Inferior vena cava collapsibility loses correlation with internal jugular vein collapsibility during increased thoracic or intra-abdominal pressure

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Abstract

Purpose Point-of-care ultrasound evaluates inferior vena cava (IVC) and internal jugular vein (IJV) measurements to estimate intravascular volume status. The reliability of the IVC and IJV collapsibility index during increased thoracic or intra-abdominal pressure remains unclear.

Methods Three phases of sonographic scanning were performed: spontaneous breathing phase, increased thoracic pressure phase via positive pressure ventilation (PPV) phase, and increased intra-abdominal pressure (IAP) phase via laparoscopic insufflation to 15 mmHg. IVC measurements were done at 1–2 cm below the diaphragm and IJV measurements were done at the level of the cricoid cartilage during a complete respiratory cycle. Collapsibility index was calculated by (max diameter – min diameter)/max diameter $\times$ 100 %. Chi square, *t* test, correlation procedure (CORR) and Fisher's exact analyses were completed.

Results A total of 144 scans of the IVC and IJV were completed in 16 patients who underwent laparoscopic surgery. Mean age was 46 ± 15 years, with 75 % female and 69 % African-American. IVC and IJV collapsibility correlated in the setting of spontaneous breathing ($r^2 = 0.86$, $p < 0.01$). IVC collapsibility had no correlation with the IJV in the setting of PPV ($r^2 = 0.21$, $p = 0.52$) or IAP ($r^2 = 0.26$, $p = 0.42$). Maximal IVC diameter was significantly smaller during increased IAP ($16.5 \text{ mm} \pm 4.9$) compared to spontaneous breathing

($20.6 \text{ mm} \pm 4.8$, $p = 0.04$) and PPV ($21.8 \text{ mm} \pm 5.6$, $p = 0.01$).

Conclusion IJV and IVC collapsibility correlated during spontaneous breathing but there was no statistically significant correlation during increased thoracic or intra-abdominal pressure. Increased intra-abdominal pressure was associated with a significant smaller maximal IVC diameter and cautions the reliability of IVC diameter in clinical settings that are associated with intra-abdominal hypertension or abdominal compartment syndrome.

Keywords Internal jugular vein · Inferior vena cava · Ultrasound · Collapsibility Index · Intra-abdominal hypertension · Abdominal compartment syndrome

Riassunto

Scopo E' stata utilizzata l'ecografia per valutare le misure della vena cava inferiore (IVC) e della vena giugulare interna (IJV), per stimare lo stato del volume intravascolare. L'affidabilità dell'indice di collapsibilità delle IVC e IJV durante l'aumento della pressione toracica o intra-addominale rimane poco chiaro.

Metodi Sono state valutate con l'ecografia tre fasi: la fase di respirazione spontanea, la fase di aumento di pressione toracica con ventilazione a pressione positiva (PPV), la fase di aumento della pressione intra-addominale (IAP) tramite insufflazione laparoscopica a 15 mmHg. Le misurazioni nella IVC sono state effettuate a 1-2 cm sotto il diaframma e le misurazioni nella IJV sono state effettuate a livello della cartilagine cricoidea durante un ciclo respiratorio completo. E' stato calcolato l'indice di collapsibilità (diametro max – min) / diametro max $\times$ 100%. Sono stati calcolati chi-square, t-test, procedure di correlazione (CORR) e analisi di Fisher.

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Risultati In 16 pazienti, sottoposti a chirurgia laparoscopica, sono state effettuate un totale di 144 scansioni della IVC e IJV. L'età media era di 46 ± 15 anni, 75% donne e 69% afroamericani. La collapsibilità delle IVC e IJV era correlava nella respirazione spontanea ($r^2 = 0.86$, $p < 0.01$). La collapsibilità della IVC non aveva alcuna correlazione con quella della IJV nella fase PPV ($r^2 = 0.21$, $p = 0.52$) o IAP ($r^2 = 0.26$, $p = 0.42$). Il diametro massimo della IVC era significativamente minore durante la IAP (16.5 millimetri ± 4.9), rispetto alla respirazione spontanea (20.6 millimetri ± 4.8 , $p = 0.04$) e alla PPV (21.8 millimetri ± 5.6 , $p = 0.01$).

Conclusione La collapsibilità delle IJV e IVC era correlato durante la respirazione spontanea, ma non vi era alcuna correlazione statisticamente significativa durante l'aumentata pressione toracica o intra-addominale. L'aumento della pressione intra-addominale è stato associato ad un significativo minore diametro massimo della IVC e bisogna prestare cautele sull'affidabilità del diametro della IVC in contesti clinici associati ad ipertensione intra-addominale o sindrome compartimentale addominale.

Introduction

Point of care ultrasound is becoming increasingly popular as a method to rapidly and reliably assess various patient physiologic parameters at the bedside, especially in the critical care setting. Of the multiple uses for bedside ultrasound (US), intravascular volume assessment has gained a great deal of attention in recent literature. The collapsibility of both the internal jugular vein (IJV) and inferior vena cava (IVC) via US guidance has demonstrated dependability and reproducibility in determining the volume status of a patient at the bedside allowing physicians to make quick and appropriate management decisions [1–5]. Studies have revealed the diameter of the IVC correlates directly to the central venous pressure (CVP) in mechanically ventilated, septic patients [1] and the IVC collapsibility index correlates with CVP in the setting of low (<0.2) and high (>0.6) collapsibility index ranges [2]. Further studies have shown that US imaging of the IJV aspect ratio accurately estimates a CVP of 8 mmHg in spontaneously breathing, critically ill patients and the presence of IJV collapsibility index greater than 39 % may be associated with hypovolemia in critically ill patients [3, 4].

Though multiple studies have examined the relationship of IVC and IJV collapsibility individually compared to intravascular volume status and CVP, no data exists on the relationship between the collapsibility of the IVC and IJV to each other. This is clinically important as many patients, specifically those who have had surgery, may undergo a

wide variety of physiologic changes during their hospitalization. One of our questions is whether IVC and IJV collapsibility index can be used interchangeable under various clinical settings of increase thoracic or intra-abdominal pressures. Theoretically in the setting of intra-abdominal hypertension, the IVC becomes compressed by extrinsic pressures and the degree of impact on IVC diameter or collapsibility caused by the increased intra-abdominal pressure is unknown. This study explores the correlation between the IVC and IJV measurements and collapsibility index in the setting of spontaneous breathing, increased thoracic pressure and increased intra-abdominal pressure. By doing so, physicians can better utilize ultrasonography in the assessment of intravascular volume status to help guide medical decision making. We hypothesize that the IVC and IJV collapsibility index will correlate irrespective of changes in thoracic or intra-abdominal pressures.

Materials and methods

This was an institutional review board approved prospective, observational study. It was carried out at a single urban, academic tertiary care center. Consent was obtained from all patients enrolled in the study. Patients had to undergo a laparoscopic surgery to be eligible for enrollment. By analyzing patients undergoing laparoscopic surgery, it was assured that consistent US measurements of the IVC and IJV under the physiologic conditions desired, spontaneous breathing, positive pressure ventilation and increased abdominal pressure would be obtained. Exclusion criteria included those patients under the age of 18, any patient in which consent was not obtainable from either the patient directly or a patient spokesperson, inability to obtain consistent ultrasonography scanning windows through the three phases or those patients converted from a laparoscopic procedure to an open procedure intra-operatively.

Three phases of US scanning were completed. Phase I, in the pre-operative setting, patients underwent a US scanning of the IVC, 1–2 cm below the diaphragm (Figs. 1, 2) [6] followed by US scanning of the IJV at the level of the cricoid cartilage (Fig. 3) [6] with the head of the bed elevated at 30° during a complete respiratory cycle. This was considered the spontaneous breathing phase. Phase II occurred in the operating room following intubation and prior to the laparoscopic portion of the procedure. The patient underwent a second US scan of both the IVC and IJV at the positions previously stated. This was labeled the positive pressure ventilation phase. Ventilator management was standardized for all patients using anesthesiology protocols for laparoscopic surgery at our institution. Phase III occurred once the laparoscopic portion of the

Fig. 1 Location of US probe for peri-hepatic inferior vena cava long views (Illustration courtesy of Killu et al. [6])

Fig. 2 Peri-hepatic long views of inferior vena cava (IVC) using ultrasonography

Fig. 3 Location of US probe for internal jugular vein (IJV) measurement (Illustration courtesy of Killu et al. [6])

procedure had commenced and the abdomen was insufflated to 15 mmHg. A third US scan was obtained of the IVC and IJV at the previously stated locations. This was labeled the increased intra-abdominal pressure phase.

Ultrasound measurements were done using a linear transducer 11 MHz and a curvilinear transducer 3 MHz of the Zonare One Ultra convertible system (Mountain View, CA). Both the IVC and IJV were measured using the B mode during a complete respiratory cycle. By analyzing each vessel's US scan through a full respiratory cycle, we were able to isolate the greatest diameter for each vessel during the various phases providing the most accurate measurements for our study. A single operator underwent a 2-h hands-on training session prior to beginning the study. The operator had extensive point-of-care ultrasound training prior to the study. The operator's US technique was supervised by the advanced critical care ultrasonographer team for the first twelve scans and randomly observed throughout the remaining study.

Once all patients were enrolled in the study, analysis of the saved US videos for each phase was reviewed and all measurements were completed. Collapsibility index (CI) for both the IVC and IJV was calculated using the following equation [7, 8]:

$$CI = (\text{maximum diameter} - \text{minimum diameter}) / \text{maximum diameter} \times 100.$$

Chi square, Fisher exact, *t*-test and correlation coefficients (CORR) analysis were then completed. Statistical significance was distinguished with a *p* value <0.05.

Results

A total of 144 scans of the IVC and IJV were completed and analyzed in the 16 patients. 1 patient had been excluded from the analysis when the laparoscopic procedure was quickly converted to an open procedure during the third phase of scanning. The mean age was 46 ± 15 years. Average body mass index (BMI) was reported as 29.5 ± 6.7 kg/m². Seventy-five percent of all patients analyzed were female and 69 % African-American. The mean tidal volume when patients were on the ventilator was 557 ± 61 mL with a positive end expiratory pressure equal to zero and a respiratory rate of 16 per the anesthesiology protocols for laparoscopic surgery at our institution. There was no statistical significance between the amount of intravenous fluid provided to all the patients enrolled during the three phases of scanning. Therefore, intravenous fluid administration did not have any influence on the overall results.

Using the maximal IVC diameter during increased intra-abdominal pressure as the reference point for comparison to the other phases of measurement, IVC diameter was significantly smaller during increased intra-abdominal pressure ($16.5 \text{ mm} \pm 4.9$) compared to spontaneous

Table 1 Maximal IVC and IJV diameter during the three phases of sonographic scanning

	Spontaneous breathing	<i>p</i>	Positive pressure ventilation	<i>p</i>	Increased intra-abdominal pressure ^a	<i>p</i>
IVC max diameter (mm ± SD)	20.6 (±4.8)	0.04**	21.8 (±5.6)	0.01**	16.5 (±4.9)	Reference point
IJV max diameter (mm ± SD)	10.1 (±3.4)	0.2	12 (5.2)	0.46	13.2 (4.9)	Reference point

** Statistical significance (*p* value <0.05)

^a Comparison of maximal IVC and IJV diameter during the three phases of sonographic scanning. The reference point for comparison was when the intra-abdominal pressure was increased to 15 mmHg during laparoscopic surgery. There is no statistical difference between IJV diameter comparatively. However, the maximal diameter of the IVC is statistically significant when comparing it during increased intra-abdominal pressure to positive pressure ventilation or spontaneous breathing alone

Table 2 Correlation analysis between the Inferior Vena Cava and Internal Jugular Vein Collapsibility in the 3 Different Phases

3 different phases	CORR procedure (<i>r</i> ²)	<i>p</i>
Spontaneous breathing	0.86	0.01*
Positive pressure ventilation	0.21	0.52
Increased intra-abdominal pressure	0.26	0.42

CORR procedure (*r*²) includes the parametric and nonparametric measures of a linear relationship between two variables

* Statistical significance (*p* value <0.05)

breathing (20.6 mm ± 4.8, *p* = 0.04) and positive pressure ventilation (21.8 mm ± 5.6, *p* = 0.01). This represents a reduction in IVC diameter of approximately 24 % when there is an increase of intra-abdominal pressure to 15 mmHg (Table 1). Maximal diameter of IJV had no significant variability in the three phases (Table 1).

CORR procedure was used to analyze the parametric and non-parametric measures of a linear relationship between IVC collapsibility and IJV collapsibility (Table 2). The IVC and IJV collapsibility had a significantly high correlation in the setting of spontaneous breathing (*r*² = 0.86, *p* < 0.01). IVC collapsibility had no statistically significant correlation with IJV collapsibility in the setting of positive pressure ventilation (*r*² = 0.21, *p* = 0.52) or increased intra-abdominal pressure (*r*² = 0.26, *p* = 0.42).

Discussion

As medicine continues its trend towards minimizing invasive management strategies and therapies, the applications for ultrasonography are sure to grow due to its non-invasive, reproducible and safe nature [5]. Accurate assessment of intravascular volume is one of the most important tenets of critical care medicine, resulting in the increased popularity of ultrasonography with its ease of use, reproducibility, and

immediate results allowing for rapid management decisions. The collapsibility of the IVC and IJV individually has been shown several times in the literature to be a simple and reliable method for assessment of intravascular volume status. Multiple studies discuss the usefulness of IVC collapsibility in fluid management for those patients with septic shock or ventilator dependence [1, 9, 10]. Other studies have demonstrated the use of IVC measurements and collapsibility index to predict right atrial pressure [11], guide fluid resuscitation [12], successfully analyze fluid removal during slow continuous ultrafiltration [7], and evaluate fluid responsiveness in the face of hemorrhagic trauma [13, 14]. Furthermore, IVC collapsibility index has also been shown on multiple occasions to correlate well with invasive CVP measurements [2, 8].

The collapsibility index of the IJV can also be used to assess volume status, specifically in the ICU [4]. Deol et al. reported that US examination accurately measures jugular venous pressure; however, it typically underestimates CVP [15]. One study demonstrated an accurate CVP analysis in ventilated patients using US compared to invasive measurement [5]. Linear increase of the CVP with incremental increases in positive end expiratory pressure was comparable between US assessment and continuous IJV invasive CVP monitoring [5]. Another study demonstrated that measurement of the IJV aspect ratio using ultrasonography was shown to be a reliable measure of CVP values between 8 and 12 mmHg as well as cardiac pre-load in spontaneously breathing, critically ill patients. Lastly, literature has verified that an IJV collapsibility index greater than 39 % is strongly associated with overall patient hypovolemia [3, 4].

Our study raises questions about the use of ultrasonography in assessing intravascular volume status in the setting of increased thoracic and intra-abdominal pressure. We demonstrated that IVC and IJV collapsibility correlates in the setting of spontaneous breathing; however, it does not correlate during increased thoracic pressure or increased intra-abdominal pressure. In lieu of the multiple studies

showing IVC and IJV measurements reliably correlating with CVP and intravascular volume independently, the question becomes which vessel measurement should clinicians use to better assess intravascular volume status and CVP in the setting of increased thoracic pressure or increased intra-abdominal pressure. Our study would suggest that IVC or IJV collapsibility can be used interchangeably to assess intravascular volume status in the spontaneous breathing patient. However, additional studies are needed to determine which vessel collapsibility index is optimal for estimating CVP and intravascular volume status during positive pressure ventilation and increased intra-abdominal pressure due to a lack of correlation in our study.

In the clinical scenario of intra-abdominal hypertension or abdominal compartment syndrome, multiple studies have reported the respiratory and hemodynamic effects from increased intra-abdominal pressure. During laparoscopic surgery with insufflation to 15 mmHg, there is an increase in thoracic pressure and a decrease in cardiac index due to a reduction in cardiac pre-load [16–19]. Although the hemodynamic changes associated with intra-abdominal hypertension have been illustrated in the literature, no study has demonstrated the impact on the sonographic IVC measurement related to the increased intra-abdominal pressure. In our study, we found a 24 % decrease in diameter of the IVC when intra-abdominal pressure is increased to 15 mmHg via standard insufflation during laparoscopic surgery. By definition, this is considered intra-abdominal hypertension [20]. Given the design of the study in a controlled operative setting with a constant measured intra-abdominal pressure, the decrease in the size of the IVC was likely from extrinsic pressures and not from decreased intra-vascular volume that would have had to occur between Phase 2 and Phase 3 measurements. These same findings of a decrease in IVC diameter are likely to occur in the clinical setting of intra-abdominal hypertension and can be associated with the known reduction in cardiac index and reduction in pre-load described in the literature. Risk factors for intra-abdominal hypertension are multiple, including abdominal trauma, abdominal burns, abdominal surgery, bowel obstruction and intra-abdominal organ dysfunction such as pancreatitis or cirrhosis [20].

Limitations to our study include the study size and that it was performed at a single center. To minimize operator variability, a single sonographer completed the scans with all images later reviewed and measurements completed by the ultrasound team. Further studies are needed to reproduce the same results among various US operators. The observational design of the study was to evaluate the IVC and IJV in three different scenarios in the controlled setting of the operating room before and during laparoscopic surgery, not including invasive hemodynamic parameters,

CVP or stroke volume variation. Another limitation to our study is that all of our patients undergoing US were relatively healthy, developing their increased intra-abdominal pressure synthetically through laparoscopic surgery. Although we cannot directly extrapolate the data from our study to a more clinically relevant setting, we speculate that similar findings will occur in the presence of clinical scenarios that lead to increased intra-abdominal pressure or increased thoracic pressure, such as abdominal compartment syndrome. Further studies are warranted to assess the critically ill patient with invasive hemodynamic monitoring, specifically CVP, in the settings of increased thoracic or increased intra-abdominal pressure to determine which, IVC or IJV collapsibility, is the most reliable for intravascular volume assessment under the varying scenarios. Finally, this study is limited in that all the participants were 18 years and older with a mean age of 46 ± 15 years. The findings of this study cannot be extrapolated to children. A recent study demonstrated that bedside ultrasonography of the IVC was not a reliable indicator of intravascular volume to CVP in acutely ill children [21]. Additional studies are required to confirm these previously published findings.

Based on the overwhelming literature supporting point of care ultrasonography as a reliable, simple and reproducible volume assessment tool, we support the use of bedside US for intravascular volume assessment and response to intravascular fluids given through trends in vessel collapsibility. Like many hemodynamic parameters used in the ICU, point of care ultrasonography should be used as an adjunct in accordance with other clinical findings in the management and treatment of critically ill patients, noting clinical scenarios like positive pressure ventilation or intra-abdominal hypertension that lead to increased thoracic or increase intra-abdominal pressures may impact the reliability of IVC and IJV measurements.

Conclusion

IVC and IJV collapsibility sometimes, but not always, correlate depending on the presence of increased thoracic or intra-abdominal pressures. Clinicians using point of care ultrasound to assess intravascular fluid status should be cognoscent whether the change in IVC measurements is truly from decreased intravascular volume or related to increased intra-abdominal pressure related to primary or secondary causes of intra-abdominal hypertension.

Compliance with ethical standards

Conflict of interest The authors, Zachary Bauman, Victor Coba, Marika Gassner, David Amponsah, John Gallien, Dionne Blyden and Keith Killu have no conflicts of interest.

Informed consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. All patients provided written informed consent to enrolment in the study and to the inclusion in this article of information that could potentially lead to their identification.

Human and animal studies The study was conducted in accordance with all institutional and national guidelines for the care and use of laboratory animals.

References

- Schefold JC, Storm C, Bercker S, Pschowski R, Oppert M, Krüger A et al (2010) Inferior vena cava diameter correlates with invasive hemodynamic measures in mechanically ventilated intensive care unit patients with sepsis. *J Emerg Med* 38:632–637
- Stawicki SP, Braslow BM, Panebianco NL, Kirkpatrick JN, Gracias VH, Hayden GE et al (2009) Intensivist use of hand-carried ultrasonography to measure IVC collapsibility in estimating intravascular volume status: correlations with CVP. *J Am Coll Surg* 209:55–61
- Keller AS, Melamed R, Malinchoc M, John R, Tierney DM, Gajic O (2009) Diagnostic accuracy of a simple ultrasound measurement to estimate central venous pressure in spontaneously breathing critically ill patients. *J Hosp Med* 4:350–355
- Killu K, Coba V, Huang Y, Andrezejewski T, Dulchavsky S (2010) Internal jugular vein collapsibility index associated with hypovolemia in the intensive care unit patients. *Crit Ultrasound J* 2:13–17
- Baumann UA, Marquis C, Stoupis C, Willenberg TA, Takala J, Jakob SM (2005) Estimation of central venous pressure by ultrasound. *Resuscitation* 64:193–199
- Killu K, Dulchavsky S, Coba V (2012) The ICU ultrasound pocket book, 2nd edn. Surgical Imagineers at Butler Graphics, INC
- Guiotto G, Masarone M, Paladino F, Ruggiero E, Scott S, Verde S et al (2010) Inferior vena cava collapsibility to guide fluid removal in slow continuous ultrafiltration: a pilot study. *Intensive Care Med* 36:692–696
- Kimura BJ, Dalugdugan R, Gilcrease GW, Phan JN, Showalter BK, Wolfson T (2011) The effect of breathing manner on inferior vena caval diameter. *Eur J Echocardiol* 12:120–123
- Barbier C, Loubieres Y, Schmit C, Hayon J, Ricôme JL, Jardin F et al (2004) Respiratory changes in inferior vena cava diameter are helpful in predicting fluid responsiveness in ventilated septic patients. *Intensive Care Med* 30:1740–1746
- Ferrada P, Anand RJ, Whelan J, Aboutanos MA, Duane T, Malhotra A et al (2012) Qualitative assessment of the inferior vena cava: useful tool for the evaluation of fluid status in critically ill patients. *Am Surg* 78:468–470
- Yildirimturk O, Tayyareci Y, Erdim R, Ozen E, Yurdakul S, Aytekin V et al (2011) Assessment of right atrial pressure using echocardiography and correlation with catheterization. *J Clin Ultrasound* 39:337–343
- Weekes AJ, Tassone HM, Babcock A, Quirke DP, Norton HJ, Jayarama K et al (2011) Comparison of serial qualitative and quantitative assessments of vena caval index and left ventricular systolic function during early fluid resuscitation of hypotensive emergency department patients. *Acad Emerg Med* 18:912–921
- Yanagawa Y, Sakamoto T, Okada Y (2007) Hypovolemic shock evaluated by sonographic measurement of the inferior vena cava during resuscitation in trauma patients. *J Trauma* 63:1245–1248
- Moretti R, Pizzi B (2010) Inferior vena cava distensibility as a predictor of fluid responsiveness in patients with subarachnoid hemorrhage. *Neurocrit Care* 13:3–9
- Deol GR, Collett N, Ashby A, Schmidt GA (2011) Ultrasound accurately reflects the jugular venous examination but underestimates central venous pressure. *Chest* 139:95–100
- Sugrue M (2005) Abdominal compartment syndrome. *Curr Opin Crit Care* 11:333–338
- Lui F, Sangosyana A, Kaplan LJ (2007) Abdominal compartment syndrome: clinical aspects and monitoring. *Crit Care Clin* 23:415–433
- Artuso D, Wayne M, Cassaro S, Cerabona T, Teixeira J, Grossi R (2005) Hemodynamic changes during laparoscopic gastric bypass procedures. *Arch Surg* 140:289–292
- Sumpelmann R, Schuerholz T, Marx G, Härtel D, Hecker H, Ure BM et al (2006) Haemodynamic, acid-base and blood volume changes during prolonged low pressure pneumoperitoneum in rabbits. *Brit J Anaesth* 96:563–568
- Kirkpatrick AW, Roberts DJ, Waele DJ, Jaeschke R, Malbrain MLNG, Keulenaer BD et al (2013) Intra-abdominal hypertension and the abdominal compartment syndrome: updated consensus definitions and clinical practice guidelines from the World Society of the Abdominal Compartment Syndrome. *Intensive Care Med* 39:1190–1206
- Ng L, Khine H, Taragin BH, Avner JR, Ushay M, Nunez D (2013) Does bedside sonographic measurement of the inferior vena cava diameter correlate with central venous pressure in the assessment of intravascular volume in children? *Pediatr Emerg Care* 29:337–341