Diagnostic accuracy of inferior vena cava evaluation in the diagnosis of acute heart failure among dyspneic patients

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Abstract

Acute dyspnea is one of the main reasons for admission to the Emergency Department (ED). A rapid and accurate diagnosis can be lifesaving for these patients. Particularly, it is important to differentiate between dyspnea due to acute heart failure (AHF) and dyspnea of pulmonary origin. The aim of this study is to evaluate the real accuracy of the evaluation of diameter and collapsibility of inferior vena cava (IVC) for the diagnosis of AHF among dyspneic patients. We analyzed 155 patients admitted for acute dyspnea to the ED of "Maurizio Bufalini" hospital in Cesena (Italy) and "Antonio Cardarelli" hospital in Naples (Italy) from November 2014 to April 2017. All patients underwent ultrasound of IVC examination with a hand-held device in addition to the traditional pathway. Patients were classified into AHF group or non-AHF group according to the current guidelines. The final diagnosis was AHF in 64 patients and dyspnea of non-cardiac origin in 91 patients. Sensibility and specificity of IVC hypo-collapsibility was 75.81% (95% CI 63.26% to 85.78%) and 67.74% (95% CI 57.25% to 77.07%) for the diagnosis of AHF. Sensibility and specificity of IVC dilatation was 69.35% (95% CI 56.35% to 80.44%) and 74.19% (95%CI 64.08% to 82.71%) for the diagnosis of AHF. AUC was 0.718 (0.635-0.801) for IVC hypo-collapsibility, 0.718 (0.634-0.802) for IVC dilatation. Our study demonstrated that the sonographic assessment of IVC diameter and collapsibility is suboptimal to differentiate acute dyspnea due to AHF or other causes in the emergency setting.

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Introduction

Acute heart failure (AHF) is one of the most common reasons for admission to the Emergency Department (ED) and dyspnea is a frequent clinical presentation [1]. A rapid diagnostic pathway is mandatory to establish the correct sequence of therapeutic actions. History, physical examination, ECG, chest X-ray, laboratory tests and multi-organ ultrasound compose the diagnostic workup using which the emergency physician interprets the clinical picture and makes therapeutic decisions. In the last years multi-organ ultrasound examination of the lung, heart and inferior vena cava (IVC) has become a useful tool for the differential diagnosis of acute dyspnea in the ED [2-4]. Since echocardiographic evaluation requires expertise and training, some studies suggest that the only sonographic assessment of IVC diameter and/or collapsibility, from which central venous pressure (CVP) can be estimated, may be enough for the identification of AHF among acutely dyspneic patients [5]. The aim of this study is to evaluate the real accuracy of the evaluation of diameter and collapsibility of IVC for the diagnosis of AHF and to evaluate the sensibility and specificity of different values of CVP for the diagnosis of AHF.

Methods

This study is a *post-hoc* analysis derived from two observational studies conducted in the ED of "Maurizio Bufalini" hospital

in Cesena (Italy) and "Antonio Cardarelli" hospital in Naples (Italy) from November 2014 to April 2017 [6,7]. One hundred and seventy (170) patients admitted to the ED for acute dyspnea or worsening of chronic dyspnea within the previous 48 hours (excluding dyspnea of traumatic origin) underwent multi-organ ultrasound of lung, heart and IVC performed with a handheld ultrasound device in addition to the traditional diagnostic pathway (clinical exam, blood gas analysis, chest X-ray, ECG, routine blood tests) [8]. NT-pro-BNP was considered negative if less than 300 pg/ml and in favor of AHF if greater than 1800 pg/ml in patients older than 75 years, 900 pg/ml in patients from 50 to 75 years old, 450 pg/ml in patients younger than 50 years.

Informed consent was obtained from each patient included in the study, which follows the principles of the Declaration of Helsinki.

IVC evaluation was performed with a pocket ultrasound device (Vscan of General Electric Healthcare) with a single probe (1.7-3.8 MHz), using cardiac preset in sub-costal window [9]. Off-line measures for IVC diameter and collapsibility were performed. The presence of IVC dilatation was established if IVC diameter was >2 cm while the presence of hypo-collapsibility was established if the variation between expiratory and inspiratory diameter of IVC was ≤50% (Video 1). Four levels of estimated right atrial pressure (eRAP) were identified according with the combination of IVC maximum diameter and collapsibility based on current guidelines [10]. Ejection fraction (EF) was estimated visually and categorized as preserved if >40% (n=100) or reduced if ≤40% (n=55) from apical view [9].

The final diagnosis, considered as the gold standard, was issued by two independent observers (one emergency physician and one internal medicine specialist) who had access to the entire medical chart (from emergency department admission to hospital discharge) of each patient. Patients were classified into AHF group or non-AHF group according to the current guidelines [11]. In patients with coexistence of heart failure and another cause of dyspnea the main diagnosis was considered AHF. In the present analysis 155 patients with available ultrasound imaging of IVC have been included. Data were analyzed using SPSS version 21.0 (SPSS, Chicago, Illinois, USA). Continuous data are expressed as mean ± 1 SD and categorical variables as percentages. Quantitative variables were compared by using Student's *t*-test while $\chi 2$ distribution was used to compare categorical variables. Multivariate logistic regression model was built to assess the association of age, sex, NT-proBNP level, creatinine and IVC collapsibility for the diagnosis of AHF. A p-level <0.05 was considered statistically significant.

Results

The final diagnosis was AHF in 64 patients and dyspnea of non-cardiac origin in 91 patients. Baseline characteristics of the study population based on diagnosis of AHF is reported in Table 1. Sensibility and specificity of IVC hypo-collapsibility was 75.81% (95% CI 63.26% to 85.78%) and 67.74% (95% CI 57.25% to 77.07%) for the diagnosis of AHF. Sensibility and specificity of IVC dilatation was 69.35% (95% CI 56.35% to 80.44%) and 74.19% (95%CI 64.08% to 82.71%) for the diagnosis of AHF. Sensibility and specificity for different levels of eRAP are reported in Table 2. AUC was 0.718 (0.635-0.801) for IVC hypo-collapsibility, 0.718 (0.634-0.802) for IVC dilatation, 0.737(0.653-0.820) for eRAP≥15 mmHg. In multivariate logistic regression model NT-proBNP level adjusted for age and IVC collapsibility are strongly and independently associated with AHF (Table 3). The study population was than divided based on preserved and reduced EF. Sensibility and specificity for IVC hypo-collapsibility and dilatation are reported in Table 4.AUC for preserved or reduced EF was respectively 0.675 (0.536-0.814) for IVC hypo-collapsibility and 0.717 (0.580-0.855) for IVC dilatation, 0.748 (0.567-0.928) for IVC hypo-collapsibility and 0.652 (0.458-0.847) for IVC dilatation.

Discussion

In patients with HF the presence of an elevated jugular venous pulse is one of the key semiotic findings and reflects the presence of elevated CVP. More accurately CVP can be estimated using ultrasound examination of IVC [12]. Patients with AHF are characterized by larger IVC diameter and reduced collapsibility compared to non AHF patients, even though increased CVP may not be always present [5]. Different studies have evaluated the diagnostic accuracy of IVC for the diagnosis of AHF among patients with acute dyspnea. In 2014 Yamanoglu *et al*. conducted a prospective observational study to distinguish between dyspnea of cardiac origin and dyspnea of pulmonary origin using the IVC diameter measurement. They found that IVC diameter above 18.3 mm have 81.3% sensibility and 73.8% specificity for the diagnosis of AHF [13]. These findings are in line with our results and the slightly better diagnostic accuracy should be explained by the better accuracy of their echocardiographic measurement and by the intensive care setting of the study.

Combined information from IVC diameter and collapsibility using a sonographic caval index (calculated as the percentage decrease in the IVC diameter during respiration) was demonstrated to be a useful clinical adjunct to establish the diagnosis of AHF in patients with undifferentiated dyspnea [14]. In particular low caval index has high specificity for the diagnosis of HF, in line with our analysis related to eRAP>15 mmHg. NT-ProBNP and IVC collapsibility are strongly and independently associated with AHF, demonstrating that fluid overload and ventricular stretching are the main pathophysiological determinant of AHF [15].

In patients with chronic heart failure (CHF) IVC diameter and collapsibility have strong correlation with volume status, natriuretic peptide and give important prognostic information [15,16]. Thus when the cause of acute dyspnea is decompensation of CHF IVC diameter can be useful for diagnostic and therapeutic approach [17,18]. Differently some patients, presenting with dyspnea due to AHF, do not have volume overload but can be affected by acute pressure overload such us in patients with hypertensive emergency. In hypertensive AHF CVP can be normal while there is a redistribution of existing fluids from the splanchnic and central circulations into the pulmonary vasculature [19]. The main cause of dyspnea in AHF is the increase in pulmonary wedge pressure due to increased afterload and volume-shift lung congestion which is not always associated with increased right atrial pressure. This is particularly true among patients with new onset AHF compared to patient with chronic HF [20]. This explains way echocardiographic assessment of IVC cannot be alone the diagnostic method of choice for the diagnosis of AHF in patients with acute dyspnea.

Our study demonstrated that the diagnostic accuracy of IVC evaluation in predicting AHF is similar among patients with preserved or reduced EF. This is in line with recent evidence form Van Aelst *et al.* who demonstrated similar echocardiographic and biomarkers signs of venous congestions in patients with heart failure with preserved or reduced EF [21].

Another aspect to bear in mind is that elevated right atrial pressure can also be a marker of acute respiratory disease such as pulmonary embolism or pneumothorax or chronic lung diseases in which dilated and not collapsing IVC do not reflect AHF but just increased pulmonary artery pressure or intrathoracic pressure.

In conclusion our study demonstrated that the sonographic evaluation of IVC diameter or collapsibility alone for the diagnosis of AHF among dyspneic patients is suboptimal. Combining infor-

Table 1. Baseline characteristics and clinical findings detected at the time of patient presentation in the emergency department.

	Acute heart failure (n=64)	Non acute heart failure (n=91)	p value
Age (years)	75.8±11.1	73.5±13.3	0.21
Women (%)	44	41	0.68
Medical history of chronic obstructive pulmonary disease (%)	23	49	0.001
Medical history of heart failure and/or ischemic heart disease (%)	41	18	0.01
Heart rate (bpm)	90.5±25.5	94.2±21.4	0.62
Systolic BP (mmHg)	141.2±30.7	132.8±22.2	0.01
Diastolic BP (mmHg)	79.7±15.6	73.7±12.7	0.09
Serum creatinine (mg/dl)	1.6±1.7	1.1±0.5	0.0001
White blood cell count (x10^3/µl)	9.5±4.5	11.9±6.1	0.002
Oxygen saturation (%)	91.8±5.0	89.8±9.0	0.005
PaO_2/FiO_2	276.2±88.7	250.4±85.5	0.84
pH	7.42±0.09	7.41±0.09	0.67
Lactate level (mmol/l)	1.94±2.19	1.68±1.13	0.09
NT-pro BNP (pg/dl)	9350±11450	2984±7034	0.007
Ejection fraction (%)	42±14	57±8	0.0001
Dilated left atrium (%)	87	25	0.0001

BP, blood pressure.

Table 2. Sensibility and specificity for different values of eRAP for the diagnosis of acute heart failure.

	Sensibility (%)	Specificity (%)
eRAp ≥10 mmHg	80.65 (68.63 to 89.58)	59.14 (48.46 to 69.23)
eRAp ≥15 mmHg	64.52 (51.34 to 76.26)	82.80 (73.5 to 89.83)

Table 3. Multivariable regression model for main determinant of acute heart failure.

	p	EXP (B)	95% CI for EXP(B)	
			Lower	Upper
Age (years)	0.597	1.016	0.957	1.080
Sex (m/f)	0.395	1.768	0.475	6.573
NT_proBNP_adjusted for age (n/y)	0.001	8.339	2.295	30.296
Creatinin (mg/dl)	0.323	1.277	0.786	2.076
IVC_collapse (n/y)	0.018	4.793	1.312	17.513

Table 4. Sensibility and specificity of IVC hypo-collapsibility and dilatation in patients with preserved and reduced ejection fraction.

	Sensibility (%)	Specificity (%)
Preserved EF		
IVC hypo-collapsibility	66.67 (40.99 to 86.66)	68.29 (57.08 to 78.13)
IVC dilatation	66.67 (40.99 to 86.66)	76.83 (66.20 to 85.44)
Reduced EF		
IVC hypo-collapsibility	79.55 (64.70 to 90.20)	70.00 (34.75 to 93.33)
IVC dilatation	70.45 (54.80 to 83.24)	60.00 (26.24 to 87.84)

EF, ejection fraction; IVC, inferior vena cava.

mation of IVC collapsibility and diameter helps to improve the diagnostic accuracy which remains suboptimal and does not differ significantly among patients with reduced of preserved EF.

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