

MEASUREMENT OF INFERIOR VENA CAVA DIAMETER BY ULTRASOUND IN INTENSIVE CARE UNIT PATIENTS WITH PNEUMONIA

By

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ABSTRACT

Background: Pneumonia is an inflammatory condition of the lung affecting primarily the alveoli, typically symptoms include combination of cough, chest pain, fever, and trouble breathing, Fluid resuscitation in critically ill patients is common and serious challenge so measurements of central venous pressure (CVP), pulmonary arterial catheterization, esophageal Doppler ultrasonography (Ultrasound) and trans esophageal echocardiography may be used to determine the volume status of critically ill patients.

Objective: To determine the value of measurement of IVC diameter by ultrasound as a noninvasive tool in assessment of intravascular volume and hydration status in ICU patients with pneumonia.

Patients and Methods: This prospective cross-sectional study was carried out in the Intensive Care Units of Chest Department, at Al- Hussein and Bab Al-sha'reia University Hospitals, during the period from November 2019 to September 2020, and included sixty persons: Thirty patients with pneumonia (diagnosed on clinical and radiological basis), and another thirty apparently healthy subjects collected from Hospital persons or patients relative matching with age, sex and body mass index. Body mass index ultrasound measurement of Inferior vena cava diameter was done for all.

Results: There was significance decrease of inspiratory IVC-D in patient's group than control's group (mean inspiratory IVC-D of patients 0.63 cm versus 0.92 cm in control's group). Also, there was significant decrease of expiratory IVC-D in patient's group than control's group (mean expiratory IVC-D in patient's group 1.46 cm versus 1.68 cm in the control's group). The IVC-CI of the patient's group in this study had highly significant increase than control's group (66% versus 46%).

Conclusion: Assessment of the physiologic characteristics of the IVC by ultra sound provides a rapid distinction between low and high volume states and offers a rapid, easily, reliable and noninvasive way to guide resuscitation in patients with pneumonia.

Key words: Pneumonia; Intensive Care Unit; Ultrasound; Inferior Vena Cava Diameter.

INTRODUCTION

A clinical definition of pneumonia is two or more of the following symptoms/physical findings: Productive cough, purulent sputum, dyspnea or tachypnea, rigors or chills, and pleuritic

chest pain in conjunction with a new opacity on chest radiograph (Thomas, 2015). Fluid resuscitation in critically ill patients is common and serious challenge. Reduced organ perfusion may result from hypovolemia and dehydration, while complications such as pulmonary edema

may result from over hydration (Wiedeman, 2016). Ultrasound measurements of the IVC diameter by bedside ultrasound are an easy, fast, reliable and noninvasive method for assessing patient's volume status and not associated with complications. In addition, many emergency departments have Ultrasound systems that can easily be used by emergency physicians (Shoemaker *et al.*, 2016).

The present work aimed to determine the value of measurement of IVC diameter by ultrasound as a noninvasive tool in assessment of intravascular volume and hydration status in ICU patients with pneumonia.

PATIENTS AND METHODS

This study was conducted at Chest Department, Al-Azhar University (Al-Hussein and Bab Alshaaria University Hospitals) during the period between November 2019 to September 2020, and included two groups: **Group (1):** Patient's group: Thirty patients with pneumonia randomly selected (diagnosed on clinical and radiological basis), and **Group (2):** Control's group: Thirty apparently healthy subjects collected from Hospital persons or patient relatives, matching with sex and body mass index.

Exclusion criteria: Patients with any of the following were totally excluded from the study; Patients aged Less than 18 years old, cardiac co morbidities, chronic chest diseases, renal failure and Hepatomegaly, morbid obesity (B.M.I. above 40 kg/m²), Patients with raised intra-abdominal pressure such as pregnancy, ascites, abdominal distension,

gastropareisis (ileus or pseudo obstruction).

Inclusion criteria: Patients equal or more than 18 years old, BMI between 20-40kg/m², patients with pneumonia admitted in ICU.

Methods:

The study was approved by The Ethics Committee of Al-Azhar University, Faculty of Medicine. After explanation of the procedure to the patients, a written or verbal consent for participation in this study was obtained by every patient. If the patient was conscious or by relatives if the patient was unconscious. All patients underwent the following: Full history and clinical examination, routine laboratory tests CBC, liver function tests, kidney function tests and urine output, assessment of severity of pneumonia according to CURB-65 score, sputum culture and examination, chest radiograph (PA, lateral views), oxygen saturation by pulse oximetry and arterial blood gases, ultrasound measurement of inferior vena cava (IVC) diameter by B mode 2-3 cm before the point of entry of the IVC into the right atrium, echocardiography, body mass index, clinical evaluation of intra-abdominal pressure. All patients in control group had undergone ultrasound measurement of inferior vena cava diameter and, body mass index.

Calculation of IVC-CI for patients and control groups:

Methods of Measuring IVC diameter and CI: The inferior vena cava (IVC) diameter measured in a supine patient in the sagittal (long-axis) subxyphoid window, making sure to angle the transducer to the patient's right. The

technique was performed using curvilinear or convex probe. The IVC visualized in a longitudinal view at the level of the caval–right atrial junction. The anteroposterior diameter of inferior vena cava (IVCD) was measured duplicately, using images frozen according to operator judgment, at the end of inspiration (iIVCD) and the end of expiration (eIVCD) in a subxiphoid location in the longitudinal axis where the anterior and posterior wall of the IVC are easily visualized and lie parallel to each other. The IVC diameter (IVC D) was measured during inspiration and during expiration at a distance of 2-3 cm from the IVC right atrial junction in the long axis. In a spontaneously breathing patient, negative intrathoracic pressure generated during inspiration draws blood from the IVC into the right atrium, resulting in varying degrees of IVC collapse. Measurements of IVC collapse are commonly reported as the collapsibility index, which is calculated as (maximum IVC diameter on expiration – minimum IVC diameter on inspiration/maximum IVC diameter on expiration). In contrast, during mechanical ventilation, the force of inspiration was generated by positive pressure and the IVC distends rather than collapsed. Studies of IVC respirophasic

variation in mechanically ventilated patients (IVC dispensability) were typically performed with fixed tidal volume in adequately sedated patients with controlled ventilation. In mechanically ventilated patients, the dispensability index was calculated as maximum IVC diameter on inspiration–minimum IVC diameter on expiration/minimum IVC diameter on expiration. The term caval index (CI) has been used to refer respirophasic changes in IVC diameter irrespective of the patient was spontaneously breathing or mechanically ventilated.

Statistical analysis: Data were collected; coded, revised, verified and computerized, statistical analysis of data was performed using Statistical package for the Social Science (SPSS) version 24. Quantitative data were expressed as mean± standard deviation (SD), range, median, and interquartile range (IQR). Qualitative data were expressed as frequency and percentage, P-values ≤ 0.05 were considered significant. Independent sample t-test was used in comparing the means of two groups or Mann-Whitney u Test.

RESULTS

Sixty persons were included in this study and were equally divided into patients and control groups, the mean age of patient's group was (58.9) in males and (58.4) in females while in control's group, the mean age was (38.75) in males and (43) in females. The mean BMI of patient's group was (25.2) in males and (29) in females, while in control's group,

the mean BMI (24) in males and (26.5) in females. The mean PaO₂ in patient's group in males was (50.4 mmHg) and in females was (52.6mmHg). The mean PaCO₂ in patient's group was (36mmHg) in males and (33.4mmHg) in females. The mean pH in patients group was (7.3) in males and (7.4) in females. The mean Hb in patient's group was (9.7g/dl) in males

and in females was (10.9g/dl). The mean WBCs in patient's group was (16.3 x10³/ul) in males and (13.9 x10³/ul) in females. The chest x -ray result in patient's group; according to side of lesions, RT lung in (16), LT lung in (5), while bilateral in (9). The lesions were pneumonic patch, bilateral diffuse infiltration and pleural effusion, the consolidation was recorded 81% of CXR. There was presence of Chest ultrasonography consolidation in (90%) and pleural effusion in (40%) of patient's

group. Patient's group according to CURB-65 score divided to CURB-65 (2): two patients 6.67%, CURB-65(3): twenty patients 66.65%, CURB-65(4): four patients 13.34%, CURB-65(5): four patients 13.34%. The mean inspiratory IVC-D for patient's group was (0.63cm) and the mean inspiratory IVC-D for control's group was (0.92cm), (p-value<0.001). There was highly statistically significant decrease of IVC-D during inspiration in patient's group than control's group (**Table 1**).

Table (1): Statistical study of IVC - D during inspiration between patients and control groups

IVC- D inspiration	Patients (n = 30)	Control (n = 30)
Range	0.3 – 1.1	0.55 – 1.5
Mean	0.63	0.92
±SD	0.21	0.24
SE	0.038	0.044
Observative difference between means	0.29	
p-value	<0.001	

T: independent sample test.

The mean expiratory IVC-D for patient's group was (1.46 cm) and the mean expiratory IVC-D for control's group was (1.68 cm), (p-value < 0.007),

There was statistically significant decrease of IVC- D during expiration in patient's group than control's group (**Table 2**).

Table (2): Statistical study of IVC - D during expiration between patients and control groups

IVC- D expiration	Patients (n = 30)	Control (n = 30)
Range	1.1 – 2	1.05 – 2.25
Mean	1.46	1.68
±SD	0.27	0.33
SE	0.049	0.06
Observative difference between means	0.22	
p-value	0.007	

T: independent sample test.

The mean IVC-CI for patient's group was (65.8 %) and the mean IVC-CI for control's group was (45.5%), (p-value <

0.001). There was highly significant increase of IVC caval index in patient's group than control's group (**Table 3**).

Table (3): Statistical study of IVC Collapsibility Index between patients and control groups

IVC Collapsibility Index	Patients (n=30)	Control (n=30)
Range	45 - 100	33.3 - 54.9
Mean	65.8	45.5
Observative difference between means	20.3	
Median	64.4	46.5
IQR	56.3 - 73.3	42.7 - 48.6
Statistical. Test	MW = 32	
p-value	< 0.001	

MW: Mann-Whitney Test.

The previous results confirmed that patients with Pneumonia who admitted to ICU had decrease in IVC-D and increase

in IVC -CI due to dehydration and unstable hemodynamic.

DISCUSSION

The IVC diameter is dependent on the total body fluid volume, the caval opening increases in width during inspiration (which encourages venous return of blood to the heart), The negative intrathoracic pressure leads to collapse of the IVC. During expiration the reverse happens causing distension of the IVC (*Gray's anatomy, 2018*).

This study was designed to determine the value of measurement of IVC diameter by ultrasound as a noninvasive tool in assessment of intravascular volume and hydration status in ICU patients with pneumonia. The IVC diameters (IVC-D) were measured during inspiration and during expiration at a distance of 2-3 cm from the IVC right atrial junction in the long axis. Measurements in non-intubated patients were obtained during their normal spontaneous inspiration and expiration while trying to avoid Valsalva maneuvers.

Ventilate patients were evaluated during normal ventilator cycling. The size and shape of the inferior vena cava (IVC) is correlated to the CVP and circulating blood volume. The IVC is a highly compliant vessel with no valve whose size varies easily with changes of intravascular pressure. As a result, normal respiratory cycle causes changes in intra- thoracic pressure which in turn influence venous return from the IVC and also affect the variation of IVC diameter. Consequently, the IVC collapses with inspiration as the blood is pumped out of the IVC due to the negative pressure created by chest expansion. In healthy subjects breathing spontaneously, cyclic changes in thoracic pressure may result in collapse of the IVC diameter of approximately 50 % (Lyon and Verma, 2012).

The demographic data in this study revealed that the mean age of the included male patients was 58.9, and the mean age of the included female patients was 58.4,

while in control group, the mean age of males was 38.75, and the mean age of females was 43. The cause of difference of ages between the two groups may be due to that the pneumonia is common to occur in old age. The same observation was reported by *Pagano et al. (2015)* who found that the mean age of patients is 58 ± 21 years old. Analysis of data by *Nafae et al. (2013)* in studying patients with pneumonia admitted to ICU found that, the age was more than 50 years old and males were predominant in presentation.

The mean BMI of the male patients was 25.2, and the mean BMI of female patients was 29, while in control group, the mean BMI of males was 24, and the mean BMI in females was 26.5. In the current study, 46.7% patients were smokers, while in the control group there were 33.3% smokers. These could be explained by the fact that smoking and addiction are more prone to respiratory illnesses. *Elshabrawi et al. (2017)* found that smokers were 35% of their patients with mean age were 25 years old. This may be the cause of this difference.

All patients in the current study were hypotensive, the mean SBP was 100 mmHg and the mean DBP was 65 mmHg. *Karacabey et al. (2016)* recorded that, the mean SBP was 117 mmHg (ranges from 60 – 220 mmHg), and the mean DBP was 70 mmHg (ranged from 30 – 140). Nearly, the same result of the present study was recorded by *Elshabrawi et al. (2017)* on studying patients with CAP, and they found that the mean SBP was 106 mmHg and the mean DBP was 64 mmHg.

Hypoxia, hypocapnia and normal PH were observed in patients of the present

study as the means PaO₂ were 50.4 mmHg and 52.6 mmHg in male and female patients respectively. The means PaCO₂ were 36 mmHg and 33.4 mmHg in male and female patients respectively. The means of PH were 7.3 and 7.4 in male and female patients respectively; similar hypoxemia was reported in patients with pneumonia by *Pagano et al. (2015)* who found that the mean PaO₂ was 55 mmHg.

Anemia and leukocytosis were common in patients of the current study. The mean hemoglobin was 9.7 gm/dl and 10.9 gm/dl in male and female patients respectively, the mean WBCs was $16.3 \times 10^3/\text{ul}$ and $13.9 \times 10^3/\text{ul}$ in male and female patients respectively. Leukocytosis also was reported by *Pagano et al. (2015)* who found that the mean TLC was $11.5 \times 10^3/\text{ul}$.

The present study showed that the chest X ray resulted in patient's group were 10% in upper lobe pneumonic patch in the right lung. 26.66% upper and middle lobes pneumonic patch in the right lung, 16.67% middle and lower lobes pneumonic patch in the right lung and 16.67% upper and lower lobes pneumonic patch in the left lung, 30% of patients were presented with bilateral diffuse infiltration, 26.66% of patients had associated right sided pleura effusion, while 13.33% of them had associated left sided pleura effusion. The consolidation was recorded in 81 % of patients by CXR. In the present study 90% of pneumonic patients showed ultrasonographic signs of consolidation. Therefore, ultrasonography was sensitive in diagnosis of pneumonia than CXR. *Nafae et al. (2013)* on studying patients with CAP diagnosed by CT chest confirmed the results of the current study,

and found that 78 of their patients had positive criteria of pneumonia by LUS (97.5%) versus 62 patients by CXR (77.5%). Also, the same results were reported by *Liu and Lian (2015)* while comparing the accuracy of LUS and CXR for the diagnosis of CAP and concluded that the LUS was found to be better than CXR (sensitivity of 94.6 versus 77.7 %). In addition, *Bourcier et al. (2014)* on studying the duration of the symptoms with respective performance of LUS and CXR for diagnosis of CAP, they observed that LUS detected more cases of CAP than CXR in the first 24 hours 76% vs 25%. These results were also suggestive that LUS was more sensitive than CXR in early diagnosis of CAP. During the follow up of patients with CAP. *Reissig et al. (2012)* found that LUS was more effectively monitor the changes of lesions early. *Wang et al. (2016)* concluded that LUS helps to reduce the overexposure of patients to radiation. Therefore, the use of LUS as a standard of care should be encouraged, especially in the ICU.

The sputum culture results in the included patients showed that 10% of them were diagnosed to have Staph aureus (MRSA), 16.67% had Pseudomonas, 13.34% had Acinetobacter, 13.34% had Klebsiella, 3.33% had Candida, while 43.32% of them revealed negative culture, CURB-65 score three or more was observed in 93% of patients in the present study and six patients of them were intubated, *Elshabrawi et al. (2017)* found that CURB-65 score three or more was present only in 30% of their patients and 12 out of 40 patients were intubated. This difference owing to that the patients in this study were old age and suffering from severe pneumonia .

In the current study, there was highly significance decrease of inspiratory IVC-D in patient's group than control's group (mean inspiratory IVC-D of patients 0.63 cm versus 0.92 cm in control group), Also there is significant decrease of expiratory IVC-D in patient's group than control's group (mean expiratory IVC-D in patient's group 1.46 cm versus 1.68 cm in the control's group), this mean that patients in the current study were suffering from dehydration and hemodynamic instability. The same results of control group of the present study was observed by *Gnanasekaran et al. (2016)* on healthy indian subjects of different ages, found that the mean inspiratory IVC-D was 0.81cm and the mean expiratory IVC-D was 1.67cm. On the other hand, *Yamanoglu et al. (2014)* when measuring the inspiratory and expiratory IVC-D of patients with severe dyspnea due to pulmonary disease (30% with pneumonia), they found that inspiratory and expiratory IVC-D were (0.44cm&1.1cm) respectively. The expiratory IVC-D of their study was the same as the present study but the inspiratory IVC-D was less than that of the current study (0.44 versus 0.64 cm), this may be due to most of their patients was suffering from severe dyspnea which explain the cause of increase IVC-CI (74%) of their patients. The IVC-CI of the patient's group in this study had highly significant increase than control's group (66% versus 46%). As regard to control's group, IVC-CI 46% also reported by *Ganasekaran et al. (2016)* on studying Indian normal subjects. On the other hand patients with hypovolemia had IVC-CI of 68,1% in studying of *Nagadev et al. (2014)*, and they conceded that an IVC –

CI of equal or greater than 50 % was strongly associated by CVP less 8 cm H₂O. *Elshabrawi et al. (2017)* on studying patients with pneumonia observed that patients with CURB-65 score (1) had mean IVC-CI was 37.5% and 15 patients with CURB-65 score (≥ 2) had mean IVC-CI was 61.5 %. The mean IVC-CI % of the present study was nearly the same as that of patients of CURB-65 score (≥ 2). This explains that why all patients in the present study were admitted to ICU as they were suffering from severe pneumonia than those of the previous study.

CONCLUSION

Earlier measurement of IVC diameter and collapsibility index may have an improve management of patients with pneumonia particularly in case of dehydration. Assessment of the physiologic characteristics of the IVC by ultra sound provides a rapid distinction between low and high volume states and offer a rapid, easily, reliable and noninvasive way to guide resuscitation in patients with pneumonia. Adding IVC-CI to severity indices may improve their prognostic value. Adding IVC-CI to CURB-65 creates a new score like (Modified CURB-65 or CURB -CI).

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قياس قطر الوريد الأجوف السفلي باستخدام الموجات فوق الصوتية في مرضى الإلتهاب الرئوي بالرعاية المركزة

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خلفية البحث: ينتج الألتهاب الرئوى من الاصابة بعدوى ميكروبية ويؤدى الى سعال مصحوب بمخاط، صعوبة بالتنفس، زيادة فى معدل التنفس عن الطبيعى، ارتفاع بدرجة الحرارة (حمى)، آلام بالصدر مع وجود غباشة بالرئة عند الفحص بالأشعة السينية وقد يؤدى الإلتهاب الرئوى الشديد إلى جفاف بالجسم ويعد تقدير كمية السوائل فى الجسم من التحديات التى تواجه الأطباء فى مناجزة مرضى الإلتهاب الرئوى ومن هنا جاء دور قياس قطر الوريد الأجوف السفلي باستخدام الموجات فوق الصوتية لتقدير كمية السوائل بالجسم في هؤلاء المرضى.

الهدف من البحث: قياس قطر الوريد الأجوف السفلي باستخدام الموجات فوق الصوتية في مرضى الإلتهاب الرئوي بالرعاية المركزة.

المرضى وطريقة البحث: أجريت هذه الدراسة في قسم الأمراض الصدرية بمستشفى الحسين الجامعي - باب الشعيرة الجامعي بجامعة الأزهر على ستين شخصا منهم ثلاثين مريضا مصابون بالتهاب رئوي شديد وتم حجزهم بالرعاية المركزة وثلاثين شخصا سليما من العاملين بالمستشفى أو أقارب المرضى بعد الموافقة من المريض أو أهليته على الاشتراك في البحث الذي تم طبقا للجنة الأخلاقيات الطبية بجامعة الأزهر وذلك في الفترة الزمنية من نوفمبر 2019 حتى سبتمبر 2020، وبعد استبعاد الحالات التي لا تتماشى مع معايير هذه الدراسة تم أخذ التاريخ المرضي كاملا لكل المرضى ثم اجراء فحص إكلينيكي شامل، صورة دم، وظائف كبد وكلي، تقييم لشدة الالتهاب الرئوى على طريقة (كرب65)، فحص ومزرعة بصاق، أشعه عادية علي الصدر خلفي أمامي، جانبي، موجات صوتية علي القلب، قياس نسبة تشبع الاكسجين وتحليل غازات

بالدم، تقييم اكلينيكي للضغط داخل البطن، قياس مؤشر كتلة الجسم، وقياس قطر الوريد الأجوف السفلي باستخدام الموجات فوق الصوتية لمجموعة المرضى، بينما تم قياس مؤشر كتلة الجسم، وقطر الوريد الأجوف السفلي باستخدام الموجات فوق الصوتية لمجموعة الأصحاء مع حساب معدل انطواء قطر الوريد الأجوف السفلي لكلتا المجموعتين.

نتائج البحث: أظهرت الدراسة أنه كان هناك نقص ذو دلالة احصائية عالية أثناء الشهيق في متوسط قطر الوريد الأجوف السفلي في مجموعة المرضى عن مجموعة الأصحاء (0.63 سم)، (0.92 سم) على التوالي بدلالة إحصائية بلغت قيمتها أقل من (0.001) أما أثناء الزفير فكان هناك نقص ذو دلالة احصائية واضحة في متوسط قطر الوريد الأجوف السفلي في مجموعة المرضى عن مجموعة الأصحاء (1.46 سم)، (1.68 سم) على التوالي بدلالة إحصائية بلغت قيمتها أقل من (0.007)، كانت هناك زيادة ذات دلالة احصائية عالية في معدل انطواء الوريد الأجوف السفلي في مجموعة المرضى (65.8%) عن الأصحاء (45.5%) بدلالة احصائية بلغت قيمتها أقل من (0.001).

الاستنتاج: قياس قطر الوريد الأجوف السفلي باستخدام الموجات فوق الصوتية في مرضى الإلتهاب الرئوي بالرعاية المركزه يعد وسيلة سريعة وغير تداخلية لتقدير كمية السوائل بالجسم، مرضى الألتهاب الرئوي الشديد والذين يحجزون بالرعاية المركزة يعانون من نقص في قطر الوريد الأجوف السفلي وزيادة في معدل انطواءه نتيجة الى نقص كمية السوائل وجفاف الجسم.

الكلمات الدالة: الإلتهاب الرئوي، العناية المركزة، الموجات فوق الصوتية، قطر الوريد الأجوف السفلي.