Outpatient Use of Focused Cardiac Ultrasound to Assess the Inferior Vena Cava in Patients With Heart Failure

Narayan M. Saha, MD, Julian J. Barbat, MD, Savitri Fedson, MD, Allen Anderson, MD, Jonathan D. Rich, MD, and Kirk T. Spencer, MD*

Accurate assessment of volume status is critical in the management of patients with heart failure (HF). We studied the utility of a pocket-sized ultrasound device in an outpatient cardiology clinic as a tool to guide volume assessment. Inferior vena cava (IVC) size and collapsibility were assessed in 95 patients by residents briefly trained in focused cardiac ultrasound (FCU). Cardiologist assessment of volume status and changes in diuretic medication were also recorded. Patients were followed for occurrence of 30-day events. There was a 94% success rate of obtaining IVC size and collapsibility, and agreement between visual and calculated IVC parameters was excellent. Most patients were euvolemic by both FCU IVC and clinical bedside assessment (51%) and had no change in diuretic dose. Thirty-two percent had discrepant FCU IVC and clinical volume assessments. In clinically hypervolemic patients, the FCU evaluation of the IVC suggested that the wrong diuretic management plan might have been made 46% of the time. At 30 days, 14 events occurred. The incidence of events increased significantly with FCU IVC imaging categorization, from 11% to 23% to 36% in patients with normal, intermediate, and plethoric IVCs. By comparison, when grouped in a binary manner, there was no significant difference in event rates for patients who were deemed to be clinically volume overloaded. Assessment of volume status in an outpatient cardiology clinic using FCU imaging of the IVC is feasible in a high percentage of patients. A group of patients were identified with volume status discordant between FCU IVC and routine clinic assessment, suggesting that IVC parameters may provide a valuable supplement to the in-office physical examination. **(Am J Cardiol 2015;116:1224−1228)**

Heart failure (HF) is a major reason for health care spending and is the leading cause for hospitalization and readmission of patients aged >65 years.[1,2] The primary reason for HF admissions is for the treatment of congestive symptoms resulting from volume overload. Characterization of hemodynamic status in the outpatient setting may allow detection of volume overload before symptom onset, preventing hospitalization. Determination of volume excess by examination of the central venous pulse is inadequate for this purpose.[3−12] Alternatively, multiple studies have shown good correlation between RA pressure and inferior vena cava (IVC) parameters performed by echocardiography.[10−12] However, full platform echocardiography is impractical for routine bedside outpatient use. Several studies have shown that assessment of the IVC with focused cardiac ultrasound (FCU) is accurate and a useful adjunct to the physical examination for hemodynamic assessment.[10,13−18] We sought to compare FCU evaluation of the IVC and standard bedside clinical assessment of volume status in an outpatient clinic serving patients with HF.

Methods

The University of Chicago Institutional Review Board approved our study. Consecutive adult patients who presented for follow-up to an HF outpatient clinic at the University of Chicago Medical Center were enrolled. Patients with previous cardiac transplant, mechanical assist devices, or dialysis-dependent renal disease were excluded.

Patients were imaged in the examination room either just before or just after the attending cardiologist visit. Subcostal IVC imaging was performed in the supine position using a hand-carried device (Vscan; General Electric Healthcare, Waukesha, Wisconsin) by 2 second-year internal medicine residents who were blinded to patient demographics, history of present illness, past medical history, and clinical evaluation of the clinic nurse and cardiologist. Each resident had no previous ultrasound training and performed 20 sonographer-supervised FCU acquisitions and measurements of the IVC from the subcostal approach before the study.

The FCU users were asked to assess IVC size and collapsibility in 2 ways. The first approach involved visually estimating the maximal IVC diameter at passive end expiration based on the image display reference ruler as either greater than or less than 2 cm. Visualized percent collapsibility was estimated by observation of luminal collapse during brief rapid inspiration/sniff as greater than or less than 50% vessel collapse. After recording their qualitative assessment, saved image loops were reviewed frame by frame by the resident on the Vscan device, and the maximal and minimal dimensions calculated with electronic calipers. The IVCl collapsibility index (IVCCI) was determined as (IVCmax − IVCmin)/(IVC max) × 100. All IVC visual assessments and measurements were made approximately 2 cm from the right atrium−IVC junction.

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See page 1227 for disclosure information.

*Corresponding author: Tel: (773) 702-5836; fax: (773) 702-1034.
E-mail address: kspencer@uchicago.edu (K.T. Spencer).

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Table 1
Demographics (all patients) (N=95)

Age (years)	64 ± 14
Body mass index (kg/m^2)	31 ± 9
Men	48%
Ejection fraction (%)	40 ± 18
Ejection fraction < 50% (%)	62%
Focused cardiac ultrasound	
Inferior vena cava diameter (cm)	1.6 ± 0.7
Inferior vena cava collapsibility index (%)	71 ± 32

Table 2
Clinical parameters used to assess volume status at the bedside (N=95)

Heart rate (beats/min)	76 ± 16
Systolic blood pressure (mm Hg)	122 ± 24
Diastolic blood pressure (mm Hg)	72 ± 12
Jugular venous pressure elevated	22%
Pulmonary crackles	1%
Abdominal distention	12%
Lower extremity edema	19%
Weight increase	15%
Congestive symptoms present	18%

The clinician (attending cardiologist), blinded to IVC imaging data, completed a questionnaire immediately after visit to document their overall assessment of patient volume status (dry, euvolemic, mild, moderate, or severe volume overload), physical examination findings, patient symptoms and postvisit diuretic plan (decrease, no change, increase). Patients were also asked to assess their own volume status using the same rating scale, blinded to the assessment and plan of the clinician. No formal echocardiogram was performed on the clinic visit day. Baseline patient echocardiographic parameters (left ventricular ejection fraction) were taken from the most recent transthoracic echocardiogram. Patients were followed by phone call questionnaire and electronic medical record review for occurrence of events, defined as, emergency room presentation and/or hospital admission for the next 30 days.

Categorical data are presented as percentages and normally distributed continuous data as mean ± standard deviation. Patients with an FCU determined IVCmax >2 cm and IVCCI ≤50% were categorized as volume overloaded, and those with IVC <2 cm and IVCCI >50% were euvolemic. Other pairings (large IVC/collapsible and small IVC/non collapsible) were labeled as intermediate. When classified in a binary analysis of euvolemic or hypervolemic, the intermediate IVC groupings were considered as hypervolemic. Regarding clinician assessment of volume status, a 5-point Likert scale was used: dry, normal volume, mild volume increase, moderate volume increase, and severe volume increase. The κ statistic was used to determine agreement between techniques. Binary logistic regression was used to analyze parameters as predictors of 30-day events.

Results

Ninety-five patients were enrolled. Five patients were lost to follow-up, and information regarding 30-day events was unable to be obtained in these patients. Baseline demographics are provided in Table 1.

Table 3
Volume status by focused cardiac ultrasound imaging of the inferior vena cava and clinical assessment (percent of patients)

MD volume status	Volume status by focused cardiac ultrasound imaging of the inferior vena cava		
	Normal	Intermediate	High
Dry	3%	0%	1%
Euvolemic	51%	8%	7%
Mild overload	16%	6%	6%
Moderate overload	0%	0%	0%
Severe overload	0%	1%	2%

There was a 94% (89 of 95) success rate of the residents obtaining images they believed could be used to visually estimate IVC size and collapsibility and 92% (87 of 95) success rate of IVC quantitative measurement. Patients in who the residents could not image the IVC had higher weights (118 vs 89 kg) but no difference in age, heart rate, or ejection fraction. Agreement between the visual and calculated IVC classification of collapsibility (greater or less than 50%) and size (greater or less than 2 cm) were excellent with κ values of 0.97 and 0.85, respectively. There was a 93% (81 of 87) concordance for the combined categorization of IVC size/collapsibility into 1 of 4 size/collapsibility pairings. When looking at binary volume status assessment (volume overloaded or not) between visual and caliper measured IVC evaluation, agreement was 97% (85 of 87).

The vital signs and examination findings recorded by the physicians to classify volume status at the bedside are provided in Table 2. Elevated jugular pulse, lower extremity edema, increased weight, and congestive symptoms were present at a similar frequency. The jugular venous pulse could not be discerned in 9% of patients, and pulmonary crackles were unusual in this outpatient population. Most patients were believed to be euvolemic by the clinical cardiologist (65%). Twenty-seven percent were believed to be mildly volume overloaded, and a small proportion were dry (4%) or severely volume overloaded (3%). Most patients self-evaluated their volume status as euvolemic (74%) with 23% mildly overloaded and 3% severely overloaded. By visual IVC assessment, 70% of patients were classified as euvolemic (small and collapsible), whereas 16% were deemed to be hypervolemic (large and noncollapsible). The remaining 14% had intermediate IVC findings (small and noncollapsible or large and collapsible).

Comparison of visual IVC and clinician volume assessment is provided in Table 3. Most patients were euvolemic by both FCU IVC and clinical bedside assessment (51%). Sixteen percent of patients believed to be euvolemic or dry on clinical assessment had an elevated right atrial pressure (RAP) by FCU IVC, and a similar percentage (16%) believed to be volume overloaded on clinical evaluation had a normal RAP by FCU (Table 3). When divided into a binary assessment of euvolemic/dry versus hypervolemic, the agreement between FCU IVC and clinical assessment was only fair with a κ statistic of 0.25. Using this binary