RESEARCH

Diagnostic accuracy of internal jugular vein ultrasound in quantification of the central venous pressure for hemodialysis patients

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Abstract

Background: Assessment of the central venous pressure (CVP) is an essential hemodynamic parameter for monitoring the dialyzing patients. Our objective of the present study is to investigate the accuracy of CVP measurement by internal jugular vein US in comparison to the direct measurement by the central venous catheters for hemodialysis patients. We included 106 patients; where their CVP was assessed in two different non invasive US methods (CVPni) separately and in combination and the obtained measurements were correlated to the invasive measurements (CVPi) by catheters.

Results: By method 1, there is a highly significant positive correlation between CVPni and CVPi ($\rho < 0.001$) and a Pearson correlation coefficient ($r = 0.913$ $n = 93$), and by method 2, there is also a highly significant positive correlation between the CVPni and CVPi in both groups ($r = 0.832$, 95%, $n = 106$, $p < 0.001$), 1.935 was the cut-off point for prediction of CVP $\geq$ 10cmH20. For differentiation between patients with CVP < 10cmH20 and $\geq$ 10cmH20, the accuracy measures (sensitivity, specificity, PPV, NPV, and overall accuracy) were 100%, 79.31%, 74.47%, 100%, and 87.10% by method 1, and were 91.11%, 85.48%, 82.00%, 92.98%, and 87.85% by method 2, while the combination of both methods had gained 88.57%, 89.66%, 83.78%, 92.86%, and 89.25%, respectively.

Conclusion: The US offered a reliable and non-invasive tool for monitoring CVP. The present study has a novelty of combining more than one US method and this had reported higher accuracy measures and outperformed the use of a single method.

Keyword: Hemodialysis, Central venous pressure, Measurement, Ultrasound

Background

Chronic kidney disease (CKD) is a worldwide health problem that has multiple etiologies. It could result in great morbidity and mortality thus exerting a high burden upon the health systems [1,2]

Dialysis is the mainstay of treatment for renal failure patients and the prevalence of the dialysis-dependent population is expected to increase over time. However, the tolerability for fluid changes during the hemodialysis sessions is limited where the hypervolemia could result in pulmonary congestion, but on the other hand, fluid deficiency results in hypotension and could promote cardiac ischemia [3, 4].

Continuous monitoring of the hydration status is considered of utmost importance and the definition of dry weight is a mandatory step in the patients' care [5]; assessment of the central venous pressure (CVP) is one of the used parameters to detect the hemodynamic changes and the patient hydration. As the mean CVP shows an initial significant decrease during the

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Baz *et al. Egyptian Journal of Radiology and Nuclear Medicine* (2021) 52:272

Page 2 of 10

first hours of the dialysis session then attains a steady decline over the following hours, so the measurement of CVP in such patients can help to early detect the dry weight [6].

Measurement of CVP is usually done by a centrally inserted venous catheter, which is an invasive procedure that could carry multiple risks [7], so it is important to have a non-invasive and reliable method that could be easily used in daily practice from the start to the end of the dialysis session [8].

Some authors had suggested that the CVP estimation by the ultrasound (US) examination of the internal jugular vein seems to be a promising surrogate for the direct invasive measurement, especially in the patients who have dialysis shunts and do not have available central venous lines [9, 10].

The present study aims to investigate the accuracy of measurement of the CVP by internal jugular vein US for hemodialysis patients in comparison to its direct measurement by the already present central venous catheters in the same patients.

Methods
Subjects

The study was designed as a prospective cross-sectional analytical study, including 106 hemodialysis patients who were recruited from the nephrology and dialysis units in our institute, during the period from October 2020 to March 2021. The ultrasound studies were performed in the ultrasound unit of the radiology department in our institute.

- **Inclusion criteria**: patients above 18 years old who had a renal failure on hemodialysis with an already present central catheter. No catheter was inserted just for the study.
- **Exclusion criteria**: patients with clinical conditions that cause increased right atrial pressure, and were not related to hypervolemia including the cardiopulmonary causes as well as the patients who had cervical or mediastinal masses or those with recent or old jugular venous thrombosis that was proved clinically or by imaging studies.

This prospective study was performed following the ethical guidelines of the Research Ethics Committee of our institute. The reference number: Code Ms-80–2020, Date of approval 16–08-2020; and it was approved by the local Research Ethics Committee of our institute. All of the participants were informed of the details and gave their written informed consent.

All of our patients were subjected to:

History taking

Every patient was requested to give the following data:

- Cause of renal impairment.
- Duration of hemodialysis?
- History of central venous obstruction by old catheter insertion or due to other causes.
- Associated diabetes mellitus (DM), hypertension (HTN), or other medical disorders?

Non-invasive CVP measurement by high-resolution ultrasound

All patients were examined by ultrasound using a General Electric Logic P6 machine that is equipped with a linear probe with 7.5–12 MHz frequency.

The probe was applied gently on the skin with a copious amount of gel to avoid compression of the neck veins.

Method 1 (Measurement of collapsing point of the internal jugular vein) (Fig. 1a).

Patients were placed in a comfortable position in 45° reverse Trendelenburg orientation and their necks were slightly extended. The catheter-free IJV was used for taking measurements. In a longitudinal view, the average point of oscillation (collapse) during quiet normal spontaneous respiration was detected and marked on the skin, and then the height (vertical distance) between the collapsing point and the sternal angle was estimated.

The CVP was calculated by adding five cm (an average distance from the sternal angle to the center of the right atrial cavity) to the measured height of the IJV (at the marked collapsing point) then the results were obtained in cmH20 and recorded as CVPni.

Method 2 (Measurement of the cross-sectional area ratio between the internal jugular vein/common carotid artery) (Fig. 1b).

Our patients were seated in a flat supine position, then the largest cross-sectional area of IJV and the CCA were taken in their short axes at the level of the thyroid cartilage; the measurements were taken at the end of expiration to minimize the effect of the thoracic pressure.

Invasive CVP measurement by an already present central venous catheter as the gold standard (CVPi) (Fig. 1c)

We had performed the study on the patients who had already central venous catheters that were inserted for other purposes, but no catheters were inserted just for the study.

A 3-way stopcock was connected to a fluid manometer through an intravenous fluid drip where the position of the H2O column was adjusted in such a way that the 3-way stopcock was at the same level as the right

Fig. 1 a, **b** photographic images for demonstration of the patient position and the measurement level for the collapsing IJV point used in method 1. **c** A photographic image for the patient's position used in method 2. **d** A photographic image for the patient position and the measurement level using the IJV catheter (CVPi) as a gold standard

atrium (about 5 cm below the sternal angle). The intravenous fluid perfusion was directed in one of the stopcock ways to feed the column. The 3-way stopcock was then turned to make the intravenous column evacuating into the IJV catheter until the equilibrium was reached, and then the CVP was estimated at the level where the intravenous fluid had stopped in the column. The mean CVP value was taken during quiet normal respiration and was recorded in cmH2O.

For the statistical analysis, our study populations were divided into two groups based on a CVP cutoff point (that was 10 cm H2O), as a threshold for the prediction of (hydration) volume responsiveness (Figs. 2, 3).
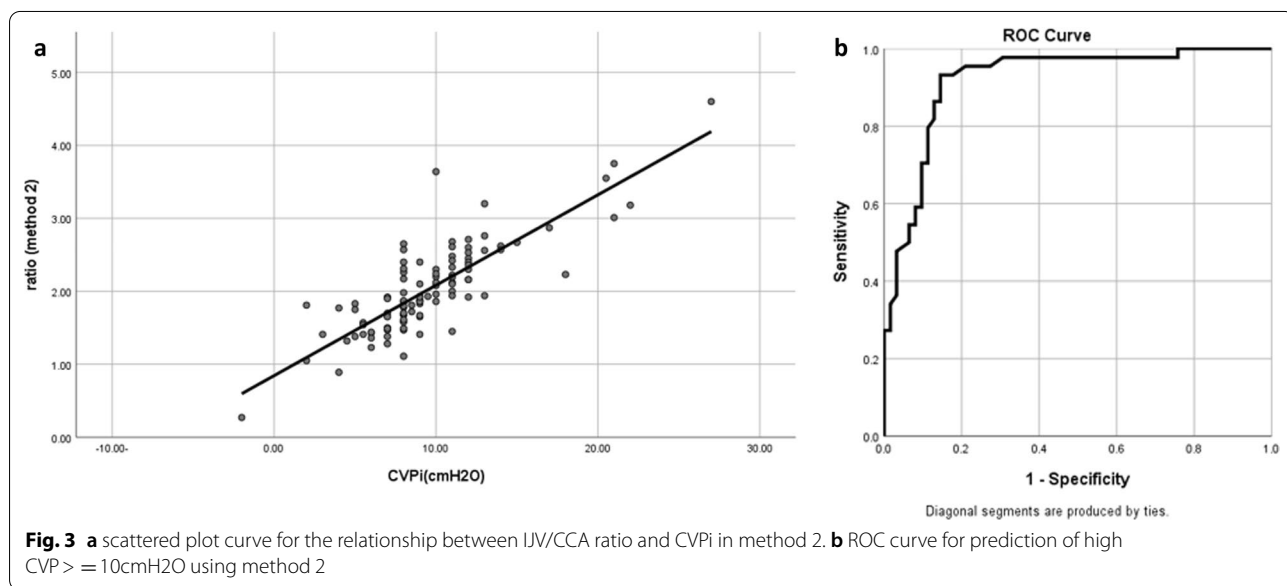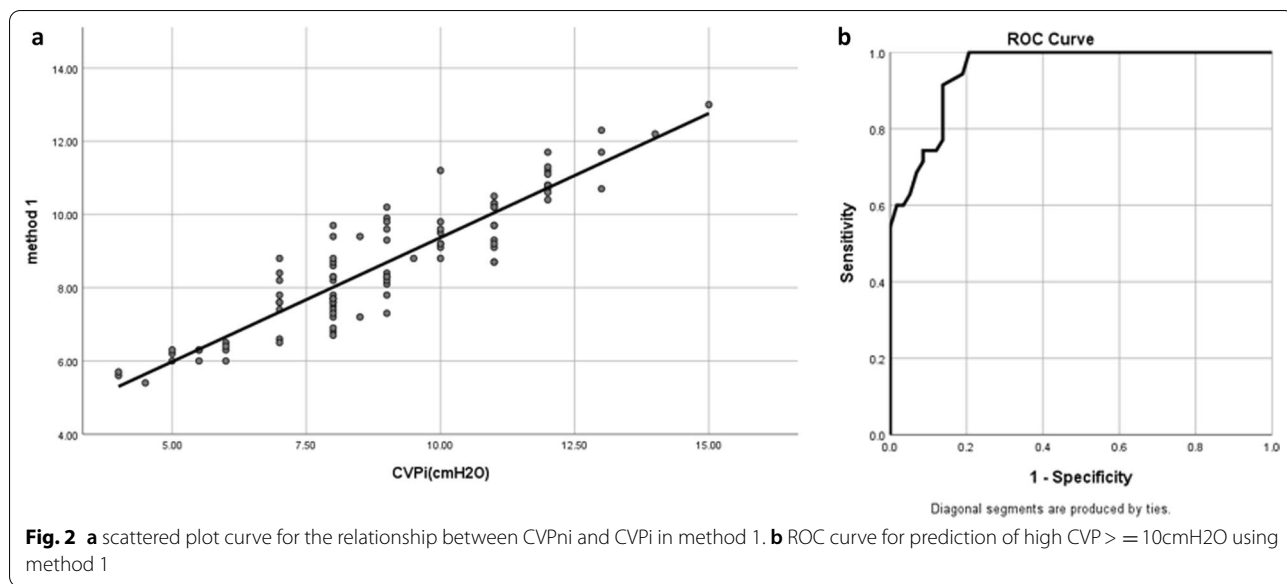
Statistical methods and data analysis

Data were coded and entered using the statistical package for the Social Sciences (SPSS) version 26 (IBM Corp., Armonk, NY, USA). Data were summarized using the mean, standard deviation in quantitative data and using the frequency (count) and the relative frequency (percentage) for categorical data. Comparisons between the quantitative variables were done using the unpaired t-test. For comparing categorical data, Chi-square ($\chi2$)

test was done. Exact test was used instead when the expected frequency was < 5. Correlations between the quantitative variables were done using the Pearson correlation coefficient. ROC curve was constructed with the area under curve (AUC) analysis performed to detect the best cutoff value of ADC for detection of CVP ≥ 10 cmH2O (recommended threshold for predicting hydration) using the 2 methods. Standard diagnostic indices including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and the diagnostic efficacy were calculated. P-values < 0.05 were considered statistically significant. Logistic regression was done to detect the predicted probability of the combination of both methods (methods 1&2).

Results

One hundred and six patients were enrolled in this study; of which 35 patients were diabetic (33%), 35 patients were hypertensive (33%), 72 patients had their left side examined (67.9%), while 34 patients had the right side (32.1%). The mean CVPi was 9.55 ± 4.17 cmH20. Sixty-two patients had a CVPi less than 10 cmH2O (58.5%) (Fig. 4) and forty-four patients had a CVPi more than or

Baz *et al. Egyptian Journal of Radiology and Nuclear Medicine* (2021) 52:272

Page 4 of 10

Fig. 2 a scattered plot curve for the relationship between CVPni and CVPi in method 1. **b** ROC curve for prediction of high CVP > = 10cmH2O using method 1

Fig. 3 a scattered plot curve for the relationship between IJV/CCA ratio and CVPi in method 2. **b** ROC curve for prediction of high CVP > = 10cmH2O using method 2

equal to 10 cmH2O (41.5%) (Fig. 5); However, there was no significant correlation between patients' gender, presence of DM, presence of HTN or the examined side, and the obtained CVPi (Table 1).

For method 1

It worth mentioning that the exact measurements of CVPni could not be obtained in nine of our patients, including those who were having a very high CVPi (their mean CVP was 19.278cmH20) as the IJV was distended all-through its neck course (Fig. 6), and for four patients who were having a low CVPi (their mean CVP was 2.25cmH20) (Fig. 7), as the IJV was collapsed

all-through its neck course. Therefore, a correlation between CVPni and CVPi was only feasible in only 93 patients out of 106.

By method 1, a highly significant positive correlation between CVPni and CVPi was found ($\rho < 0.001$) and a Pearson correlation coefficient ($r = 0.913$) for the studied patients ($n = 93$), while AUC for the ROC curve was 0.951 in the patients with CVPi $\geq$ 10cmH20. The mean CVPni for patients with CVPi < 10 cmH20 was 7.66 ± 1.20 cmH20 and it was 10.33 ± 1.09 cmH20 for patients with CVPi ≥ 10 cmH20 (Fig. 2a) (Table 2).

The AUC for the ROC curve in predicting CVP $\geq$ 10cmH20 was 0.951 (95% CI: 0.913–0.988)

Baz *et al. Egyptian Journal of Radiology and Nuclear Medicine*   (2021) 52:272
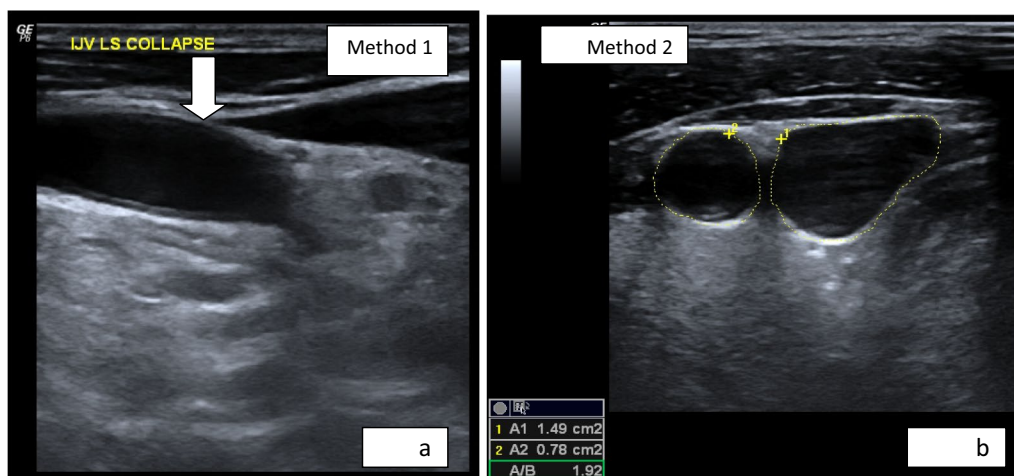
Page 5 of 10

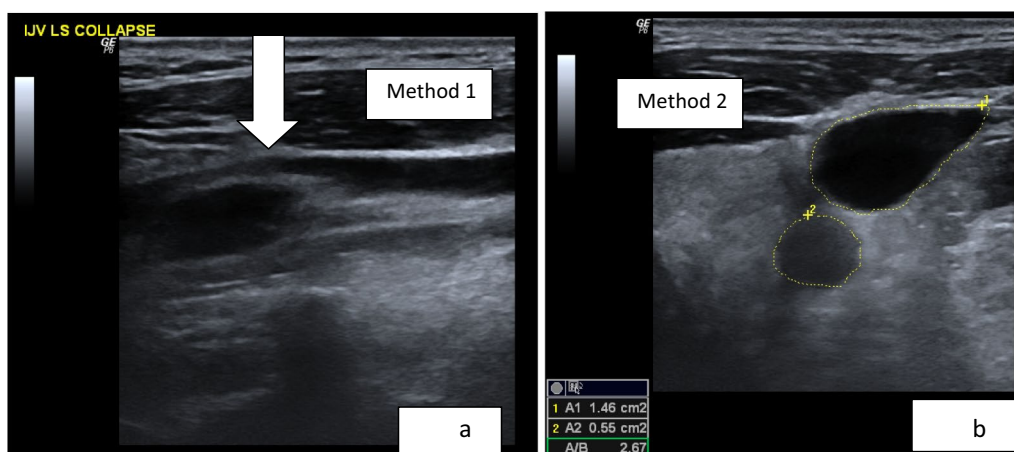**Fig. 4** Ultrasound images for A 49 years old female patient (**a**) a longitudinal ultrasound image for the collapsing point of the IJV (vertical white arrow) (method 1) and it was 7.6 cmH20 (**b**) transverse ultrasound image demonstrating the cross-sectional areas (marked as dotted yellow lines by manual tracers) of the IJV ($= 1.49$ cm^2) and the CCA area ($= 0.78$ cm^2) and the ratio ($= 1.92$) (method 2). The Invasive CVP measurement (by the catheter) was 7 cmH20

Fig. 5 Ultrasound images for a 54 years old male patient (**a**) a longitudinal ultrasound image for the collapsing point of the IJV (vertical white arrow) (method 1) and it was 13 cmH20 (**b**) transverse ultrasound image for the cross-sectional areas (marked as dotted yellow lines by manual tracers) of the IJV ($= 1.46$ cm2) and the CCA area ($= 0.55$ cm2) and the ratio ($= 2.67$) (method 2). The Invasive CVP measurement (by the catheter) was 15 cmH20

(Fig. 2b). The cut-off point of 8.65cmH20 was calculated for the prediction of CVP of ≥ 10cmH20.

Forty-seven patients had CVPni > 8.65cmH20, out of them 35 patients had CVPi $\geq$ 10cmH20 and 12 patients had CVPi < 10cmH20. Forty-six patients had CVPni < 8.65cmH20 and all of them had CVPi < 10cmH20 (Table 3).

For differentiating between patients with CVP < 10cmH20 and $\geq$ 10cmH20, method 1 had gained a sensitivity of 100%, a specificity of 79.31%, a positive predictive value of 74.47%, and a negative predictive value of 100% with an accuracy of 87.10% when compared to CVPi (Table 4).

For method 2
IJV area

The mean IJV cross-sectional area for patients with CVP < 10 cmH20 was 0.92 ± 0.31 cm^2 while it was 1.26 ± 0.37 cm^2 for patients with CVP $\geq$ 10 cmH20. There was a significant association between the IJV area and CVPi in both groups (p < 0.001).

Baz *et al. Egyptian Journal of Radiology and Nuclear Medicine*   (2021) 52:272

Page 6 of 10

Table 1 Showing no significant correlation between the patient sex, presence of DM, presence of HTN or the examined side, and between CVPi

Count	CVPi				P value
	< 10 cmH2O		> = 10 cmH2O		
	%	Count (%)	%	Count (%)	
Sex					
Male	34	54.8	24	54.5	0.976
Female	28	45.2	20	45.5	
HTN					
Yes	21	33.9	14	31.8	0.825
No	41	66.1	30	68.2	
DM					
Yes	20	32.3	15	34.1	0.843
No	42	67.7	29	65.9	
Side					
R	19	30.6	15	34.1	0.708
L	43	69.4	29	65.9	

HTN: hypertension; DM: diabetes mellitus; L: left side; R: right side

CCA area

The mean CCA cross-sectional area for patients with CVP < 10 cmH20 was 0.54 ± 0.16 cm2, while for patients with CVP $\geq$ 10 cmH20 it was 0.51 ± 0.13 cm^2. There was no significant association between the CCA cross-sectional area and CVPi (p = 0.222).

IJV/CCA cross-sectional area ratio

The mean IJV/CCA cross-sectional area ratio for patients with CVPi < 10 cmH20 was 1.69 ± 0.39, while for patients with CVPi $\geq$ 10 cmH20 it was 2.50 ± 0.58.

A highly significant positive correlation between the IJV/CCA cross-sectional area ratio and CVPi was existing in both groups (r = 0.832, 95%, n = 106, p < 0.001) (Table 5 & Fig. 3a).

The AUC for the ROC curve for predicting CVP $\geq$ 10cmH20 was 0.919 (95% CI: 0.865–0.973) (Fig. 3b). 1.935 was the calculated cut-off point for the prediction of CVP of $\geq$ 10cmH20.

Fifty patients had IJV/CCA cross-sectional area ratio > 1.935, out of them 41 had CVPi $\geq$ 10cmH20 and 9 had CVPi < 10cmH20. Fifty-six patients had IJV/CCA area ratio < 1.935, out of them 53 had CVPi < 10cmH20 and 3 had CVPi $\geq$ 10cmH20 (Table 6).

For the differentiation between patients with CVP < 10cmH20 and $\geq$ 10cmH20, method 2 had a sensitivity of 91.11%, a specificity of 85.48%, a positive predictive value of 82.00%, and a negative predictive value of 92.98% with an accuracy of 87.85% relative to CVPi (Table 7).

Combination of both methods

For differentiating between patients with CVP < 10cmH20 and $\geq$ 10cmH20, the combination of both methods (methods 1 and 2) had gained a sensitivity of 88.57%, a specificity of 89.66%, a positive predictive value of 83.78%, and a negative predictive value of 92.86% with an accuracy of 89.25% as compared to CVPi (Table 8).
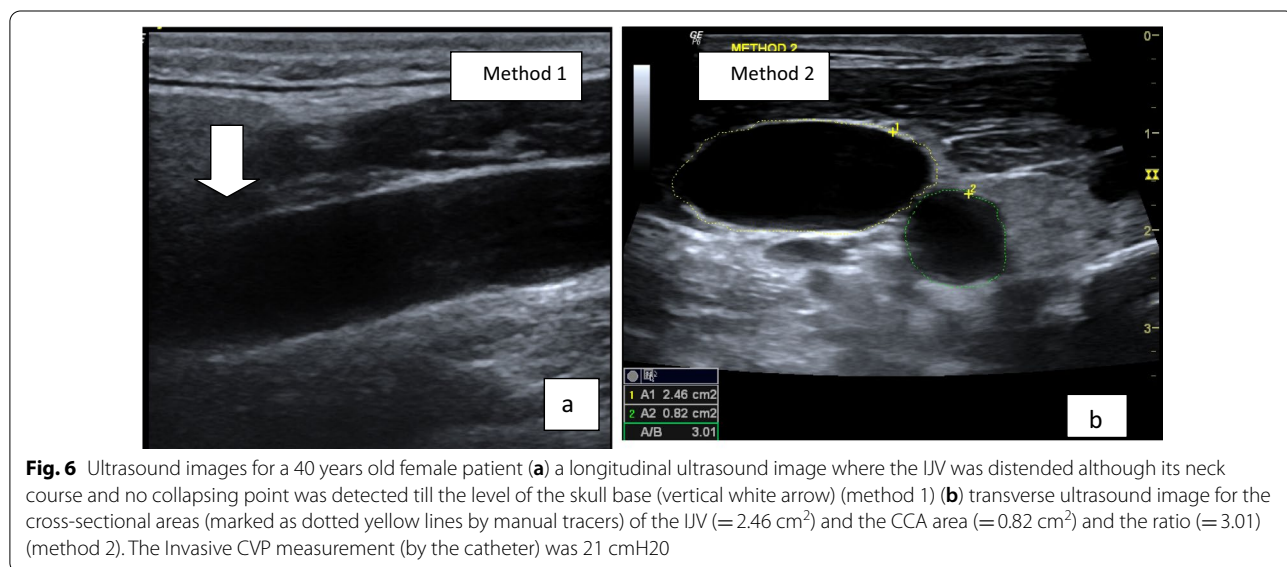

Fig. 6 Ultrasound images for a 40 years old female patient (**a**) a longitudinal ultrasound image where the IJV was distended although its neck course and no collapsing point was detected till the level of the skull base (vertical white arrow) (method 1) (**b**) transverse ultrasound image for the cross-sectional areas (marked as dotted yellow lines by manual tracers) of the IJV (= 2.46 cm^2) and the CCA area (= 0.82 cm^2) and the ratio (= 3.01) (method 2). The Invasive CVP measurement (by the catheter) was 21 cmH20
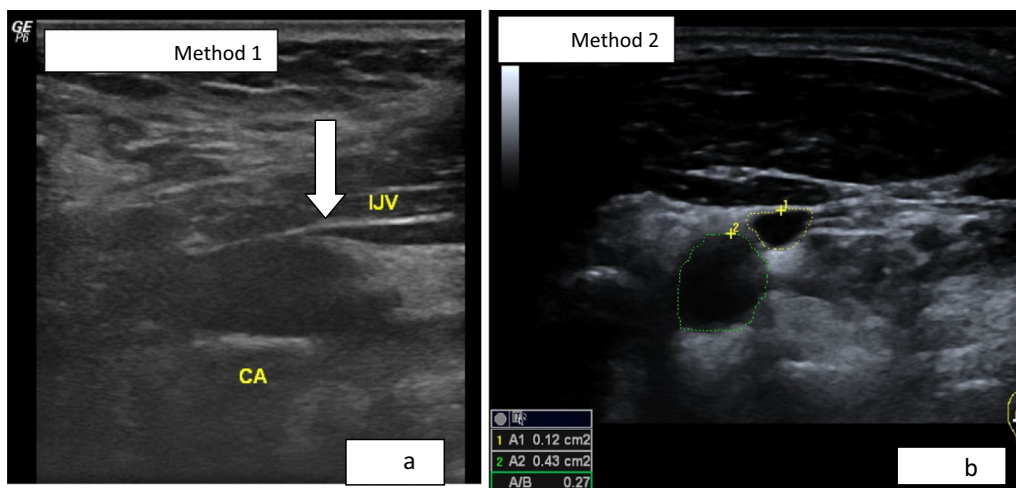
Fig. 7 Ultrasound images for a 56 years old male patient (**a**) a longitudinal ultrasound image for the collapsing point of the IJV (vertical white arrow) (method 1) where the IJV was collapsed all through its neck course with the collapsing point was almost detected at the level of the sternoclavicular joint (**b**) transverse ultrasound image demonstrating the cross-sectional areas (marked as dotted yellow lines by manual tracers) of the IJV ($=0.12$ cm^2) and the CCA area ($=0.43$ cm^2) and the ratio ($=0.27$) (method 2). The Invasive CVP measurement (by the catheter) was 2 cmH20

Table 2 Showing the correlation between (CVPni) and CVPi in method 1

		method 1
CVPi (cmH2O)	Pearson correlation	0.913
	P value	< 0.001
	N	93

Table 5 Showing the correlation between IJV/CCA area ratio and CVPi

		Ratio (method 2)
CVPi (cmH2O)	Pearson correlation	0.831
	P value	< 0.001
	N	106

Table 3 For classification by the cut-off value in method 1

		CVPi	
		> = 10 cmH2O	< 10 cmH2O
		Count	Count
method 1	> 8.65	35	12
	< 8.65	0	46

Table 6 For the classification by the cut-off value in method 2

		CVPi	
		> = 10 cmH2O	< 10 cmH2O
		Count	Count
Ratio (method 2)	> 1.935	41	9
	< 1.935	3	53

Table 4 Showing the accuracy measures of method 1

Statistic	Value	95% CI
Sensitivity	100.00%	90.00–100.00%
Specificity	79.31%	66.65–88.83%
Positive likelihood ratio	4.83	2.92–8.00
Negative likelihood ratio	0.00	
Positive predictive value	74.47%	63.80–82.84%
Negative predictive value	100.00%	
Accuracy	87.10%	78.55–93.15%

Table 7 Showing the accuracy measures in method 2

Statistic	Value	95% CI
Sensitivity	91.11%	78.78–97.52%
Specificity	85.48%	74.22–93.14%
Positive likelihood ratio	6.28	3.41–11.56
Negative likelihood ratio	0.10	0.04–0.27
Positive predictive value	82.00%	71.21–89.35%
Negative predictive value	92.98%	83.79–97.14%
Accuracy	87.85%	80.12–93.37%

Baz *et al. Egyptian Journal of Radiology and Nuclear Medicine* (2021) 52:272

Page 8 of 10

Table 8 showing the accuracy measures of the combination of both methods (1 and 2)

Statistic	Value	95% CI
Sensitivity	88.57%	73.26–96.80%
Specificity	89.66%	78.83–96.11%
Positive likelihood ratio	8.56	3.98–18.44
Negative likelihood ratio	0.13	0.05–0.32
Positive predictive value	83.78%	70.58–91.75%
Negative predictive value	92.86%	83.73–97.04%
Accuracy	89.25%	81.11–94.72%

Discussion

The hemodynamic monitoring in the dialyzing patients during the dialysis sessions necessitates the CVP measurement. This is used to be done by central catheters in the IJV. The invasive nature of this procedure, especially in patients who do not have an indwelling catheter has directed the researchers for finding a non-invasive substitute.

The IJV US could be used for assessing the CVP and it has offered a simple and reliable alternative for the catheter measurement.

In this context, we used the IJV US for the CVP measurement in two different methods based on the literature review, including the collapsing point (method 1) of the IJV and the cross-sectional area measurements for the IJV and the CCA (method 2).

For method 1; our results are consistent with the Kerleroux et al. study, which had exclusively enrolled the hemodialysis patients like those in our study, but their sample size was much smaller than ours (22 patients) and they had reported a significant correlation between CVPni and CVPi with P < 0.0001 [10].

Siva et al. had also reported a highly significant positive correlation between CVPni and CVPi ($\rho = 0.004$) in their study population (44 patients) using method 1 [11].

Congruence with Xing et al. was also present, where they had used the same principle (in method 1) as ours for CVPni measurement. However, they used echocardiography in their patients for more accurate detection of the right atrium center instead of using the five cm additive estimation [12]. Despite being a more accurate method, but it would significantly decrease the merit of being a simpler and less time-consuming procedure, consequently, it requires more training for the operator when compared to the other methods used in our study and Kerleroux et al., Siva et al. studies [10, 11]. Nonetheless, Xing et al. had also reported a similar significant positive correlation between CVPni and CVPi in both preoperative measurements ($r = 0.90$; $\rho < 0.01$) and in postoperative measurements ($r = 0.93$; $\rho < 0.01$) for their patients (118 patients) [12].

For method 2; our results are concordant with those of Hossein-Nejad et al. who performed their study on 52 non-ventilated patients and also reported a highly significant positive correlation between IJV/CCA cross-sectional area ratio and CVPi ($r = 0.728$, $p < 0.0001$ at inspiration, and $r = 0.736$, $p < 0.0001$ at expiration), while the AUC for the ROC curve was 0.882 for predicting patients with CVPi < 10cmH20. They calculated a cut-off point ($= 2$) for the prediction of CVP $\geq$ 10cmH20, and they found a significant correlation between the IJV area and CVPi with no significant correlation between CCA area and CVPi [13]; however, our sample size is almost double theirs.

Bailey et al. had also documented similar results to ours. They had concluded that the IJV/CCA cross-sectional ratio could predict the value of CVP. Their preliminary results suggested that if the IJV/CCA cross-sectional area ratio was at least 2, then the CVP seemed to be $\geq$ 8 mmHg which is nearly close to 10 cmH20 ($\rho < 0.001$). It was a pilot study that was conducted in the pediatric burn population with a small sample size including only six patients [14].

Bano and Canuad had performed their study on 49 ventilated and non-ventilated patients. However, they measured IJV/CCA diameter ratio instead of cross-sectional area ratio and found a significant positive correlation between IJV/CCA diameter ratio and CVPi in only non-ventilated patients at end-expiration ($r = 0.439$, $n = 24$, $\rho = 0.032$), and calculated a cuff-off (IJV/CCA) diameter ratio ($= 1.75$) for predicting CVP $\geq$ 10 cm H20 [15], which is matching with our results. However, they found no significant correlation between the IJV/CCA diameter ratio and CVP in non-ventilated patients at inspiration ($r = 0.308$, $n = 24$, $p = 0.143$) and in ventilated patients at both inspiration and expiration ($r = 0.343$, $n = 25$, $p = 0.094$ and $r = 0.346$, $n = 25$, $p = 0.094$, respectively). Our study was performed on non-ventilated patients and all our measurements were taken at end-expiration, so our results are concordant with theirs regarding their sub-group of non-ventilated patients who were being examined at end-expiration.

Donahue et al. had utilized only the IJV diameter and IJV cross-sectional areas in both supine and 35° reverse Trendelenburg positions at both end-inspiration and end-expiration. They depicted a significant difference in IJV diameter in patients with a CVP < 10 or $\geq$ 10 cm H2O and a significant positive correlation was present between the IJV end-expiratory diameter and CVP ($r = 0.82$) in the supine position [16]. Their results are in line with ours as we also had found a significant correlation between the IJV area and CVPi ($\rho < 0.001$).

A contradiction with the results of Elsadek et al. who had performed their study on smaller sample size (16 pediatrics patients) and had detected a poor correlation between IJV diameter or IJV area and the volume status (as predicted by left ventricular end-diastolic area) (LVEDA) [17]. However, the smaller sample size, the different age groups, and most importantly the use of LVEDA as a predictor of volume status instead of CVPi are all considered as probable causes for this contradiction.

Comparison and combination of both methods were then performed in terms of novelty; to our knowledge, our study was the first one to include and compare these two methods. Both methods show overall comparable accuracy for differentiation of patients with CVPi < 10cmH20 and ≥ 10cmH20 (87.10% for method 1 and 87.85% for method 2). Upon using both methods together for the same patient we had achieved a higher accuracy level approaching 89.25% which is better than using either method 1 or method 2 that had an accuracy of 87.10% and 87.85%, respectively. Thus, we propose the application of both methods together is recommended to improve the confidence in the acquired measurements; moreover, the experience with both methods could be beneficial when one of the two methods is not applicable or feasible for use in one patient.

It worth mentioning that one of the strengths of this study is the homogeneity of the studied sample (Non-ventilated adult hemodialysis patients) but on the other hand, it is considered one of its limitations as it is not applicable for ventilated patients.

Some additional limitations were met in this work including.

For Method 1, its limitation was the inability to measure the extremes of CVP as no collapse point for the IJV was detected along its neck course. In our study, the exact measurements of CVPni could not be obtained in nine patients with very high CVPi (mean CVP for these 9 patients was 19.278 cmH20) as the IJV was distended all-through its neck course, moreover, the measurements were not feasible in another four patients who had a low CVPi (mean CVP for these 4 patients was 2.25cmH20) as the IJV was collapsed all-through its neck course. Nevertheless, this limitation is of little clinical importance because it could still detect if the CVP is low (below 5cmH20) or very high.

For Method 2, it only gives an estimate and not a direct reading of the CVP, however, in agreement with other studies [13, 15, 16]; we found that method 2 was able to accurately differentiate between CVPi < 10cmH20 and ≥ 10cmH20, and this is considered as an important issue during resuscitation of the critically ill patients. Further studies on larger samples are recommended to find out IJV/CCA cross-sectional area ratios that are well correlated with the exact CVPi values.

Finally, we recommend (from our experience) US measurement of CVP as the first method of choice in patients with a dialysis arteriovenous fistula, to avoid insertion of central venous catheters that could carry a risk of central venous thrombosis and deprives the patient of future central access by either Mahurkar or Permacath in case of a dysfunctional fistula.

Conclusion

The US of the IJV had offered a simple, feasible, cheap, reliable, and non-invasive technique that could be used for repeated monitoring of the CVP. The present study has a novelty of combining more than one US method and it had reported a higher accuracy of the acquired measurements as compared to the use of a single US method.

Declarations

Ethics approval and consent to participate
The protocol was reviewed and approved by the local ethics committee of the radiology department, Kasr Alainy hospital, Cairo University. The reference number: Code Ms-80–2020, Date of approval 16–08-2020. All patients had given their written consents to participate in this work.

Consent for publication
All patients had given their written consents for publication of this work.

Competing interests
All authors had no competing interests.

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Baz *et al. Egyptian Journal of Radiology and Nuclear Medicine*   (2021) 52:272

Page 10 of 10

References

1. Sarnak MJ, Levey AS, Schoolwerth AC et al (2003) Kidney disease as a risk factor for the development of the cardiovascular disease: a statement from the American Heart Association Councils on Kidney in Cardiovascular Disease, High Blood Pressure Research, Clinical Cardiology, and Epidemiology and Prevention. Hypertension 42:1050–1065
2. Bikbov B, Purcell CA, Levey AS et al (2020) Global, regional, and national burden of chronic kidney disease, 1990–2017: a systematic analysis for the Global Burden of Disease S. The Lancet 395(10225):709–733
3. Henderson LW (2012) Symptomatic intra-dialytic hypotension and mortality: an opinionated review. In: Seminars in dialysis Oxford, UK: Blackwell Publishing Ltd; 25(3) 320-325
4. Burton JO, Jefferies HJ, Selby NM et al (2009) Hemodialysis-induced repetitive myocardial injury results in a global and segmental reduction in systolic cardiac function. Clin J Am Soc Nephrol 4(12):1925–1931
5. Sinha AD, Agarwal R (2009) Opinion: can chronic volume overload be recognized and prevented in hemodialysis patients? The Pitfalls of the clinical examination in assessing volume status. In: Seminars in dialysis Oxford, UK: Blackwell Publishing Ltd.; 22(5) 480–482
6. Thalhammer C, Segerer S, Augustoni M et al (2015) Acute effects of hemodialysis on central venous and arterial pressure characteristics. Nephrology 20(2):91–95
7. Eisen LA, Narasimhan M, Berger JS et al (2006) Mechanical complications of central venous catheters. J Intensive Care Med 21(1):40–46
8. Stenberg J, Lindberg M, Furuland H (2016) Clinical praxis for assessment of dry weight in Sweden and Denmark: a mixed-methods study. Hemodial Int 20(1):111–119
9. Thijssen S, Kappel F, Kotanko P (2013) The absolute blood volume in hemodialysis patients: why is it relevant, and how to measure it. Blood Purif 35(1–3):63–71
10. Kerleroux B, Pasco J, Dupuis M et al (2018) Ultrasonographic assessment of the internal jugular vein for the estimation of central venous pressure in hemodialysis patients: a preliminary study. J Clin Ultrasound 46(4):253–258
11. Siva B, Hunt A, Boudville N (2012) The sensitivity and specificity of ultrasound estimation of central venous pressure using the internal jugular vein. J Crit Care 27(3):315-e7
12. Xing, C. Y., Liu, Y. L., Zhao, M. L., et al. (2015). A new method for noninvasive quantification of central venous pressure by ultrasound. Circulation: Cardiovascular Imaging, 8(5), e003085.
13. Hossein-Nejad H, Mohammadinejad P, Ahmadi F (2016) Internal jugular vein/common carotid artery cross-sectional area ratio and central venous pressure. J Clin Ultrasound 44(5):312–318
14. Bailey JK, McCall J, Smith S et al (2012) Correlation of internal jugular vein/common carotid artery ratio to central venous pressure: a pilot study in pediatric burn patients. J Burn Care Res 33(1):89–92
15. Bano S, Qadeer A, Akhtar A (2018) Measurement of the internal jugular vein and common carotid artery diameter ratio by ultrasound to estimate central venous pressure. Cureus 10(3)
16. Donahue SP, Wood JP, Patel BM et al (2009) Correlation of sonographic measurements of the internal jugular vein with central venous pressure. Am J Emerg Med 27(7):851–855
17. Elsadek WM, Elaela AHA, Nassar HM et al (2017) Sonographic evaluation of internal jugular vein diameter and cross-sectional area measurements in correlation with left ventricular end-diastolic area as a tool for preoperative assessment of volume status in pediatric patients undergoing cardiac surgery. Anesth Essays Res 11(2):453

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