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Relationship between Central Venous Pressure and Collapsibility Indices of Internal Jugular Veins and Inferior Vena Cava in Heart Failure Patients

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ABSTRACT

Background: Heart failure (HF) is number one reason for hospitalization in people over 65 years with nearly 1 million patients hospitalized every year in US and Europe. **Objectives:** To study the correlation between invasive central venous pressure (CVP) and collapsibility indices of internal jugular veins (IJVs) and inferior vena cava (IVC) utilizing ultrasonography in hospitalized HF patients. **Methods:** This prospective observational study had been conducted on 55 participants aged from >18 years old with decompensated HF admitted to CCU of Menoufia University hospitals. Clinical evaluation was done by using EVEREST score. CVP catheter was inserted via right (RT) subclavian vein. Ultrasound examination was performed using the GE Vivid S5 diagnostic US system.

Results: There was positive correlation between CVP and expiration diameter of (IVC, RT IJV and LT IJV) at admission and discharge. Negative correlation existed between CVP and CI of (IVC, RT IJV and LT IJV) at admission and discharge. CVP, expiration, inspiration diameter of (IVC, RT IJV and LT IJV) and EVEREST score had been significantly lower at discharge contrasted to at admission (P <0.001). CI of (IVC, RT IJV and LT IJV) were significantly greater at discharge compared to at admission.

Conclusions: Assessment of diameters of IVC, RT IJV and LT IJV showed strong positive correlation with invasive CVP. CI of IVC, RT IJV and also LT IJV showed strong negative correlation with invasive CVP. LT IJV can be used as an indicator for follow up volume status but less sensitive than RT IJV.

Keywords: Central Venous Pressure, Inferior Vena Cava, Internal Jugular Vein, Collapsibility Index, Heart Failure.

INTRODUCTION

Heart failure (HF) is a worldwide epidemic impacting a minimum of 26 million individuals globally and is on the rise in prevalence [(1)]. Heart failure patients need to be closely monitored since lingering congestion might lead them to be readmitted, which raises the death risk. Heart failure patients can be monitored using both invasive and non-invasive techniques [(2)].

Most common invasive methods are central venous pressure which requires invasive, labour-intensive, and time-consuming central venous catheter insertion. It is also impractical in pre-hospital settings and during an emergency resuscitation situation. Non-invasive methods have increased its use recently such as echocardiographic IVC evaluation (diameters and CI) as it reflects changes of CVP [(3)].

The collapsibility index (CI) of the IVC serves as an indicator for the early identification of intravascular volume alterations. The CI of the IVC, assessed using ultrasound (US), has been employed for predicting fluid responsiveness in critical care medicine for several years due to its non-invasive nature, quick diagnostic capability, and cost-effectiveness [(4,5)].

Ultrasound was used for evaluation changes of RT and LT IJVs (diameters and CI) and correlated it with changes in CVP in hospitalized HF patients at admission and discharge after diuretics and antifailure therapy. Changes in LT IJV were also studied for follow up volume status if RT IJV wasn't available due to thrombosis, central venous catheter, cancer or burn on RT side of the neck and any other causes [(6)].

The purpose of this work was to assess the relationship between changes in invasive central venous pressure (CVP) and changes in collapsibility indices of right IJV, left IJV and IVC by ultrasound (non-invasive) in hospitalized HF patients.

PATIENTS AND METHODS

This prospective observational work had been conducted on 55 participants aged from >18 years old, both genders, with decompensated HF hospitalised at the critical care unit (CCU) of Menoufia University hospitals and CVP catheter had been already inserted in RT subclavian vein. Evaluation of participants had been conducted at admission and discharge.

Ethical considerations:

The work had been conducted from November 2021 to November 2022 following approval from the Ethics Committee Menoufia University Hospitals (number of approval: 12/2021SARD 9). Each participant provided a well-informed written consent. The Helsinki Declaration was followed throughout the study's conduct.

Exclusion criteria were patients with mechanical ventilation, histories of radiation or surgical intervention to the neck or chest, significant organic tricuspid regurgitation, prior or current upper extremity deep venous thrombosis, and pregnancies.

All patients were subjected to complete history taking, clinical examination, laboratory tests [full blood picture (CBC), C-reactive protein (CRP), renal and liver

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function test, random blood sugar and cardiac enzymes], 12 leads-electrocardiogram (ECG), clinical evaluation by EVEREST score (Peripheral oedema, orthopnoea, JV distension and total score) and radiological investigations [echocardiography and US examination of IJVs].

Invasive CVP measurement

It was assessed employing an indwelling central venous catheter (CVC) introduced into RT subclavian vein. The participant had been placed in supine posture and zero point had been determined at the level of patient's RT atrium at mid axillary line in the 4^{th} intercostal space. The stopcock was turned so that the IV solution flowed into the manometer filling to the 20-25 cm level. Then the stopcock was turned so that the solution in manometer flowed into the patient. The fall in the height of column of fluid was observed in manometer. The level at which solution stabilized or stopped moving downward was recorded. This was the CVP by cm H_2O. CVP and position of the patient were recorded. Chest X-ray was done after insertion of CVC via RT subclavian approach to confirm entry of CVC to RT atrium.

Ultrasound examination of IVC and IJVs [(6)]

It was performed using the GE Vivid S5 diagnostic US system model 2017 US machine (made in India), which was utilised for all the examinations. 3SC-RS probe type for IJV and IVC imaging (3.5 MHZ) was used. an expert sonographer, unaware of the CVP measures, conducted the ultrasound exams. Bedside ultrasound pictures were acquired with the individual in the supine posture. The IJV was visualised in a transverse plane, 2 cm superior to the clavicle, at the conclusion of expiration. The maximum and minimum anteroposterior (AP) diameters were assessed throughout four breathing cycles, and the CI was calculated using the formula (Maximum diameter - Minimum diameter) / Maximum diameter × 100%. IVC measures were obtained in a longitudinal plane using a cardiac transducer positioned subxiphoid.

IVC measurements (expiration, inspiration, CI)

The subjects were positioned supine, and the probe was positioned in the subxiphoid region, with measures obtained 2 cm inferior to the hepatic veins.

Internal jugular veins measurements

RT and LT IJV measurements: (Expiration, inspiration, CI). All the measurements were done on right and left IJVs with the participants lying supine. The USG transducer was positioned bilaterally on the neck in the transverse plane, 2 cm superior to the sternoclavicular joint, above the IJVs. The IJVs were distinguished by colour flow Doppler and compressibility assessment. Minimal pressure had been applied to avoid compressing or obliterating the vein. Measures were conducted when the whole vein circumference seemed observable. The maximum (in expiration) and minimum (in inspiration) AP diameters were estimated. Corresponding CI was computed and derived.

Statistical analysis

Statistical analysis has been performed using SPSS v26 (IBM Inc., Chicago, IL, USA). The Shapiro-Wilk test and histograms have been employed to assess the data distribution normality. Quantitative parametric variables had been displayed as mean and standard deviation (SD) and contrasted among both groups using an unpaired Student's t-test. Quantitative non-parametric data had been displayed as median and analysed using the Mann-Whitney test. Qualitative factors were expressed as frequencies and percentages (%). A correlation between different parameters had been performed employing Pearson moment correlation equation for linear relation of normally distributed variables. A two tailed P value < 0.05 was considered statistically significant.

RESULTS

Demographic data and comorbidities are enumerated in **Table 1**

Table 1: Demographic data and comorbidities of the studied patients

		N=55
Age (years)		58.8±7.7
Sex	**Male**	43(78.18%)
	Female	12(21.82%)
Comorbidities	**DM**	32(58.18%)
	HTN	42(76.36%)
	Dyslipidaemia	46(83.64%)
	IHD	53(96.36%)
	Smoking	27(49.09%)

Data are presented as mean ± SD or frequency (%). HTN: hypertension, DM: diabetes mellitus, IHD: ischemic heart disease.

Echocardiogram data are enumerated in **Table 2.**

Table 2: Echocardiogram of the studied patients

		N=55
Echocardiogram	**LV EDD (cm)**	6±0.64
	LV ESD (cm)	4.8±0.58
	EF (%)	42.2±6.74
	FS (%)	21.8±3.53
	RV basal diameter (cm)	3.5±0.34
	TAPSE (cm)	1.9±0.19

Data are presented as mean ± SD, LV EDD: left ventricular end-diastolic diameter, LV ESD: left ventricular end-systolic diameter, FS: fractional shortening, EF: ejection fraction, RV: right ventricular, TAPSE: tricuspid annular plane systolic excursion.

Clinical evaluation by EVEREST score (Peripheral oedema, orthopnoea, JV distension and total score), CVP via RT subclavian catheter, expiration and inspiration diameters of (IVC, RT IJV and LT IJV) were significantly lower at discharge than admission. CI of (IVC, RT IJV and LT IJV) were significantly higher at discharge than admission **(Table 3)**.

Table 3: Composite congestion score (EVEREST), CVP via RT subclavian catheter, IVC, RT IJV and LT IJV measurements of the studied patients at admission and discharge

		Admission	Discharge	P
Composite congestion score (EVEREST)	Peripheral oedema	2	1	**<0.001***
	Orthopnoea	2	1	**<0.001***
	JV distension (cm H_2O)	3	2	**<0.001***
	Total score	8	4	**<0.001***
CVP via RT subclavian catheter		21.25±2.88	11.24±1.41	**<0.001***
Delta change		-10 ± 2.95		--
IVC	Expiration diameter (cm)	2.45±0.35	2.05±0.35	**<0.001***
	Delta change of expiration	-0.4±0.23		--
	Inspiration diameter (cm)	1.86±0.29	1.43±0.32	**<0.001***
	Delta change of inspiration	-0.43±0.18		--
	CI	0.24±0.07	0.31±0.08	**<0.001***
	Delta change of CI	0.07 ± 0.07		--
RT IJV	Expiration diameter (cm)	1.19±0.15	1.05±0.13	**<0.001***
	Delta change of expiration	-0.14±0.07		--
	Inspiration diameter (cm)	0.88±0.18	0.69±0.13	**<0.001***
	Delta change of inspiration	-0.19±0.11		--
	CI	0.27±0.08	0.34±0.08	**<0.001***
	Delta change of CI	0.07±0.05		--
LT IJV	Expiration diameter (cm)	1.07±0.11	1±0.12	**0.002***
	Delta change of expiration	-0.07±0.07		--
	Inspiration diameter (cm)	0.73±0.14	0.66±0.11	**0.002***
	Delta change of inspiration	-0.07±0.08		--
	CI	0.31±0.08	0.35±0.07	**0.003***
	Delta change of CI	0.04±0.04		--

Data are presented as mean ± SD or median. *: significant. CVP: central venous pressure, IVC: inferior vena cava, RT IJV: right internal jugular vein, LT IJV: left internal jugular vein, CI: collapsibility index.

There were positive correlations between CVP via RT subclavian catheter and expiration diameter of (IVC, RT IJV and LT IJV) at admission and discharge. There were negative correlations between CVP via RT subclavian catheter and CI of (IVC, RT IJV and LT IJV) at admission and discharge **(Table 4)**.

Table 4: Correlation between CVP via RT subclavian catheter, expiration diameter and CI of (IVC, RT IJV and LT IJV) measurements at admission and discharge of the studied patients

			Admission	Discharge
CVP via RT subclavian catheter				
IVC measurements	Expiration diameter	r	0.577	0.634
		P	**< 0.001***	**<0.001***
	CI	r	-0.687	-0.709
		P	**< 0.001***	**<0.001***
RT IJV measurements	Expiration diameter	r	0.794	0.644
		P	**< 0.001***	**<0.001***
	CI	r	-0.626	-0.592
		P	**< 0.001***	**<0.001***
LT IJV measurements	Expiration diameter	r	0.297	0.301
		P	**0.028***	**0.026***
	CI	r	-0.357	-0.268
		P	**0.007***	**0.047***

*: Significant. r: correlation coefficient, CVP: central venous pressure, IVC: inferior vena cava, RT IJV: right internal jugular vein, LT IJV: left internal jugular vein, CI: collapsibility index.

There was positive correlation between CI of IVC and CI of (right IJV and left IJV) at admission and discharge. There was positive correlation between expiration diameter of IVC and expiration diameter of (right IJV and left IJV) at admission and discharge respectively **(Table 5)**.

Table 5: Correlation between expiration diameter of IVC and expiration diameter of (right IJV and left IJV measurements) at admission and discharge and between CI of IVC and CI of (right IJV and left IJV measurements) at admission and discharge of the studied patients

		Admission	Discharge
Expiration diameter of IVC			
RT IJV	r	0.630	0.538
	P	**< 0.001***	**< 0.001***
LT IJV	r	0.304	0.342
	P	**0.024***	**0.011***
CI of IVC			
RT IJV	r	0.699	0.793
	P	**<0.001***	**<0.001***
LT IJV	r	0.302	0.291
	P	**0.025***	**0.031***

*: significant. r: correlation coefficient, RT IJV: right internal jugular vein, LT IJV: left internal jugular vein, CI: collapsibility index, IVC: inferior vena cava, CVP: central venous pressure.

There was negative correlation between CVP via right subclavian catheter change and CI change of IVC, right IJV and left IJV measurements **(Table 6)**.

Table 6: Correlation between Δ CVP via right subclavian catheter change and Δ CI change of IVC, right IJV and left IJV measurements of the studied patients

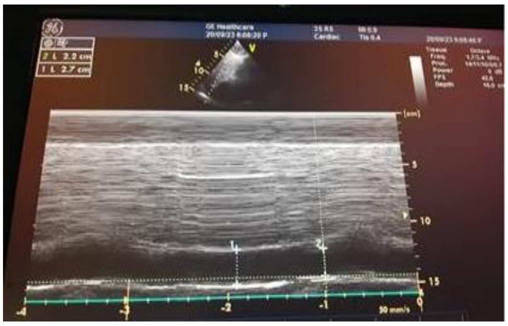
		Δ CVP via RT subclavian catheter change
Δ CI change of IVC	r	-0.741
	P	**<0.001***
Δ CI change of RT IJV	r	-0.627
	P	**< 0.001***
Δ CI change of LT IJV	r	-0.304
	P	**0.024***

*: significant. CVP: Central venous pressure. IVC: Inferior vena cava, IJV: internal jugular vein, CI: Collapsibility index.

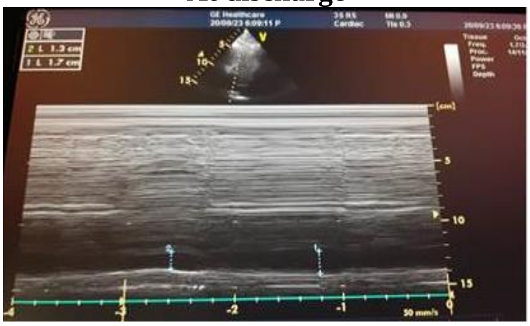
CASE 1

At admission **At discharge**

IVC

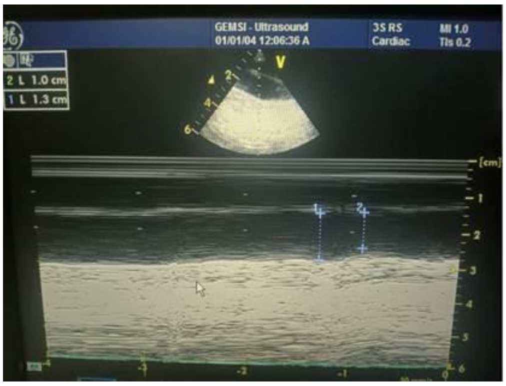


CI= 0.18



CI= 0.23

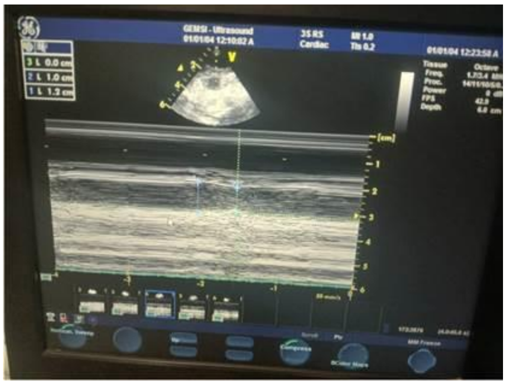
Rt IJV



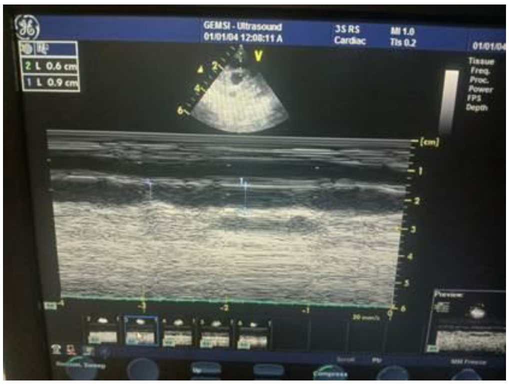
CI= 0.23

CI= 0.4

Lt IJV



CI= 0.17



CI= 0.33

Figure 1: Inferior vena cava, right and left internal jugular veins at admission and discharge.

DISCUSSION

HF is a global pandemic and life-threatening syndrome impacting a minimum of 26 million individuals globally and is on the rise in prevalence [1]. HF patients need to be closely monitored since lingering congestion might lead them to be readmitted, which raises the morbidity and mortality risks. Heart failure patients can be monitored using both invasive and non-invasive techniques [2].

Regarding our results, clinical evaluation by EVEREST score showed improvement at discharge compared to admission in response to anti-failure therapy. EVEREST score showed positive correlation with CVP, expiration and inspiration diameters of (IVC, RT IJV and LT IJV) and showed negative correlation with CI of (IVC, RT IJV and LT IJV).

Regarding our results, CVP via RT subclavian catheter was significantly lower at discharge than admission. These results are supported by **Bocchino *et al.*** [7] who studied 200 hospitalized patients admitted with acute heart failure and showed that high CVP in admission was reduced at discharge (mean CVP: 14.0 ± 6.1 mmHg) due to diuretics and anti-failure measures.

Regarding IVC changes of diameter during expiration and inspiration, our results showed that there were significantly lower at discharge compared to admission. These findings had been in line with **Carbone *et al.*** [8] who investigated 48 patients (n = 25 with IHD and n = 23 non-IHD) received biochemical examinations (including NT-proBNP), echocardiography and IVC evaluation by hand-carried US and showed that diameter of IVC was significantly reduced and there was increase in collapsibility index shown at discharge compared to admission in studied HF patients due to diuretics and anti-failure measures.

Regarding CI of IVC, our results were significantly higher at discharge in comparison with admission. These findings were in line with **Jobs *et al.*** [9] who studied 388 participants with acute decompensated HF and showed that diuretics and anti-failure therapy reduced symptoms and signs of congestion and reduced the IVC diameter ≤21 mm and increased IVC collapsibility >50%.

Regarding RT IJV changes of diameter during (expiration and inspiration) and CI of RT IJV, our results showed that diameters of expiration and inspiration of RT IJV were reduced and CI of RT IJV was significantly higher at discharge than admission. **Broilo *et al.*** [10] who studied 39 mechanically ventilated patients, revealed that changes of diameter of RT IJV showed significantly reduction (r = 0.51, p < 0.001) and CI of RT IJV increased (The area under the ROC curve was 0.903 (95% CI 0.765 - 0.973; cut-off value = 11.86)) after anti failure therapy at discharge in comparison with admission.

Regarding Delta change of expiration diameter of RT IJV, it was -0.1 ± 0.07 cm. **Rahman and Ahmed** [11] who found that upon discharge, the mean maximum diameter and mean minimum diameter of the IJV were substantially decreased to 0.92(0.09) cm and 0.54(0.12) cm compared to admission values of 1.36±0.15 cm and 1.26(0.18) cm respectively (p <0.001). Also, **Brolio *et al.*** [10] who found significant improvement in Delta change of expiration diameter of RT IJV with anti-failure measures.

Regarding LT IJV changes of diameter during expiration and inspiration, they were significantly lower at discharge than admission. These results agreed with **Guarracino *et al.*** [12] who studied 50 patients and observed in their study that the diameters of LT IJV were reduced at discharge than admission (r=0,45, P = 0,001) in response to anti-failure therapy.

A positive correlation existed between expiration diameter of IVC and expiration diameter of RT IJV at admission and discharge. These results agreed with **Kasem *et al.*** [13] who studied 35 patients and observed in their study that a positive correlation existed between expiration diameter of IVC and expiration diameter of RT IJV at discharge (r = 0.923, P < 0.001 and r = 0.390, P = 0.021, correspondingly). Additionally, **Parenti *et al.*** [14] who studied 43 hospialized patients, revealed a substantial positive correlation among IVCDmax and IJV ratio and CVP (r=0,35, P = 0,02 and r=0,35, P = 0,03 respectively).

A positive correlation existed between CI of IVC and CI of RT IJV at admission and discharge. These outcomes were supported by **Jassim *et al.*** [15] who studied 70 patients and observed that a significant correlation existed between IVC-CI and IJVs-CI at 0° (r=-0.484 (P=0.0001), r=-0.416 (P=0.001), respectively).

There was positive correlation between CI of IVC and CI of LT IJV at admission and discharge. These findings were consistent with **Iizuka *et al.*** [16] who studied 27 patients and showed that there was positive correlation between CI of IVC and CI of LT IJV (0.57 (95% CI: 0.37 - 0.77) and 0.57 (95% CI: 0.37 - 0.77), correspondingly. but with less sensitivity than RT IJV (95% (CI): 0.75 - 0.99) due to wider diameter, more superficial and direct continuity to RT atrium characters of RT IJV.

There was negative correlation between CVP via RT subclavian catheter change and CI change of (IVC, RT and LT IJV). That was supported by **Ilyas *et al.*** [17] who studied 100 hospitalized patients and declared that a strong negative correlation existed between CVP (10.38 ± 4.14 cm H2O) and (IVC, RT and LT IJV) collapsibility indices (%) (r = -0.827, p < 0.0005, r = -0.472, p < 0.0005, r = -0.456, p < 0.001), correspondingly. **Urakov *et al.*** [18] studied 31 volunteers and demonstrated that a negative correlation existed between CVP change (9.78 ± 3.74 cm H2O) and CI change of LT IJV measurements(r = -0.496, p < 0.0001).

LIMITATIONS

Limitations of the study involved that the sample size was relatively small. Cardiologists are unfamiliar of RT IJV and LT IJV measurement. Radiologist was required to perform examination and evaluation of IJV. Time consuming. In obese patients, IVC view was difficult. Lack of cooperation of patients during asking patients for expiration and inspiration during examination.

CONCLUSIONS

CVP and EVEREST scores showed significant reduction at discharge compared to admission and also showed strong positive correlation in response to anti-failure measures. Assessment of diameters of IVC, RT IJV and LT IJV showed strong positive correlation with invasive CVP. Assessment of collapsibility indices of IVC, RT IJV and LT IJV showed strong negative correlation with invasive CVP. Assessment of IVC diameter and CI showed strong positive correlation with RT IJV and LT IJV. LT IJV may be used as an indicator for follow up volume status but less sensitive than RT IJV when correlates with CVP.

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