Could internal jugular vein ultrasound be useful in the assessment of patients with heart failure? A systematic review

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ABSTRACT

Many recent studies have validated the internal jugular vein ultrasound (IJV-US) for estimating volemic status in critical patients. If research confirms its accuracy in detecting intravascular volume, congestion, and prognosis, this method could help manage heart failure (HF) because it is simple, fast, and applicable in several settings. This review examines the IJV-US's reliability, diagnostic accuracy, and ability to predict poor outcomes for HF, as well as its correlation with surrogate congestion tests like natriuretic peptides and elevated central venous pressure (CVP). Our systematic review followed the PRISMA statement for systematic reviews and meta-analyses. Eleven studies examined the reliability and validity of IJV-US measures in predicting congestion, volume status, and prognosis in adult spontaneously breathing HF patients. We searched PubMed, Cochrane Library, and EMBASE. IJV-US measurements using Valsalva and sniffing seem more accurate for predicting congestion, volume status, high CVP, and poor prognosis. The IJV ratio in chronic HF and out-hospital patients and the absence of IJV area [cross-sectional area (CSA)] changes in acute HF (AHF) and in-hospital patients are the most validated measurements. No evidence suggests the method is reliable between and within raters. AHF patients' IJV ratio and CSA absence appear to correlate with CVP and atrial natriuretic peptides. In conclusion, the IJV-US may be useful for managing HF patients, but more research is needed to confirm its reliability and prognostic accuracy. Develop a standard US protocol lastly.

Introduction

Clinical identification of patients with heart failure (HF) and congestion remains challenging even for experienced physicians: symptoms and signs are late manifestations of congestion and are neither sensitive nor specific.[1,2]

For these reasons, the ultrasound assessment of volume status could be a useful tool to assess these patients and inferior vena cava (IVC) ultrasound has been proposed as a feasible measure of congestion in HF patients.[3] This method has several limits: i) it is often not executable for habitus or surgery wounds; ii) probably it is not reliable; iii) it could be influenced by the abdominal pressure.

Therefore, in the last years, many studies tested other ultrasound measures as surrogates of Intravascular volume status and central venous pressure (CVP).

In this context, the ultrasound of the internal jugular vein (IJV) is emerging as a valid alternative to IVC ultrasound.[4-7]

The method to detect IJV and to obtain its measurements by using ultrasound is shown in the *Supplementary Material*.

The following ultrasound measures of IJV have been tested:[8-18] antero-posterior, end-expiratory IJV diameter (AP-IJV Dmax); the end-expiratory IJV area [maximal area in transversal section, cross-sectional area (CSA)] and its change before and after Valsalva maneuver; the ratio between the maximal diameter during the Valsalva maneuver to that at rest (at the end of the expiratory phase), the jugular vein diameter (JVD) ratio; the collapsibility index of IJV: the respiratory variation percentage calculated as [(maximum diameter e minimum diameter)/maximum diameter] and the antero-posterior diameter collapsibility after "sniff" maneuver; the IJV meniscal levels identified using the transverse and longitudinal views with the patient at end-expiration, IJV meniscus.

If research supports the accuracy of IJV-US in detecting intravascular volume, congestion, and prognosis, this method could have a fundamental role in the assessment of patients with HF.

In particular, it could confirm the HF diagnosis, evaluate of risk for poor outcomes during hospitalization or in ambulatory settings, and guide the diuretic therapy.

To our knowledge, there are few reviews on the role of the ultrasound of IJV in the assessment of patients with HF.[5,7] Furthermore, there are no reviews on its reliability and validity in predicting the prognosis among HF patients.

It could be interesting to check if the findings of published reports on the validity and correlation with the reference standards for the diagnosis of congestion of ultrasound measures of IJV are divergent. For these reasons, we decided to conduct this systematic review.

Primary objectives

To evaluate the IJV-US diagnostic accuracy for diagnosis of HF and its effectiveness in predicting poor outcomes in these patients and to evaluate the reliability of the IJV-US method.

Secondary objectives

To evaluate the IJV-US measures correlation with surrogate tests of congestion: the natriuretic peptides and elevated CVP value and to evaluate the quality of included studies.

Questions behind the review

1) Which internal jugular ultrasound measurement is best to predict the congestion, volume status, and poor prognosis among HF patients?
2) What is the internal jugular ultrasound method's level of reliability?
3) Is there a correlation between the Internal Jugular ultrasound measurements and CVP or atrial natriuretic peptides?
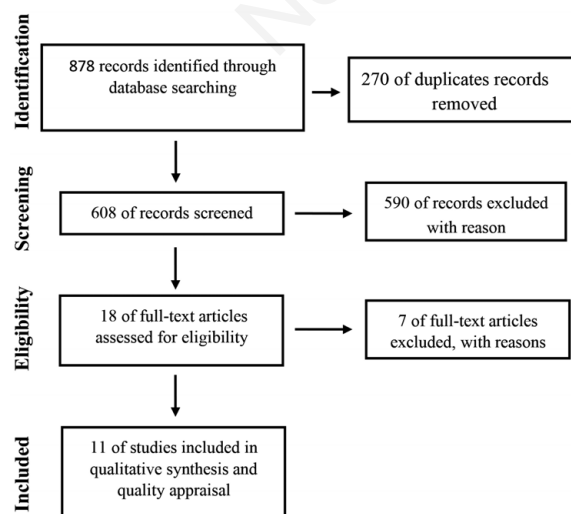4) How is the quality of reporting and methodology of studies selected?

Figure 1. Review of the selection process.

Methods

Design

This systematic review was conducted according to the PRISMA statement for reporting systematic reviews and meta-analyses.[19] The flow diagram in Figure 1 schematically shows each step of the review process.

Eligibility criteria

Studies in English that investigated the reliability and/or the validity of the IJV-US measures in predicting congestion and volume status and/or prognosis in adult spontaneously breathing patients with HF; reports on the correlation between the IJV-US measures and the CVP or natriuretic peptides.

Data extraction and search strategy

A broad search of the literature was initially performed by an expert in literature searching using PubMed, Cochrane Library, and EMBASE. All the articles available, starting from the year 1965 until the 18th of March 2024 were considered. A total of 878 records were retrieved (Figure 1).

Three researchers independently and in a blinded manner reviewed the three lists from the literature database and, by the records' title and abstract inspection, removed duplicates and reports that they did not consider relevant to the aims of the review.

After the review selection process, 11 studies met the inclusion criteria for the systematic review, exploring the aims of the review (Figure 1). The reasons for exclusion were justified in each phase of the selection.

We also searched for other studies that could be included by checking the references list of the eleven papers included,[8-18] and the three reviews excluded.[5-7]

An appraisal of the reporting quality of the studies selected for the analysis was independently conducted by three authors using the Quality Assessment of Diagnostic Accuracy Studies, (QUADAS) 2 guidelines.[20]

A narrative summary was used to synthesize the data to provide a narrative description and order the evidence with commentary and interpretation.

The three reviewers' yes/no level of agreement for each study was entered into an Excel 2010 (Microsoft Corporation) spreadsheet, and Fleiss' kappa for an observed agreement was performed. We obtained a Fleiss' kappa score of k=0.78, equating to a high level of agreement between the raters.

Inclusion criteria were clinical trials that tested the following measures: i) the reliability of IJV-US measures; ii) the validity of IJV-US measures in predicting congestion; iii) the validity of IJV-US measures in predicting prognosis (poor outcome: mortality and/or re-admission); iv) the IJV-US measures' correlation with the CVP or natriuretic peptides in spontaneously breathing patients. We included studies conducted on all ages of adult patients (>18 years) in the English language.

Statistics and outcome measures

Reliability coefficients were extracted from articles: inter-rater and intra-rater reliability, kappa coefficient (weighted and un-weighted), intra-class correlation coefficient, Pearson

correlation coefficient, and Spearman's rank correlation co-efficient.

The IJV-US diagnostic accuracy for HF and congestion in HF patients should be tested by the validity of IJV-US measures in predicting HF and elevated value of CVP.

The prediction measured by AUC (ROC curve), is the ability of the test (IJV-US) to correctly classify those with and without the HF and those with and without elevated CVP value.

Accuracy indexes were extracted from articles as below: accuracy, sensitivity, specificity measure; ROC curves with areas under the ROC curves (AUCs).

IJV effectiveness in predicting poor outcomes, mortality and re-admission, among patients with HF should be tested as a relative risk, odds ratio, and likelihood ratio.

We considered correlation indexes for the following: linear regression; Pearson or Spearman's rank correlation coefficients. Correlation is a statistical technique that can show whether and how strongly pairs of continuous variables (*i.e.*, IJV-US diameters or natriuretic peptides values and CVP value) are related.

Results

A total of eleven studies have been included with 1,818 patients. Seven full-text papers have been excluded for reasons. Characteristics of the included studies are listed in Table 1.

The index test was measured using: antero-posterior IJV end-expiratory diameter (AP-IJV max) in three studies, IJV ratio in four studies, IJV meniscus in two studies, IJV-area in two, IJV collapsibility index in two studies.

The quality of studies was moderate-low: many reports had an unknown risk of bias in the reference and flow and timing items according to QUADAS-2 guidelines (Table 2).

The patient population is quite homogenous: 556 out-hospital patients with chronic HF included, 989 in-hospital patients with acute HF (AHF), and 273 patients with advanced HF.

Diagnostic accuracy for diagnosis and prognosis of HF of IJV-US and its reliability are shown in Table 3.

In two studies,[8,9] the vertical height of the IJV meniscus obtained by using either the transverse or longitudinal US views and by measuring from sternal notch with 5 cm added, greater than or equal to 8 cm H20 could be valid in predicting HF diagnosis based on chest X-ray or echocardiography.

Although it is difficult to compare findings from studies that used different outcomes to test HF prognosis (death at 30 and/or 90 days and/or 1.5 years; all causes of death *vs.* death for HF), probably a IJV ratio lower than 2 could predict death and re-hospitalization for HF in short and long follow-up in both out-hospital settings and in patients with advanced HF.[11,12,17]

The absence of changes in the AP-IJV diameter and the IJV area (CSA), during the Valsalva maneuver and sniffing, could be related to a high CVP in patients with AHF and advanced HF.[13,16,17]

Albaeni *et al.* suggested that a 3-point score based on ultrasound of IVC maximum diameter, IVC collapsibility index (the variation, during respiratory cycle, of the dimensions of IVC in B mode), IJV collapsibility index, IJV-c (the variation, during respiratory cycle, of the antero-posterior diameter of

IJV in B mode) could predict high CVP in HF patients but both measurements seem to have low sensitivity and high specificity.[18] Furthermore, in the same study, patients with low IJV-c had a high risk of high CVP: odds ratio =8, P<0.001.

Patients with AHF and no change in the area of IJV or low IJV ratio could have high natriuretic peptides.[10,15]

There is little data on the IJV-US reliability. Only two studies tested, as secondary outcomes, inter-rater and intra-rater reliability of the IJV ratio and the IJV area.[10,13]

Discussion

The studies included in this review suggest that the IJV-US could be a useful method to predict congestion and poor outcomes in short and long follow-ups among chronic and acute patients with HF. However, further research should confirm IJV-US reliability before using it in clinical practice.

Which internal jugular ultrasound measurement is best to predict the congestion, volume status, and poor prognosis among heart failure patients?

Internal jugular ultrasound measurements obtained by using dynamic maneuvers such as Valsalva and sniffing seem more valid to predict congestion, volume status, high CVP, and poor prognosis. The most validated measurements are the IJV ratio, in chronic HF and out-hospital patients and the absence of changes in the IJV area (CSA) in AHF and in-hospital patients.

What is the internal jugular ultrasound method's level of reliability?

There is no evidence that the method has a good inter-rater and intra-rater reliability.

Is there a correlation between the internal jugular ultrasound measurements and central venous pressure or atrial natriuretic peptides?

In patients with AHF, some measures appear to correlate with CVP and atrial natriuretic peptides: IJV ratio and the absence of changes in the IJV area (CSA).

How is the quality of reporting and methodology of studies selected?

We found a moderate quality among the papers collected.

The role of point-of-care ultrasonography (POCUS) in patients with HF and suspected volume overload has been extensively studied. Many reports suggest that the lung ultrasound is superior to chest X-ray and clinical signs for diagnosing congestive HF.[21]

Table 1. Characteristics of studies on internal jugular vein ultrasound measures.

Author	Study design	Target population/setting	US measures/protocol	Outcome	Results	Conclusions
Pellicori et al., 2019 UK	Prospective observational	342 Chronic HF outpatient	*IJV ratio at 45°, at left side Valsalva IVC max,min IVC-c B lines 28 zones LVEF; TAPSE; septal E/e'	Re-hospitalization or death at 90 days	In a multivariable analysis, if IJV ratio <4: HR 2.64 (95% CI, 1.03-6.79) for outcome	IJV ratio <4, IVC>20mm, B line≥14 suggest a greater risk of adverse outcome regardles LVEF Correlation amongst US measures and NT-proBNP modest
Pellicori et al., 2015 UK	Prospective observational	311 chronic HF outpatient	IJV ratio 45°, left side Valsalva IVC max,min IVC-c B lines 28 zones LVEF; TAPSE	All cause death and HF hospitalization at 1.5 years inter-rater reliability	IJV ratio valid in predicting outcomes at 1 yr (AUC=0.72) Lower IJV ratio (2.3) had a HR=10.05 (95% CI, 3.07 to 32.93) of outcomes CV for IJV ratio by two operators=9.9%; intraclass correlation coeffic =0.95 CV between M-mode and 2D=5.3%	US of IJV identifies congestion and HF patients at risk of death and hospitalization
Pellicori et al., 2014 UK	Prospective observational	211 chronic HF outpatient	IJV ratio 45°, left side Valsalva LVEF; TAPSE	Comparison of US-IJV measures and pro-BNP between control and HF patients Correlation between US-IJV measures and pro-BNP inter-rater reproducibility	IJV ratio inversely correlates with pro-BNP (r=-0.39, P=0.001) Increasing IJV diameter at rest and during deep inspiration correlates with increasing proBNP (r=0.37 and r=0.34 respectively)	Resting and minimum IJV diameter is greater in HF patients and increases with higher concentrations of pro-BNP and with other measures of congestion. IJV ratio is associated with measures of diastolic function and RV dysfunction
TzadoK et al., 2018 Israel	Prospective Observational	59 AHF patient	AP-IJV size and area at 60°, supraclavear area; cross-sectional view, respiratory change	Correlation of change in IJV area to BNP levels	A cut-off of BNP>100pg/ml showed Spec.=0,69; Sens=0.7 for AHF 84% of patient with BNP >300pg/ml had no change of IJV area	This study shows that ultrasound of the IJV may be a useful tool for the diagnosis of ADHF
Jang et al., 2011 USA	Obs prospective	119 pat. With acute dyspnea in ED	Meniscus of IJV at end expiration chest x-ray as gold standard for Pulmonary oedema (POe)	IJV meniscus accuracy in predicting POe	IJV meniscus ≥8 cm H2O has a: Sens 98% (95% CI, 82-99) Spec 43% to predict outcome LR – (Meniscus <8cm)=0.04 LR + (Meniscus <8cm)=1.7	US-JVD is a sensitive test for identifying pulmonary oedema on chest x-ray in dyspnoeic patients with suspected HF
Vaidya et al., 2021 India	Obs prospective	72 pat. Waiting for heart transplant or left ventricular assist device	AP-IJV max at end expiration; AP-IJV min(inspir.); AP-IJV collapsibility; AP-IJV after sniff at 0°, right RAP by right heart catheterization	IJV US measures' accuracy in predicting RA pressure	Accuracy in predict RA pressure >10mmHg: AP-Max ≥1 cm: AUC=0.66 No IJV collapsibility with sniff: AUC=0.75 AP-IJV max ≥1cm cm +no collapsib.: AUC=0.7 AP-IJV max ≥1cm cm + <50% variation on respiration: AUC=0.69	The IJV diameters are reliable and easier alternatives in bedside estimation of RA pressure.
Simon et al., 2010 USA	Obs prospective	67 pat AHF in-hospital	Change of IJV CSA at end-expiration and after Valsalva; supine at right side RAP	IJV CSA change after Valsalva accuracy in predicting RAP intra and inter observer variability (20 images between 2 raters)	A IJV CSA change after Valsalva >17% predicts low RAP (<12mmHg): NPV=94%, PPV=60% A IJV CSA change after Valsalva ≤17% predicts high RAP (>12mmHg): AUC=0.86 (95% CI, 0.75-0.97; P<0.001) intra-reability: ICC=0.88; k=1 inter-rebility: ICC=0.88, k=0.9	IJV CSA change after Valsalva appears capable of reliably ruling out elevated RAP This approach could help guide therapy and potentially reduce the need for invasive pressure measurement and it could be used to assess response to treatment

Table 1. Continued from previous page.

Author	Study design	Target population/setting	US measures/protocol	Outcome	Results	Conclusions
Simon et al., 2018 USA	Obs prospective	137 pat AHF in-hospital	Change of IJV CSA at end-expiration and after Valsalva at admission and discharge; supine (45°) at right side RAP	IJV CSA change after Valsalva accuracy in predicting RAP and 30-day readmission	A IJV CSA change after Valsalva <66% predicts high RAP (>12mmHg): AUC=0.79 (95% CI, 0.68-0.90; $P<0.05$) with Sens=77%, Spec=75%, PPV=87%, NPV=60%, regardless their LVEF. Pat. with IJV CSA after Valsalva at discharge larger than at admission (CSA ≥66%) have low risk of 30-day readmission (NPV=91%; $P<0.05$); Pat. with IJV CSA after Valsalva at discharge smaller than at admission (CSA <66%) have high risk of 30-day readmission (HR=5.2) regardless age, sex, atrial peptides	This bedside ultrasound technique strongly correlates to invasive RAP measurement in ADHF patients, identifies restoration of euvolemia, and is predictive of 30-day ADHF readmission. This tool could help guide inpatient ADHF treatment and may lead to reduced readmissions
Jang et al., 2011 Amer J Em Med	Obs retrospective	102 pat. With acute dyspnea in ED	Meniscus of IJV at end expiration Cardiac-ECHO (C-ECHO) gold standard for POe	IJV meniscus accuracy in predicting Poe	Accuracy for HF diagnosis by C-ECHO with IJV meniscus ≥8 cm H2O: Sens 99% (95% CI, 92-100) Spec 59% (95% CI, 41-74) LR – (Meniscus <8cm)=0.01 LR + (Meniscus <8cm)=2.4	This study suggests that JVD-US by EPs is predictive of CHF using echocardiography performed by the department of cardiology as the criterion standard
Albaeni et al., 2022	Obs prospective	124 AHF in-hospital	AP-IJV max ^IJV collapsibility (IJV-c) §IVC collapsib (IVC-c) IVC max	Accuracy in predicting CVP based on IVC-max, IJV-c, IVC-c Risk of high CVP of the model	IVC-max >21mm with negative IJV-c and IVC-c predict high CVP (AUC=0.84, 95% CI, 0.77-0.92) In multivariate analyses: IVC-max >21mm had OR=3.2 (P 0.06) IVC-c <50% had OR=3 ($P<0.03$) IJV-c had OR=8 ($P<0.001$)	A 3-point score, based on Ultrasound of IVC-max, IJV-c, IVC-c could predict high CVP in HF patients but it seems to have low sensitivity and high specificity
Ammirati et al., 2024 Italy	Obs prospective	201 Chronic HF with EF <50%	IJV ratio RAP right heart catheterization	Accuracy in predicting CVP Risk of death or heart transplant	IJV ratio threshold 1,6 has AUC=0.74 (95%, CI=0.64-0.84) in predicting high(>7mmHg) or low (<7mmHg) RAP IJV ratio <1.6 predicts death, heart transplant or LV assist device (log rank p)	Ultrasound-assessed IJV distensibility identifies patients with chronic advanced HF with normal CVP and better outcomes

US, ultrasound; UK, United Kingdom; IJV, internal jugular vein; IVC, inferior vena cava; LVEF, left ventricular ejection fraction; TAPSE, tricuspid annular plane excursion; HR, hazard ratio; CI, confidence interval; NT-proBNP, N-terminal pro-brain natriuretic peptide; HF, heart failure; AUC, aurea under the curve; CV, coefficient of variation; RV, right ventricular; AHF, acute heart failure; ADHF, acute decompensated heart failure; ED, emergency department; Poe, pulmonary oedema; JVD, jugular vein diameter; AP, antero-posterior; RAP, right atrial pressure; CSA, cross sectional area; NPV, negative predictive value; C-ECHO, cardiac echo; LR, likelihood ratio; EPs, electrophysiology; CVP, central venous pressure; OR, odds ratio; EF, ejection fraction; k, kappa; ICC, intra-class correlation coefficient; AP-IJV max, antero-posterior maximum diameter; IJV-c, collapsibility index in B Mode; CSA-IJV max, maximum area of internal jugular vein; IVC-c= inferior vena cava collapsibility index. *IJV ratio, IJV maximum diameter during Valsalva/IJV maximum diameter rest in expiratory phase; ^ IJV-c, collapsibility index is the variation, during respiratory cycle, of the antero-posterior diameter of IJV in B Mode; § IVC-c, inferior vena cava collapsibility index, is the variation, during respiratory cycle, of the dimensions of IVC in B mode.

Table 2. Results of quality assessment of diagnostic accuracy studies 2.

Study	Risk of bias				Applicability concerns		
	Patient selection	Index test	Reference standard	Flow and timing	Patient selection	Index test	Reference standard
Pellicori *et al.*, 2019	Yes	Yes	?	?	Yes	Yes	No
Pellicori *et al.*, 2015	No	Yes	?	?	Yes	Yes	Yes
Pellicori *et al.*, 2014	No	?	?	?	Yes	Yes	Yes
Tzadok *et al.*, 2018	Yes	?	?	?	Yes	Yes	Yes
Jang *et al.*, 2011	Yes	Yes	?	?	Yes	No	?
Vaidya *et al.*, 2021	Yes	?	?	Yes	?	Yes	Yes
Ammirati *et al.*, 2024	Yes	Yes	Yes	?	Yes	Yes	Yes
Simon *et al.*, 2010	?	Yes	Yes	?	Yes	Yes	Yes
Simon *et al.*, 2018	Yes	Yes	Yes	?	Yes	Yes	Yes
Albaeni *et al.*, 2022	Yes	Yes	Yes	No	No	Yes	No
Jang *et al.*, 2011	?	Yes	?	No	Yes	Yes	No

Yes, low risk; No, high risk; ? unknown risk.

Table 3. Comparison of internal jugular vein ultrasound measures effectiveness in patients with heart failure.

	IJV meniscus ≥8 cm	IJV expirat (max)	IJV sniff	CSA-IJV change (%) after Valsalva	IJV ratio
Reliability				[10]Intra ICC=0.9 (Spearman) [10]Intra ICC=0.88 [10]Inter:0.97 (Spearm) [10]Inter ICC=0.88	[7]Good intra mean diff =0.4 [7]Good inter mean diff=0.22
Validity in predicting heart failure diagnosis*	[5]Accuracy respect CXR: Sens: 98% (95% CI, 89-99) Spec:43% (95% CI, 31-56) LR +=1.7 (95% CI, 1.4-2.1) [6]Accuracy respect C-ECHO: Sens:99% (95% CI, 92-100) Spec=59% (95% CI, 41-74) LR +=2.4 (95% CI, 2-4)				
Validity in predicting prognosis**		[8]HR=7,6 (95% CI, 2.65-21.58) [8]AUC=0.77	[8]HR=7.9 (95% CI, 2.6-24.5) [8]AUC=0.77	[11]HR=5.2	[8]AUC=0.72 for IJV ratio=4 [8]HR=10 for IJV ratio <2.3 [9]HR=2.6 for IJV ratio <4 [9]AUC=0.76 [18]IJV ratio ≤1.6 predicts death (log-rank P=0.03)
Validity in predicting CVP		[13]IJV Max ≥1 cm has AUC=0.7 for CVP>10mmHG	[13]AUC=0.8 for CVP >10mmHG	[11]A CSA change <66% predicts RAP >12 mmHg (AUC=0.8) [10]A CSA change >17% predicts low CVP (<12mmHg): NPV=94% [10]A CSA change <17% predicts high CVP: AUC=0.9 (95% CI, 0.75-0.97)	[18]AUC=0.74 for CVP ≥7 mmHg with IJV ratio=1.6 [19]AUC= 0.84 for CVP ≥10 mmHg with 3-point US score (IVC >21mm+IJV-c <50%+IVC-c<50%)
Correlation with atrial peptides	[7]r=0.37	[7]r=0.34		[7]r=-0.39	

*Diagnosis of heart failure has been based on clinical criteria according to a group of experts; **prognosis was based on mortality and hospitalization for heart failure; CSA-IJV change was the percentage of the IJV area changes after a Valsalva maneuver, IJV ratio, IJV after Valsalva/IJV max at rest; ^IJV-c, collapsibility index is the variation, during respiratory cycle, of the antero-posterior diameter of IJV in B Mode; § IVC-c, inferior vena cava collapsibility index, is the variation, during respiratory cycle, of the dimensions of IVC in B mode. HF, heart failure; CVP, central venous pressure; IJV, internal jugular vein; CSA-IJV, internal jugular vein area; CxR, chest X-ray; CI, confidence interval; LR, likelihood ratio; NPV, negative predictive value; Sens, sensitivity; HR, hazard ratio; AUC, area under curve; ICC, intra-class correlation coefficient; r, correlation coefficient.

In this context, IJV-US may be considered an adjunctive tool to lung ultrasound when performing POCUS for suspected congestion.

Volume overload should be related to congestion and venous pressures and these findings often anticipate symptoms and signs of HF. So, an early detection of elevated venous pressure could be fundamental to intensify treatment before symptoms and signs worsen.

The data of this and previous reviews suggest that, in case of congestion and high CVP, the internal JVDs should be increased as well as the dimension of the veins. Furthermore, the IJV respiratory excursions should be decreased.[5,7]

Naturally, we should be cautious in interpreting the IJV-US measures in some clinical contexts: for example in patients with cor pulmonale, pulmonary embolism or cardiac tamponade, because a high IJV diameter does not exclude hypovolemia.

Unfortunately, only a few studies excluded the previous conditions as possible causes of changes in IJV size.[10,12,17]

Similar to Chaudhary *et al.*, the data of this review suggest that the IJV-US could be feasible and useful in determining the volume status of patients in several settings: out-hospital, in-hospital and emergency department.

The IJV-US examination could be used specifically when the IVC ultrasound method is not feasible because of poor acoustic windows (obesity, abdominal air interposition, surgical wounds).

The main views for the IJV-US exam were the apex of the sternocleidomastoid muscle and supraclavicular with a decubitus of patients at 45°, but there was a great heterogeneity on the side of exams: right *vs.* left (*Supplementary Table 1*).

Limits of internal jugular vein ultrasound

IJVs are easily compressible and it is important to apply only a very light pressure on the neck to avoid inaccurate vein measurements.

Many factors could affect IJV measurements using ultrasound: patient position, the side of exam (right *vs.* left neck), previous neck surgery, IJV thrombosis, and presence of catheters.

There is no standardization of technique because the researchers used several protocols to validate the method. The most validated measurements, IJV ratio and the IJV area (CSA) before and after the Valsava, are difficult to use in patients with dyspnea.

Limits of review and Conclusions

We found overlapping cohorts in several published studies.[8-12]

It is difficult to compare the results of studies collected because of their different protocols and statistical methodologies used to test the outcomes. For the same reasons, we were not able to perform statistical inferences for a meta-analysis.

In conclusion, the ultrasound of the internal jugular, for its ease and speed of execution, could be a valuable tool to support the clinician in the assessment of patients suffering from HF both in the diagnosis and in the therapeutic management.

It's clear that it should be integrated into the clinical eval-

uation based on symptoms, signs and other diagnostic tools: laboratory and radiology.

In addition, it should be used together with other ultrasound methods (for example echocardiography, pulmonary ultrasound, IVC ultrasound) to confirm the diagnosis of congestion, define the etiology of cardiac failure and exclude other causes of elevated CVP.

Finally, the ultrasound of the IJV, associated with other ultrasound methods (ultrasound of lung and IVC, doppler of portal veins, hepatic and renal) could be used to quantify the extent of congestion and estimate the prognosis of patients with HF.

In particular, it could be used for the calculation of the risk of hospitalization for congestion in both discharge and outpatient patients.

However, before using the method in clinical practice, one should check which ultrasound measurements are more reliable and show less variability in execution between different operators and exclude other causes of elevated CVP.

Once the most reliable measurements have been defined, an ultrasound protocol should be developed to include them and validated for diagnostic and prognostic accuracy.

In any case, there would be many areas of research to be developed: check the ranges of values of ultrasound measurements of the jugular in a population of healthy, exclude variability in measurements due to laterality or different acoustic windows, confirm accuracy in predicting best gold standards of the volemic state (*e.g.*, thermodilution, bioimpedance).

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Online supplementary material:

Figure S1. The minimum anterior-posterior diameter of internal jugular vein (D1= antero-posterior-internal jugular vein minimum). IJV, internal jugular vein; CC, common carotid artery.

Figure S2. The maximum anterior-posterior diameter of internal jugular vein (D2= antero-posterior-internal jugular vein max diameter). IJV, internal jugular vein; CC, common carotid artery.

Figure S3. Aspect ratio of internal jugular vein. Aspect ratio, antero-posterior-internal jugular vein maximum diameter (D2)/lateral – internal jugular vein max diameter (D3). IJV, internal jugular vein; CC, common carotid artery.

Figure S4. The maximum area of internal jugular vein (cross-sectional area-internal jugular vein max), in the expiratory phase. IJV, internal jugular vein; CC, common carotid artery.

Figure S5. The collapsibility index (using the M-mode), derived by the formula: [(max diameter, D1 in figure-min diameter, D2 in figure)/(max diameter, D1 in figure)]× 100%.

Figure S6. Internal jugular vein before Valsalva. IJV, internal jugular vein; CC, common carotid artery.

Figure S7. Internal jugular vein after Valsalva. The internal jugular vein ratio derived from the formula: antero-posterior maximum internal jugular vein diameter after Valsalva (antero-posterior-IJV max post-Valsalva)/antero-posterior maximum internal jugular vein diameter at rest, before Valsalva (antero-posterior-internal jugular vein max pre-Valsalva). Internal jugular vein ratio values less than 2 suggest that the patients could have high central venous pressure. IJV, internal jugular vein; CC, common carotid artery.

Figure S8. The internal jugular vein meniscus is the point at which the vein collapses in the neck. IJV, internal jugular vein.

Table S1. Comparison of side, view and decubitus of internal jugular vein ultrasound measures among studies collected.

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