed. (P = 0/288) (Table 2).

Table 2. The averages and standard deviations of the jugular collapsibility index and the diameters of the internal jugular vein at the end of the inhalation and the exhalation after the fluid therapy.

Consequences	8 cc/kg	10 cc/kg	12 cc/kg	P value
The diameter of the internal jugular vein at the end of the inhalation	16.39±4.62	17.72±4.64	18.94±4.02	0.001*
The diameter of the internal jugular vein at the end of the exhalation	14.03±4.23	15.04±4.03	16.36±4.08	0.001*
Internal jugular collapsibility index	14.40±8.62	15.12±9.74	13.62±10.38	0.288

*** The significance level of the P-value is less than 0.05. The *REPEATED MEASURED TEST has* been used. In each group, the mean value is ± SD.**

Discussion

This study was conducted to investigate the effect of three different tidal volumes on internal jugular vein collapsibility index in hypovolemic mechanically-ventilated patients before and after fluid therapy. The present study was performed on patients who were hospitalized in the intensive care unit of Mousavi hospital in Zanjan. Thirty patients entered the study. The results of the study showed that there was no significant difference between the three tidal volumes (8, 10, and 12 CC/kg) in the internal jugular vein collapsibility index. The jugular vein diameters at the end of the inhalation and exhalation before and after the fluid therapy were significantly different between the three tidal volumes. As a result, higher tidal volumes not only increase the diameter of the internal jugular vein during inhalation, but also increase this diameter during exhalation. According to the formula of the internal jugular vein collapsibility index which is obtained from the difference of the diameter at the end of exhalation and inhalation divided by the diameter at the end of inhalation, it can be expected that despite the difference in the jugular vein diameters, the index does not have significant differences.

Because there has been no study on the relationship between tidal volume and internal jugular vein collapsibility index, there was no study to compare with the present study.

Thudium and et al., have investigated the effect of increased intrathoracic pressure on the internal jugular vein collapsibility index. They showed that changing the patient's position from 30 degrees to 0 degrees

affects the intrathoracic pressure and changes the internal jugular vein collapsibility index (15). Their study results are contrary to the present study, in which the increase in intrathoracic pressure following the increase in tidal volume had no effect on the internal jugular vein collapsibility index. The cause of this difference can be attributed to the method of increasing intrathoracic pressure. The increase in the tidal volume leads to decrease of the venous return which could explain the different results between the two studies.

Taccheri et al., have shown that inferior vena cava distensibility was not a reliable indicator of preload responsiveness in the patients who are under $Vt < 6$ mL/kg compared to $Vt \geq 8$ mL/kg (16). It is not surprising that a low Vt, induces lower changes in intrathoracic and transmural pressures. This different change in intrathoracic pressure could explain the effect of different tidal volumes on hemodynamic index in patients. Their results are opposite to the present study which the different tidal volumes did not affect internal jugular vein collapsibility index. These differences depend on the site of index and volume of blood which returns to the atrium.

Suehiro et al., have shown that for valuable prediction of fluid therapy response with stroke volume variability index, the tidal volume should be at least 8 cc/kg. (17). Reuters et al., indicated that with increasing the tidal volume, the hemodynamic-associated parameters such as stroke volume variation (SVV) increased (18). Their results are not consistent with the results of the present study. However, in their study, the comparison was only made between the tidal volumes of 6 and 8 cc/ kg, and stroke volume variation (SVV) was considered as the hemodynamic index.

Baker et al., also reported a minimum tidal volume of 8 cc/kg for the value of pulse pressure changes in the diagnosis of hypovolemia (19). Alvarado et al., have proven that Pulse pressure variation (PPV) is helpful in predicting fluid responsiveness in patients ventilated at tidal volume (Vt) >8 mL kg−1 (20). Pulse pressure is a hemodynamic index which could be influenced by increasing tidal volume changes. Their study results are contrary to the present study. These contradictory results could be explained by site of hemodynamic index. PPV is dependent on arterial vessels structural opposite of jugular vein collapsibility index which shows changes of vein vessels.

The present study showed that there is no correlation between tidal volume and internal jugular collapsibility index. As a result, the results of this study could not affect the confounding variables such as sex and type of disease, and other issues. As shown in the results, the internal jugular collapsibility index in the tidal volume group of 12 cc/kg was slightly increased compared to the other two groups but was not statistically significant. This could originate from the influence of the low power of study as a result of the low sample size. This study's findings could be used to guide similar studies with sufficient sample size and high power.

Conclusion

The internal jugular collapsibility index is a dynamic parameter that can easily be recorded from a bedside monitor and reliably predict preload responsiveness. One of the major limitation of the index is its application in patients receiving controlled mechanical ventilation that may be unreliable during different tidal volume levels. The present study shows that the internal jugular collapsibility index is not associated with tidal volume in hypovolemic patients and after fluid therapy; however, maximum and minimum diameters of internal jugular vein could be affected by different tidal volumes. Until more evidence becomes available, the study directors do not recommend choosing among the three tidal volumes 8, 10, and 12 cc/kg.

Strenghts of the study

According to the authors, this study was carried out for the first time which can be the basis for further studies.

Limitations of the study

Because similar studies were not available, the generalization and comparison of data were not possible. Also, due to the lack of measurement of cardiac stroke volume, it was not possible to prove the response to more accurate fluid therapy. The University Ethics Committee did not allow more samples due to the lack of previous studies which resulted in the lower power of the study.

Source of support

This work was a part of the thesis by Fatemeh Safavi that was supported by Zanjan University of Medical Sciences (grant Number IR. ZUMS.REC.1396.208).

Acknowledgments

The authors would like to thank all the study participants for their contribution and also Zanjan University of Medical Sciences for supporting the conduction of this study.

Conflict of Interest

The authors declare no conflict of interest.

Funding

None Declared.

References

1. Ultrasound guidelines: emergency, point-of-care, and clinical ultrasound guidelines in medicine.Ann Emerg Med. 2017;69(5):e27-e54. [DOI:10.1016/j.annemergmed.2016.08.457] [PMID]
2. Frankel HL, Kirkpatrick AW, Elbarbary M, et al. Guidelines for the appropriate use of bedside general and cardiac ultrasonography in the evaluation of critically ill patients-part I: general ultrasonography.Crit Care Med. 2015;43(11): 2479-502. [PMID] [DOI:10.1097/CCM.0000000000001216]
3. Levitov A, Frankel HL, Blaivas M, et al. Guidelines for the appropriate use of bedside general and cardiac ultrasonography in the evaluation of critically ill patients-part II: cardiac ultrasonography. Crit Care Med.2016;44(6):1206-27. [DOI:10.1097/CCM.0000000000001847] [PMID]
4. Killu K, Coba V, Blyden D, et al. Sonographic assessment of intravascular fluid estimate (SAFE) score by using bedside ultrasound in the intensive care unit. critical care research and practice. 2020; 2020:9719751. [DOI:10.1155/2020/9719751] [PMID] [PMCID]
5. Zeraatchi A, Naghibi T, Kafili H, Sabet S.Is there an optimal positive end-expiratory pressure to measure the internal jugular vein collapsibility index? A pilot study in mechanically ventilated patients.Arch Anesthesiol Crit Care. 2021;7(4): 223-6. [DOI:10.18502/aacc.v7i4.7628]
6. Kilic Y, Kayhan G, Bilir A, Gulec M. Ultrasonographic measurement of the internal jugular vein as a predictor of hypotension following the induction of anesthesia.Int J Clin Exp.2020;13(10):7857-64.
7. Frankel HL, Kirkpatrick AW, Elbarbary M, et al. Guidelines for the appropriate use of bedside general and cardiac ultrasonography in the evaluation of critically Ill patients-part I: general ultrasonography. Crit Care Med. 2015;43(11): 2479-502. [PMID] [DOI:10.1097/CCM.0000000000001216]
8. Bauman Z, Coba V, Gassner M, et al. Inferior vena cava collapsibility loses correlation with internal jugular vein collapsibility during increased thoracic or intra-abdominal pressure. J Ultrasound. 2015;18(4):343-8. [PMID] [PMCID] [DOI:10.1007/s40477-015-0181-2]
9. Kent A, Patil P, Davila V, et al. Sonographic evaluation of intravascular volume status: Can internal jugular or femoral vein collapsibility is used in the absence of IVC visualization? Ann Thorac Med. 2015;10(1):44.
10. Ilyas A, Ishtiaq W, Assad S, et al. Correlation of IVC diameter and collapsibility index with central venous pressure in the assessment of intravascular volume in critically ill patients.Cureus. 2017;9(2): e1025 [DOI:10.7759/cureus.1025]
11. Haliloglu M, Bilgili B, Kararmaz A, Cinel I. The value of internal jugular vein collapsibility index in sepsis.Ulus Travma Acil Cerrahi Derg. 2017; 23(4):294-300.
12. Broilo F, Meregalli A, Friedman G. Right internal jugular vein distensibility appears to be a surrogate marker for inferior vena cava vein distensibility for evaluating fluid responsiveness. Rev Bras Ter Intensiva.2015;27:205-11. [PMID] [PMCID] [DOI:10.5935/0103-507X.20150042]
13. Killu K, Coba V, Huang Y, Andrezejewski T, Dulchavsky S. Internal jugular vein collapsibility index associated with hypovolemia in the intensive care unit patients.J Ultrasound. 2010; 2(1):13-7. [DOI:10.1007/s13089-010-0034-3]
14. Van den Berg PC, Jansen JR, Pinsky MR. Effect of positive pressure on venous return in volume-loaded cardiac surgical patients.J Apply Physiol. 2002;92(3):1223-31. [DOI:10.1152/japplphysiol.00487.2001] [PMID]
15. Thudium M, Klaschik S, Ellerkmann RK, Putensen C, Hilbert T. Is internal jugular vein extensibility associated with indices of fluid responsiveness in ventilated patients? Acta Anaesthesiologica Scandinavica. 2016;60(6):723-33. [DOI:10.1111/aas.12701] [PMID]
16. Taccheri T, Gavelli F, Teboul JL, Shi R, Monnet X. Do changes in pulse pressure variation and inferior vena cava distensibility during passive leg raising and tidal volume challenge detect preload responsiveness in case of low tidal volume ventilation? Crit Care. 2021;25(1):1-2. [PMCID] [DOI:10.1186/s13054-021-03515-7] [PMID]
17. Suehiro K, Okutani R. Influence of tidal volume for stroke volume variation to predict fluid responsiveness in patients undergoing one-lung ventilation. J Anesthesia.2011;25(5):777-80. [DOI:10.1007/s00540-011-1200-x] [PMID]
18. Reuter DA, Bayerlein J, Goepfert MS, et al. Influence of tidal volume on left ventricular stroke volume variation measured by pulse contour analysis in mechanically ventilated patients.Intens Care Med. 2003;29(3):476-80. [DOI:10.1007/s00134-003-1649-7] [PMID]
19. De Backer D, Heenen S, Piagnerelli M, Koch M, Vincent J. Pulse pressure variations to predict fluid responsiveness: influence of tidal volume.Intens Care Med. 2005;31(4):517-23. [DOI:10.1007/s00134-005-2586-4] [PMID]
20. Alvarado Sánchez JI, Caicedo Ruiz JD, Diaztagle Fernández JJ, Ospina-Tascón GA, Cruz Martínez

LE. Use of pulse pressure variation as predictor of fluid responsiveness in patients ventilated with low tidal volume: A systematic review and meta-analysis. Circ Respir Pulmon Med. 2020;14:1-10. [DOI:10.1177/1179548420901518] [PMID] [PMCID]

How to Cite This Article:

Zeraatchi A, Safavi F, Naghibi T. Evaluation of the Effect of Three Different Tidal Volumes on Internal Jugular Vein Collapsibility Index in Hypovolemic Mechanically-Ventilated Patients Before and After Fluid Therapy. J Adv Med Biomed Res. 2023; 31(147): 342-7.

Download citation:
BibTeX | RIS | EndNote | Medlars | ProCite | Reference Manager | RefWorks

Send citation to:
Mendeley Zotero RefWorks