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Value of internal juguler vein distensability and carotid artery Doppler in assessment of fluid responsiveness in sever sepsis and septic shock patients

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ABSTRACT

Transthoracic echocardiography (TTE) is becoming the choice of hemodynamic assessment tool in many intensive care units. It has been gaining popularity due to its noninvasiveness where the benefit far outweighs the risk. The Doppler study of carotid artery circulation and internal juguler vein ultrasound are simple and overpasses this common limit among intensive patient. Moreover, it showed to be an easy-learning tool. Transthoracic echocardiography provides an accurate and noninvasive measurement of cardiac output. Measurements of VTI and its variations are directly correlated with variations in cardiac output. The standard definition of volume responsiveness is a >15% increase in cardiac output in response to volume expansion.

Key Words: Carotid artery, Internal juguler vein, sever sepsis and septic shock, TTE

INTRODUCTION

Sepsis is a systemic, deleterious host response to infection leading to severe sepsis (acute organ dysfunction secondary to documented or suspected infection) and septic shock (severe sepsis plus hypotension not reversed with fluid resuscitation). Severe sepsis and septic shock are major healthcare problems, affecting millions of people around the world each year, killing one in four (an often more), and increasing in incidence. [1, 2]

Sepsis, a syndrome of physiologic, pathologic, and biochemical abnormalities induced by infection, is a major public health concern. [1]The reported incidence of sepsis is increasing, [2, 3] likely reflecting aging populations with more comorbidities, greater recognition, [4] and, in some countries reimbursement-favorable coding. [5] Although the true incidence is unknown, conservative estimates indicate that sepsis is a leading cause of mortality and critical illness worldwide. [6]

Sepsis is defined according to The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis -3), as life-threatening organ dysfunction caused by a dysregulated host response to infection. Organ dys function can be identified as an acute change in total SOFA score (Sequential Organ Failure Assessment Score)≥ 2 points consequent to infection. The baseline SOFA score can be assumed to be zero in patients not known to have pre-existing organ dysfunction. Patients with suspected infection who are likely to have a prolonged ICU stay or to die in hospital can be promptly identified at the bedside with(quick SOFA), ie, alteration in mental status, systolic blood pressure ≤ 100 mm Hg , or respiratory rate ≥ 22/ min[8]

Materials and Methods

1. Left ventricular outflow tract (LVOT) velocity time integral (VTILVOT) will measured by echo (GE Vivid 3 Machine) using (TransducerProbe2.5MhzPhasedArray)byplacing the pulsed wave Doppler sample gate in the LVOT in apical-5-chamber window . VTILVOT is obtained by manually tracing the Doppler velocity spectrum. LVOT velocity time integral is recorded before and after fluid challenge of 500 ml of NaCl 0.9% within 15 minutes. Relative

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changes in (VTILVOT) is expressed in percentage as follows:

- Changes (%) =100 X (post-FC value – baseline value)/ baseline value.
- Responder is defined by an increase of 15% or more.
- Non responder is less than 15%. (14)

2. Carotid artery peak velocity will measured by (GE Vivid 3 Machine) using (Transducer Probe 2.5MhzPhasedArray). On the two-dimensional image, the optimal image of the long-axis view will obtained at the left common carotid artery. The sample volume will placed on the centre of the lumen, 2 cm proximal to the bulb, and a pulsed wave Doppler examination will performed. The peak velocity will measured automatically and the maximum and minimum values during one respiratory cycle will recorded.DVpeak-CA will calculated as follows:

100×(maximum peakvelocity–minimum peak velocity) / [(maximum peak velocity + minimum peak velocity)/2]

- Responder is defined by an increase of 15% or more.
- Non responder is less than 15%.

3. The IVC will visualized by placing the patient in supine positionand subxiphoid view of the heart will obtained by placing the probe on the patient's abdomen just below the xiphoid bone with the marker facing to the right of the patient. Once an appropriate subxiphoid view of the heart is obtained, the probe is rotated 90 degrees until the marker is pointing toward the head of the patient. When the IVC is visualized in its longitudinal plane as it enters the right atrium. Using the M-mode the diameters of the IVC will recorded 2 cm away from its point of entry in right atrium or just distal to the hepatic vein.

- IVC collapsibility index will calculated from the following formula:

$$\frac{IVC\,expiratory\,diameter - IVC\,inspiratory\,diameter}{IVC\,expiratory\,diameter} \times 100$$

4. The IJV will visualized by putting probe just between 2 heads of sternocleidomastoid muscle at the the base of the neck .the vein located 1cm_1.5cm from the surface of skin.

Evaluation of IJV distensibilty by the ratio of difference between IJV maximal antero posterior diameter during inspiration and minimum expiratory diameter to minimum expiratory diameter x100.

RESULTS

The current study was carried on 50 adult male and female patients who were admitted to the critical care medicine department in Alexandria main university hospital with the diagnosis of sever sepsis and /or septic shock, All patients war mechanically ventilated in mandatory minute ventilation (MMV) with ventilator parameters adjusted to maintain Pplat<30 cmH2o ,Pco2<40 mmHg(Tidal volume 6to8ml\kg,PEEP 5cmH2o,respiratory rate 16 b\min ,Fio2 of 0.4) and sedated the study was conducted until the two groups contained 25 patients.

Echocardiographic examination, Carotid Doppler, IVC collapsibility index and IJV distensibilty was done for all the 50 patients, together with fluid administration of 500 ml of NaCl 0.9% before separating the patients into two groups according to Relative changes in (VTILVOT)):

Responder (R): 25 sever and /or septic shock patients with increase in (VTILVOT) of 15% or more after fluid challenge of 500 ml of NaCl 0.9% within 15 minutes.

Non responder (NR): 25 sever and /or septic shock patients with increase in (VTILVOT) less than 15% after fluid challenge of 500 ml of NaCl 0.9% within 15 minutes.

Echocardiographic examination, Carotid Doppler and IJV distensibilty was done for all the 50 patients, after fluid administration and the result was showed in Figure-1 &2.

DISCUSSION

The present observational study was conducted to compare between LVOT VTI, carotid artery VTI and internal juguler vein distensability measurements as a useful predictor to fluid responsiveness after infusion of 500 ml of NaCl 0.9% within 15 minutes in patients with severe sepsis and/or septic shock.

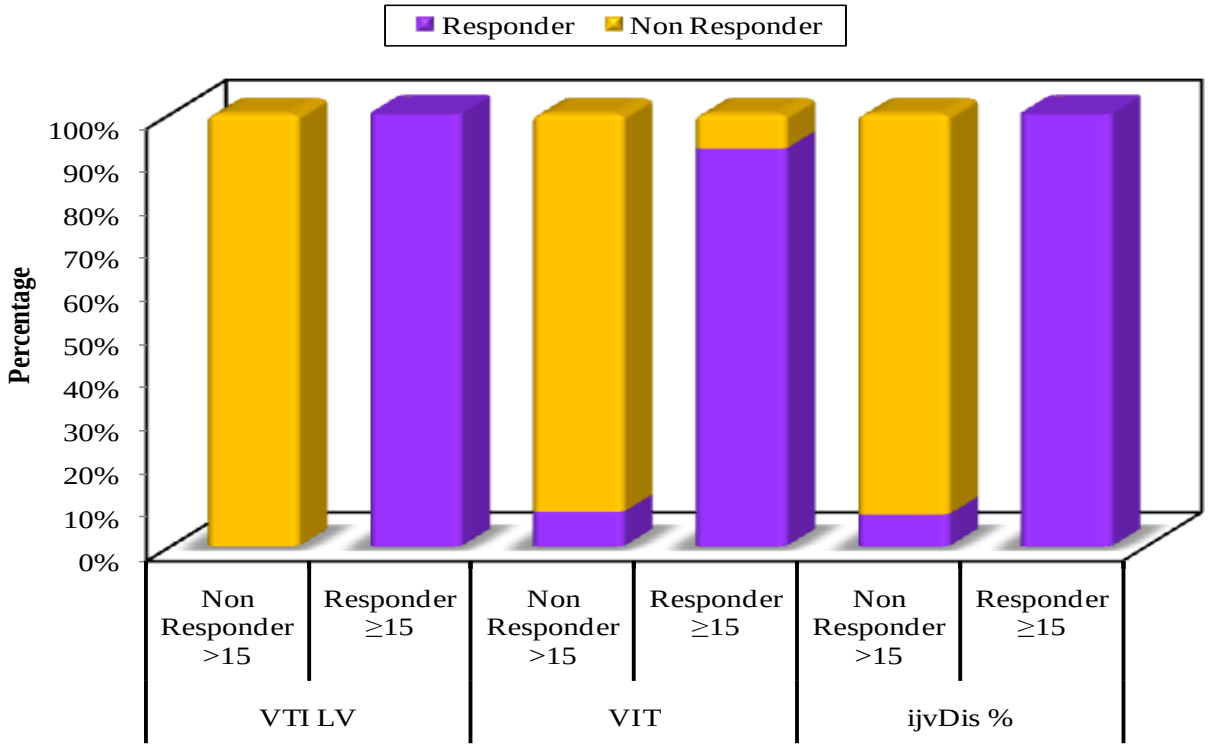
The study was conducted on 50 adult male and female patients admitted to Critical Care Department in Alexandria Main University Hospital with the diagnosis of severe sepsis and/or septic shock. All patients in this study were having the Criteria of severe sepsis and/or Septic shock (severe sepsis plus hypotension not reversed with fluid resuscitation).Patients with cardiac arrhythmias were excluded as cardiac arrhythmias may cause high VTI variability. Also patients with Right ventricular failure Aortic insufficiency may cause VTI variability. And patients with carotid artery stenosis. Echocardiographic examination was done for all included patients and LVOT VTI was measured before fluid resuscitation, after infusion of a fluid bolus of 500 cc over 15 minutes, and (%LVOT VTI) variations was calculated which separated the studied population into two groups.

Responders (R): 20 severe sepsis patients with LVOT ΔVTI 500 ≥ 15%.

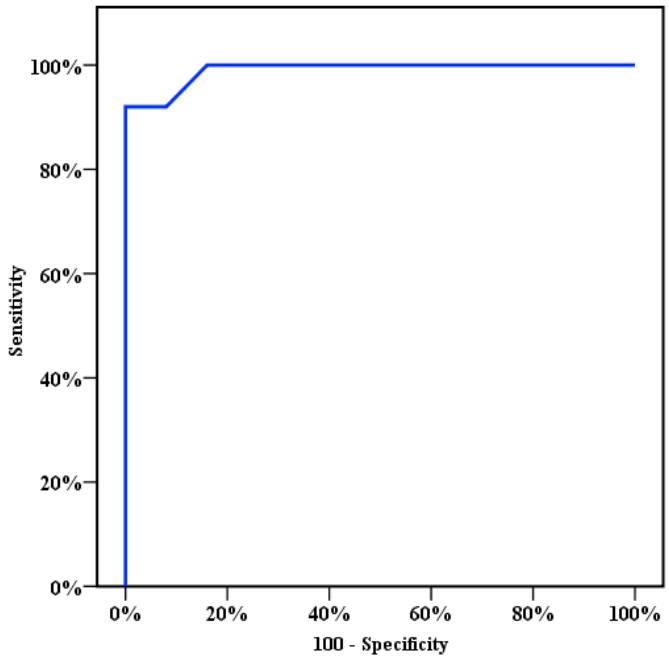
Non-responders (NR): 20 severe sepsis patients with LVOT ΔVTI 500 < 15%.

Simultaneously Velocity time integral of carotid artery (VTIC) and internal juguler distensability (IJVD) was recorded before and after fluid challenge of 500 ml of NaCl 0.9% within 15 minutes, and Velocity time integral variation (%VTIC) and internal juguler distensability variation (%IJVD) was calculated.

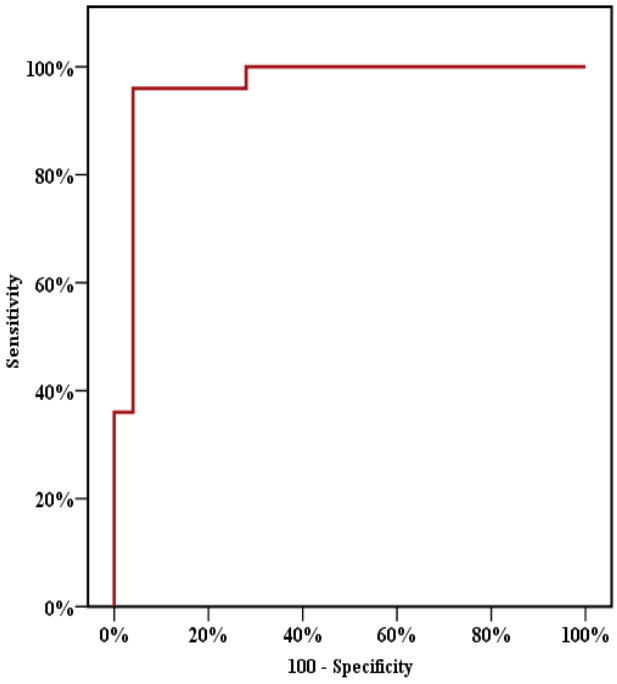
Figure-1. Echocardiographic examination, Carotid Doppler and IJV distensibilty



ROC curve for percent of change of VTIc



ROC curve for percent of change of ijvDis



Concerning the demographic data in our results there was no significant differences between responders and non-responders as regard age or APACHE II score Our results agreed with other studies as Muller et al[24] and Oliveira-Costa. [25]

Pneumonia was the most common cause of severe sepsis in our study followed by urinary tract infection .Several epidemiological studies agree with our results and showed that the lung is the primary source of

infection in both severe sepsis and in septic shock, followed by the abdomen and the urinary tract.[20]

We assessed hemodynamic changes during fluid challenge and found that SAP, MAP change percentages was higher in responder group than non-responder group. While HR change percentage was higher in non-responder group than responder group. In agreement with our results Neil et al [22] who assess Physiological changes after fluid bolus therapy in sepsis. This study examined 33 critically ill septic patients and record Physiological changes after fluid bolus therapy and find that The median increase in mean arterial pressure in responders was 9.5 mmHg (range 7 to 15.2 mmHg) versus 4.8 mmHg (range 1 to 13 mmHg) in non-responders. Similarly, the median increase in central venous pressure was 3 mmHg (range 2.6 to 3.4 mmHg) in responders versus 3.7 mmHg (range 2 to 5.2 mmHg) in non-responders. The median decrease in heart rate was 3.3 b/m in responders (range 1.5 to 10 b/m decrease) and 1.2 b/m in non-responders (range 0 to 4 b/m decrease).

Our study showed that PP change percentage was higher in responder group than non-responder group. Soubrier et al[27] who investigated whether the respiratory changes in arterial pulse pressure (ΔPP) and in systolic pressure (ΔSP) could predict fluid responsiveness in spontaneously breathing (SB) patients found that these variables lack sensitivity and their dependence to respiratory status.

In the assessment of response to Fluid challenge using Carotid Doppler and IJV distensability our study showed that the change of VTIC and IJVD% before and after Fluid challenge was higher in responder group than non-responder group. ROC curve was constructed and The best cut off value of (VTIC) was≤15.4% While the best cut off value of (IJVD%) was ≤15% .In agreement with our results Fabio et al [ahmed] who assess hemodynamic response to a fluid challenge using Jugular vein distensibility in critically ill ventilated patients. This study examined 50 critically ill patients, of these, 30 were R. Responders presented higher IJV distensibility and PPV before fluid challenge than NR (P <0.05). An IJV distensibility more than 18% prior to volume challenge had an 80% sensitivity and 85% specificity to predict R. Pairwise comparison between IJV distensibility and PPV ROC curves revealed similar ROC area under the curve results.

Interestingly, combining IJV distensibility more than 9.7% and PPV more than 12% predicted fluid responsiveness with a sensitivity of 100% and specificity of 95%.

Miguel et al [29] who assess Respiratory variation in carotid peak systolic velocity predicts volume responsiveness in mechanically ventilated patients with septic shock We performed a prospective cohort study at an intensive care unit, studying the effect of 59 fluid challenges on 19 mechanically ventilated patients with septic shock.

Pre-fluid challenge ΔCDPV and other static or dynamic measurements were obtained. Fluid challenge responders were defined as patients whose stroke volume index increased more than 15 % on transpulmonary thermodilution. This study examined 59 patients, 19 mechanically ventilated patients with septic shock.

Fluid responsiveness rate was 51 %. The ΔCDPV had an AUROC of 0.88 (95 % confidence interval (CI) 0.77–0.95); followed by stroke volume variation (0.72, 95 % CI 0.63–0.88), passive leg raising (0.69, 95 % CI 0.56–0.80), and pulse pressure variation (0.63, 95 % CI 0.49–0.75). The ΔCDPV was a statistically significant superior predictor when compared with the other parameters. Sensitivity, specificity, and positive and negative predictive values were also the highest for ΔCDPV, with an optimal cutoff at 14 %. There was good correlation between ΔCDPV and SVI increment after the fluid challenge.

As regards IVCCI the best cut off value was ≤50% with sensitivity, specificity, PPV, and NPV was 88%, 88%, 88%, 88% respectively. The accuracy was 95.4%. In responder group IVCC (2) patients were non-responder (<50%) and (23) patient were responder (≥50%)In non-responder group IVCC (21) patients were non-responder (<50%) and (4) patient were responder (≥50%)in responder group IVCC% was (66.16 ± 13.51) and In non-responder group IVCC% was (23.28 ± 16.53).

In agreement with our results as regards the IVCCI cutoff value Brennan JM et al[30] evaluated echocardiographic imaging of IVC for estimation of the right atrial pressure (RAP) in patient undergoing right heart catheterization. This study was done on 102 patients using (RAP) 10 mmHg or above to indicate clinically significant (RAP). Echocardiographic examination of the IVC was done and IVC diameters were recorded both during passive respiration and after asking the patient to inspire maximally or sniff. The collapsibility index cutoff value with optimum predictive use for RAP greater than 10 mm Hg were 20% with passive respiration and 40% after sniff, the AUC was 0.93, 0.91 respectively. Concerning the 20% cutoff value during passive respiration had sensitivity, specificity, PPV and NPV 73%, 82%, 57% and 90% respectively with accuracy 80%. While the 40% cutoff value after sniffing had sensitivity, specificity, PPV and NPV 73%, 84%, 62%, and 90% respectively with accuracy 81%. There was no significant difference in the AUC between IVCCI during passive respiration and sniffing. In our study we performed the examination during passive respiration as most of the patients were not cooperative to perform the sniffing. In addition Brennan JM et al, performed his study on hemodynamically stable patients performing right heart catheterization to assess the volume status, however in our study we selected patients with severe sepsis in need of fluid resuscitation to assess the fluid responsiveness. This may explain our higher cutoff value during passive respiration.

Similar study by Muller et al[31]who assessed the usefulness of IVCCI recorded by (TTE) to predict fluid responsiveness in spontaneously breathing critically ill

patients with acute circulatory failure (ACF). This study examined 40 patients with ACF including those with severe sepsis, bleeding and dehydration. IVCCI after 500cc fluid resuscitation showed best cutoff value of 40% with AUC 0.77 (p0.08) with sensitivity, specificity, PPV and NPV of 70%, 80%, 72% and 83% respectively. In comparison to our results which showed a best cut off value of 37% with AUC 0.908 (p<0.001) with sensitivity, specificity, PPV, NPV was 90%, 70%, 75%, 87.5% respectively, although we didn't include patients with bleeding or dehydration as Muller et al did as they may be still hemodynamically stable and not in need of fluid resuscitation as patients with severe sepsis or septic shock where fluid resuscitation is main stay treatment, and this could explain our higher AUC value.

Manuel et al who assess brachial artery peak velocity variation to predict fluid responsiveness in mechanically ventilated patients. This study examined 38 mechanically ventilated patients for whom fluid administration was planned due to the presence of acute circulatory failure. Volume expansion (VE) was performed with 500 mL of a synthetic colloid. Patients were classified as responders if stroke volume index (SVi) increased ≥ 15% after VE. The respiratory variation in Vpeakbrach (ΔVpeakbrach) was calculated as the difference between maximum and minimum values of Vpeakbrach over a single respiratory cycle, divided by the mean of the two values and expressed as a percentage. Radial arterial pressure variation (ΔPPrad) and stroke volume variation measured using the FloTrac/Vigileo system (ΔSVVigileo), were also calculated. Results in VE increased SVi by ≥ 15% in 19 patients (responders). At baseline, ΔVpeakbrach, ΔPPrad and ΔSVVigileo were significantly higher in responder than non-responder patients [14 vs 8%; 18 vs. 5%; 13 vs 8%; P<0.0001, respectively). A ΔVpeakbrach value>10% predicted fluid responsiveness with a sensitivity of 74% and a specificity of 95%. A ΔPPrad value >10% and a ΔSVV >11% predicted volume responsiveness with a sensitivity of 95% and 79%, and a specificity of 95% and 89%, respectively.

Marik et al made a systemic review to determine the relationship between CVP and fluid responsiveness and blood volume, 24 studies included in this analysis and the pooled area under the ROC curve was 0.56,in other word the likelihood that CVP can accurately predict fluid response is only 56% (no better than flipping a coin). So they concluded that there is a poor relationship between CVP and blood volume and low ability to predict fluid response. The explanation for our results may return to that in our study we selected only 50 patients with severe sepsis and septic shock with hemodynamic instability. Also patients with pulmonary hypertension, tricuspid insufficiency were excluded from our study as these problems may affect the readings of CVP giving high false readings. On the other hand, Marik et al review included 830 human adult patients with a wide spectrum of surgical and medical disciplines without excluding patients having the problems excluded in our study.

In surviving sepsis campaign (SSC) guidelines 2012, CVP is still used as a goal in the early goal directed therapy for patients with severe sepsis and septic shock during the 1st 6 hours from admission of the patient to the emergency department. A CVP target of 8-12 mmHg in non-ventilated and 12-15 mmHg in ventilated patients must be achieved. However, due to multiple CVP limitations SSC recommended the use of dynamic test to assess further fluid responsiveness of these patients. therefore ΔCVP can't be used to predict fluid responsiveness.

Conclusion

- That Carotid Doppler and Internal Juguler Vein Distensability parameters are a reliable predictor to fluid responsiveness in patients with severe sepsis and septic shock as well as Transthoracic echocardiography in dynamic monitoring the change in stroke volume after a maneuver that increases or decreases venous return (preload).
- When using Carotid Doppler parameters (velocity time integral variation) (VTIc) and Internal Juguler Vein Distensability (IJVD%) after fluid challenge of 500 ml of NaCl 0.9% within 15 minutes may be of value in differentiating between responders and non-responders in patients with severe sepsis and/or septic shock with sensitivity 96% and specificity 88%for (%VTIc) change and sensitivity 96% and specificity 84%for (IJVD%) change.

Conflict of Interests

Authors declare that there is no conflict of interests regarding the publication of this paper.

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