Diameter and collapse index of inferior vena cava as a clinical indicator of resuscitation for critically ill hypotensive patients

Seongpyo Mun (spmun@chosun.ac.kr)
Department of surgery, Chosun University School of Medicine

Original research

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Abstract

Purpose The role of diameter and collapse index of inferior vena cava (DCIIVC) in reflecting intravascular volume status and fluid responsiveness remains unclear. We aimed to evaluate the effectiveness of DCIIVC as a clinical indicator for fluid resuscitation (FR) in critically ill hypotensive patients.

Methods This retrospective study enrolled hypotensive patients admitted to the surgical intensive care unit (SICU) between May 2018 and April 2019. Between May and October 2018, fluid therapy was conducted by a physician's decision (non-DCIIVC group, 32 patients). Between November 2018 and April 2019, DCIIVC was used as a guide (DCIIVC group, 30 patients). Clinical outcomes of the two periods were compared.

Results Total amount of fluid intake (TAFI) of non-DCIIVC and DCIIVC group in 24 h was 4,130 and 3,560, respectively ($p < 0.05$). TAFI in 48 h was 8,420 and 6,910, respectively ($p < 0.01$). Lactate levels at admission, 24 and 48 h after admission were 4.1 vs 3.8, 3.2 vs 3.1, and 1.9 vs 2.1 mmol/L, respectively. Mean duration of mechanical ventilation, ICU stay, and hospital stay were 4.1 vs 4.5, 7.2 vs 6.3, and 18.1 vs 17.2, respectively. Overall mortality was 16.7% vs 13.3%. There was no significant difference in any other characteristic except TAFI.

Conclusion DCIIVC can be used as a tool for indicating FR in critically ill hypotensive patients. This can help physicians infuse fluid restrictively, without adverse outcomes.

Introduction

Fluid therapy is one of the most important management procedures for critically ill hypotensive patients. Previously, Swan–Ganz catheter has been used to assess the preload and afterload of the patients; however, it is losing popularity due to its invasiveness. The surviving sepsis campaign guidelines 2012 recommend using central venous pressure (CVP), but it is not recommended in Sepsis 3 anymore because of its poor correlation with the volume status of the patients.[1] Pulse pressure variation (PPV), stroke volume variation (SVV), or echocardiogram is also used for this purpose, but these require special equipment and examination technique.[2]

Lactate is used as an indicator for fluid therapy in septic patients. The sepsis 3-hour recommends administering 30 ml/kg of crystalloid when mean arterial pressure reaches < 65 mmHg or lactate levels are 4 mmol/L. However, obtaining venous lactate levels takes dozens of minutes to several hours. When lactate is used as a clinical guide, it is quite confusing to decide whether patients need more fluid. Blind fluid therapy without a clinical indicator for fluid therapy can result in adverse outcomes when patients' hemodynamics has a very narrow range of compensation.

Measuring the diameter and collapse index of inferior vena cava (DCIIVC) with ultrasound is quite simple, and it can be examined by medical or non-medical staff after short-term instructions.[3] Contrary to lactate measurement, ultrasound provides results simultaneously with the procedure. DCIIVC is well known as a tool of point-of-care for restrictive fluid therapy for heart failure or fluid removal for hemodialysis.[4,5] We aimed to evaluate the clinical usefulness of DCIIVC as a tool of point-of-care for fluid resuscitation (FR) in critically ill hypotensive patients.

Methods

IRB approval

This retrospective study was approved by institutional review board (IRB) of Chosun university hospital (No 2019-04-005-002).

DCIIVC measurement and FR

We have been using DCIIVC as an indicator for FR since May 2018 in the surgical intensive care unit (SICU). If a patient's systolic blood pressure was < 90 mmHg, DCIIVC was checked at the time of admission. Abnormal DCIIVC was defined as diameter < 15 mm and collapse index > 50%. Collapse index was calculated by [(maximum diameter – minimum diameter)]/maximum diameter during respiratory cycles. During FR, DCIIVC was checked by two physician assistants. The checking point of DCIIVC was IVC at the lower margin of the inlet of the hepatic vein (Fig. 1). When a patient had abnormal DCIIVC, FR was conducted until the IVC diameter became > 15 mm or the IVC collapse index became < 50%. Before using DCIIVC, the amount of FR was decided by physician's decision using CVP, lactate level, or patient's weight. FR was carried out in a rate of 2,000 ml/hour until DCIIVC became normal. DCIIVC was checked in every 15 minutes. After DCIIVC became normal, fluid infusion was maintained in 120 ml/hour

Clinical data and statistical analysis

The clinical outcomes of two periods, non-DCIIVC group (May 2018–October 2018, 32 patients) and DCIIVC group (November 2018–April 2019, 30 patients) were compared. The total amount of fluid intake (TAFI); lactate levels at admission, 24, and 48 h after admission; duration of mechanical ventilation; ICU stay; total hospital stay, incidence of acute kidney injury, pulmonary edema, and congestive heart failure; and overall mortality were compared between the two periods. Student t-test was used to analyze statistical significance.

Results

The number of patients non-DCIIVC and DCIIVC group was 32 and 30. The average age of patients was 66 and 64 years. The male and female ratio was 20:12 vs 17:13. The main causes of admission were major trauma, post major surgery, abdominal sepsis, brain death and major burn. Mean arterial pressure was 60.14 vs 61.1 mmHg. The mean diameter of IVC was 17.3 vs 16.9 mm. The mean collapse index of IVC was 64% vs 67% (Table 1). There was no statistical significance between the groups.

TAFI of non-DCIIVC and DCIIVC group in 24 h was 4,130 vs 3,560, respectively ($p < 0.05$). TAFI in 48 h was 8,420 vs 6,910 ($p < 0.01$). Lactate at admission, 24 and 48 h after admission were 3.5 vs 3.8, 3.2 vs 3.1, and 1.9 vs 2.1. The mean duration of mechanical ventilation, ICU stay, and hospital stay were 4.1 vs 4.5, 7.2 vs 6.3, and 18.1 vs 17.2. The number of patients of acute kidney injury were four vs two in non-DCIIVC and DCIIVC group. The number of pulmonary edema were two and one. Overall mortality was 16.7% vs 13.3% (Table 2). There was no significant difference in any characteristic, except TAFI,

Discussion

Although fluid therapy is the fundamental method for the management of critically hypotensive patients, the exact assessment of volume status (VS) is not easy. SVV or PPV needs arterial catherization. Non-invasive methods such as pulse oximeter plethysmography, impedance plethysmography or impedance phlebography require specific device and its' accuracy is still questionable. Ultrasound is widely used in many medical fields. One of the advantages of using ultrasound is that it provides real-time results, contrary to other radiologic tests. The technique for examination is also simple that nonphysician can perform. Measuring DCIIVC and evaluating VS of the patients is much easier.[3,6] DCIIVC shows very high potential as a tool for point-of-care. DCIIVC has been introduced as a useful tool of measuring VS in rapid ultrasound in shock (RUSH) for the evaluation of critically ill patients.[7] DCIIVC is used for the real-time monitoring of fluid removal during continuous renal replacement therapy and fluid therapy for heart failure.[4,8,9,10] The qualitative assessment of DCIIVC has also been carried out in a prospective study and demonstrated that DCIIVC offers a rapid, non-invasive way to evaluate VS in critically ill patients.[11] Despite its accuracy and usefulness, DCIIVC is not widely used as a clinical indicator for FR.

There are several reasons. One of them is that the usefulness of DCIIVC is debatable. DCIIVC is known to reflect VS well. The IVC diameter can be used as a point-of-care to guide heart failure (FH) management. In acute HF syndrome, CIIVC ≥ 0.5 on admission suggests a volume shift from the central vein into the pulmonary vasculature and is helpful in diuretic use.[12] However, some studies had negative conclusions about the metrics of IVC. The IVC diameter checked on computed tomography was not a good indicator of VS in hemodynamically normal trauma patients.[13] Even meta-analysis has different results. Two meta-analyses showed that DCIIVC is a reliable parameter for hypovolemia and has a great value in predicting fluid responsiveness.[14,15] However, other meta-analyses on DCIIVC concluded that it is not a reliable method to predict fluid responsiveness.[16,17] Hence, the effectiveness of DCIIVC to predict VS or fluid responsiveness has not yet reached a conclusion.

We wanted to clarify the effectiveness of DCIIVC as clinical indicator for FR by retrospective analysis. The uniqueness of this study is the evaluation of the clinical outcomes of DCIIVC, contrary to a previous study that evaluated the accuracy for fluid responsiveness or correlation with hypovolemia or lactate levels. These parameters do not always agree with the clinical outcomes. Moreover, previous studies have evaluated mainly medical patients with cardiac or renal concerns. This study included surgical patients. Usually, hypotension of surgical patients is caused by bleeding, hypovolemia or septic condition due to acute insult. Because their previous hemodynamic function was normal, meticulous control of FR will result in favorable recovery. The results of this study showed that using DCIIVC as the indicator for FR made physician use lesser fluid than using CVP, lactate or patient's weight with similar hemodynamic recovery and clinical outcomes. DCIIVC can be a useful guide of point-of-care for fluid therapy in shock patients requiring strict volume control.

DCIIVC-guided FR failed to improve clinical outcomes in this study. We believe this is because of the diverse characters of the patients. The cause of hypotension was variable. Some patients had hypovolemia, but other had sepsis or brain death. DCIIVC needs to be evaluated in the same disease group in a future prospective study.

We used the IVC of the hepatic vein inlet as the location of examination. DCIIVC can be measured at the level of the renal vein or junction of the hepatic inlet. Compared to the IVC at the level of the renal vein, the IVC at the hepatic vein inlet is much easier to find and can be checked during Focused Assessment with Sonography in Trauma. If we check the IVC near the heart, the chance of failure is very low, but this location does not show equivalent results and is not recommended.[18]

This study has some limitations. The study is an analysis of two different periods and the strength of evidence is very weak. We checked the anteroposterior diameter of the IVC. A previous study recommended not to measure DCIIVC in the vertical direction because true collapse of the vessel does not occur in the vertical direction.[19]

Conclusion

DCIIVC can be used as a tool of point-of-care for FR in critically ill hypotensive patients. Using DCIIVC as a guide for resuscitation helps physician infuse fluid restrictively, without adverse outcomes.

Declarations

Ethics approval and consent to participate

This study was approved by institution review board of Chosun University Hospital

Availability of data and material

Not applicable in this section.

Competing interests

Not applicable in this section.

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Authors' contributions

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Tables

Characteristics	DCIIVC Group (30)	Non DCIIVC group (30)	P
Age (range)	64(17-70)	66 (17-70)	NS
Sex (Male: Female)	17:13	19:11	NS
Main cause of ICU admission			NS
Pneumonia	5	4	NS
COPD exacerbation	4	5	NS
cerebrovascular accident	4	2	NS
Post major surgery	3	5	NS
Abdominal infection	2	2	NS
Major trauma	4	2	NS
Hypotension of unknown origin	2	4	NS
Heart failure	2	2	NS
Dengue fever	0	2	NS
Major burn	2	1	NS
Liver cirrhosis	2	1	NS
Systolic blood pressure (mmHg)	73(60-89)	71(55-89)	NS
Diameter of IVC (mm)	18.9(15-24)	18.3(14-23)	NS
Collapse index of IVC (%)	37(12-61)	34(14-64)	NS

Table 1. Characteristics of the patients. ICU intensive care unit; COPD chronic obstructive lung disease; CVA cerebrovascular accident; SOFA sequential organ failure assessment; IVC inferior vena cava

Characteristics	DCIIVC group (N=30)	Non DCIIVC group (N=30)	P
Total amount of fluid input in 24 hours (ml)	3,560	4,130	<0.05
Total amount of fluid input in 48 hours (ml)	6,910	8,420	<0.01
Lactate at admission (mmol/L)	3.8(2.5-4.4)	3.5(2.1-4.2)	NS
Lactate in 24 hours (mmol/L)	3.1(2.1-3.2)	3.2(2.2-3.6)	NS
Lactate in 48 hours (mmol/L)	2.1(0.6-2.8)	1.9(0.7-2.8)	NS
Duration of mechanical ventilation (days)	4.5(1-14)	4.1(1-11)	NS
Duration of ICU stay (days)	6.3(2-21)	7.2(2-19)	NS
Duration of hospital stay (days)	17.2(7-35)	18.1(11-45)	NS
Mortality (%)	4(13.3)	5(16.7)	NS

Table 2. Clinical outcomes. DCIIVC diameter and collapse index of inferior vena cava; ICU intensive care unit;

Figures

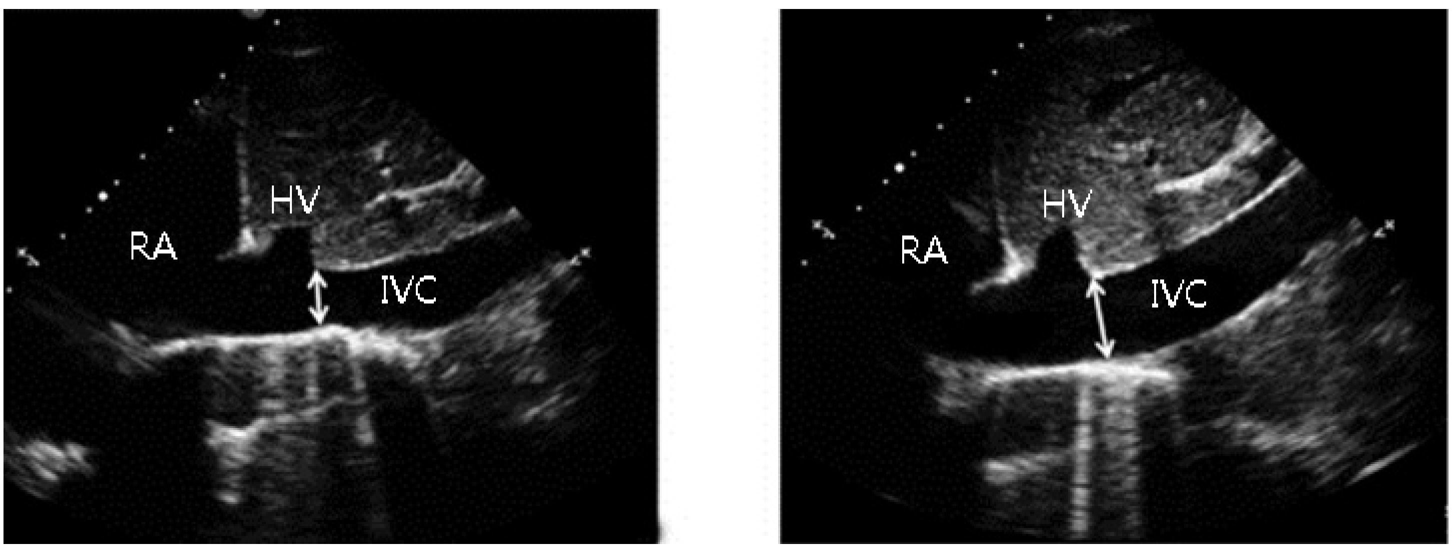

Figure 1

Diameter and collapse index were checked at the point of the lower margin at the inlet of the hepatic vein during expiration (left) and inspiration (right). RA; right atrium, HV; hepatic vein, IVC; inferior vena cava.