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Focused cardiac ultrasound as a predictor of readmission in acute decompensated heart failure

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Abstract

Acute decompensated heart failure (ADHF) is a common reason for admission to the hospital, and readmission is frequent. Multiple factors contribute to rehospitalizations, but inadequate assessment of volume status leading to persistent congestion is an important factor. We sought to determine if focused cardiac ultrasound (FCU) of the inferior vena cava (IVC), as a surrogate of volume status, would predict readmission of ADHF patients after index hospitalization. Patients admitted with a primary diagnosis of ADHF were prospectively enrolled. All patients underwent FCU of the IVC on admission and then daily. 82 patients were enrolled. Patients demonstrated improvement in heart failure physical examination findings and symptoms during the hospitalization. There was a reduction in the size of the IVC and a significant increase in patients with small collapsible vena cava. Logistic regression analysis of physical examination, patient symptoms, and IVC parameters at discharge demonstrated IVC collapsibility and patient reported dyspnea improvement as the only significant variables to predict readmission or emergency department visit. FCU assessment of IVC size and collapsibility may be useful in patients with ADHF to predict risk of being readmitted within 30 days of hospital discharge.

Keywords

Focused cardiac ultrasound; Inferior vena cava; Hospital readmission; Congestive heart failure

Introduction

Heart failure is a common reason for admission to the hospital, and after discharge readmission is frequent [1, 2]. Multiple factors contribute to heart failure rehospitalizations, and a number of interventions have been designed to facilitate care at, or after, patient

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Compliance with ethical standards

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Informed consent: Informed consent was obtained from all individual participants included in the study.

discharge to reduce readmissions [3–5]. Unfortunately, rates of readmissions remain high [6].

One of the main factors for acute decompensated heart failure (ADHF) admission is congestion, thus the goal in hospitalized patients is to reduce cardiac filling pressures sufficiently, so that patients can be safely managed in an ambulatory setting [7]. However, even an experienced clinician can have trouble assessing volume status based on physical exam alone [8]. Most patients experience significant improvement in clinical congestion during hospitalization, but the potential exists for persistent subclinical congestion, which can lead to earlier readmission. Further, over diuresis resulting in renal injury while hospitalized portends a worse prognosis, including increasing rate of readmission [9, 10].

Focused cardiac ultrasound (FCU) is an emerging modality, and clinicians from a variety of specialties are comfortable using this technology [11]. FCU of the inferior vena cava (IVC) has proven useful in the diagnosis of heart failure [12–19]. We sought to determine if FCU of the IVC during hospitalization for heart failure could be used to predict risk of hospital readmission.

Materials and methods

Patients admitted to the general cardiology services at the University of Chicago Medical Center with a primary diagnosis of ADHF were prospectively screened. Subjects were excluded if they were admitted to an intensive care unit, required renal replacement therapy, were undergoing evaluation for heart transplantation or left-ventricular assist device prior to admission, or were unwilling or unable to provide informed consent.

After admission, all subjects underwent FCU of the IVC, performed by one of six internal medicine residents who were not involved in the inpatient care and blinded to all clinical data. Subcostal IVC imaging was performed in the supine position using a hand carried ultrasound device (Vscan, General Electric Healthcare, Waukesha, Wisconsin). Each resident had no prior ultrasound training and performed a minimum of ten sonographer-supervised FCU acquisitions and measurements of the IVC from the subcostal approach prior to the study. The FCU users were asked to measure the maximal IVC diameter at passive end expiration with electronic calipers and to assess collapsibility by visually estimating luminal collapse during brief rapid inspiration/sniff as greater or less than 50%. All IVC visual assessments and measurements were made approximately 2 cm from the RA–IVC junction.

Subjects were imaged at the bedside on admission and then daily including the day of discharge. No management decisions were prescribed to any of the teams by protocol, each service managed the patients according to their clinic judgment. No management was mandated by the results of the IVC imaging. Subjects were asked if symptoms were improved from admission on a daily basis (dyspnea, orthopnea, and paroxysmal nocturnal dyspnea).

Baseline demographic information was collected for each patient. Vital signs, weight, serum chemistries, and primary team reported physical examination findings (jugular venous pulse

distention, pulmonary rales, lower extremity edema) were recorded. Readmission or emergency department (ED) visits were ascertained by review of medical records and phone interview 30 days after hospital discharge. The primary endpoint was a composite of hospital readmission and ED visits, in the 30 days following discharge.

Categorical data are presented as percentages and normally distributed continuous data as mean $\pm$ standard deviation. Log-transformed values for BNP (logBNP) were used to reduce the effect of the typical skewness of BNP values. Statistical differences were assessed with the use of *t* tests and Chi square analysis. Binary logistic regression was used to assess for predictors of readmission. A *p* value < 0.05 was considered statistically significant. Receiver operator curve was calculated for IVC discharge diameter. Optimal cut points were selected by maximizing accuracy. Intra-observer variability is reported as the coefficient of variation.

Results

82 patients were enrolled in the study. 70 subjects completed the study and were subsequently analyzed. 12 subjects were excluded from the study based on events occurring during hospitalization including transfer to the intensive care unit (9), transfer to cardiac surgery (1), initiation of hemodialysis during admission (1), and leaving against medical advice (1).

Patient demographics, co-morbidities and left ventricular ejection fraction (LV EF) are shown in Table 1. Subjects were older, female predominate with frequent comorbidities and 1/3 had heart failure with preserved LV EF. Table 2 contains the baseline laboratory and physical findings. The majority of subjects had physical examination evidence of volume overload and the mean admission BNP was $> 10,000$. On admission, patients had a mean IVC diameter of 2.2 cm. The IVC was not collapsible in 70% of patients. While the majority of subjects had elevated estimated right atrial pressure (RAP) with dilated and non-collapsible IVC, 19% had an initial IVC assessment that suggested a low or normal RAP. Intra-observer variability was 8.0% for IVC maximal dimension.

Overall length of stay was 4.9 ± 2.4 days. There was a significant reduction in weight from admission of 4.4 ± 4.8 kg. There was improvement in heart failure physical examination findings over the hospitalization (Table 2). However, 62% of patients had at least one physical examination finding abnormal at time of discharge (elevated JVP, rales or at least 1 + edema). Subjects reported symptom improvement that varied between 37 and 60% (Table 2).

There was a reduction in the size of the IVC during the hospital stay. There was also a significant decrease in the percentage of subjects with enlarged, non-collapsible IVCs, and a corresponding increase in patients with small collapsible vena cava (Table 3). At discharge, only 50% of patients were estimated to have a low or normal RAP by IVC assessment. Despite being ready for discharge by the treating teams, nearly 1/4 of patients had an estimated RAP that was significantly elevated, although this was a 50% reduction from admission when over one-half had RAP in this range (Table 3).

Logistic regression analysis of physical examination (jugular venous pressure, rales, edema), patient symptoms (dyspnea, paroxysmal nocturnal dyspnea, orthopnea) and IVC parameters (size, collapsibility) at discharge demonstrated IVC collapsibility and patient reported dyspnea improvement as the only statistical significant variables to predict readmission or ED visit. The ROC for IVC maximal dimension was only fair with AUC of 0.63 and optimal value was 2.1 cm.

Discussion

Readmissions for ADHF are prevalent and costly [20, 21]. Attempts at reducing heart failure readmissions have demonstrated variable successes, however the overall rates of re-hospitalization for ADHF remain high [20]. The causes for readmission after treatment for ADHF are complex and involve many social, economic and compliance post-hospitalization factors. However, it appears that inadequate restoration of a euvolemic state also contributes. The proposed mechanism is simple, patients who leave the hospital in a state of continued volume excess have less capability to tolerate outpatient fluctuations in volume status, and are therefore more likely to present in a decompensated state soon after discharge. New invasive technologies that monitor outpatient volume status support maintenance of euvolemia to reduce readmission [22].

If discharge at an optimal volume status is important to keep readmissions low, it is unclear whether complete resolution of volume overload physical examination findings or patient symptoms would be an adequate endpoint for ADHF admission. It seems clear in clinical practice, providers don't require symptom and sign resolution as mandatory end-points for discharge, as 23–42% of patients had either elevated jugular venous pressure, rales or edema at discharge. Additionally, resolution of patient symptoms was not universal as only 37–60% of patients reported improvement in presenting congestive symptoms.

Analysis of the data in this trial suggests that a plethoric, non-collapsible IVC and a patient stating their breathlessness had not improved as the most potent variables to predict readmission. Physical examination findings failed to predict readmission, which may reflect, that even experienced clinicians can have trouble assessing volume status based on physical exam alone [8]. Failure for dyspnea to improve seems intuitive as a predictor of ongoing volume overload and thus readmission and it isn't clear why these patients were felt to be ready for discharge. Using FCU IVC as a predictor of persistent volume overload has physiologic support in that ultrasound assessment of IVC size and collapsibility, although described as an estimate of right atrial pressure, in patients with heart failure correlates with invasive assessment of LV filling pressures [23,24]. In addition, IVC size change correlates with reduction in pulmonary capillary wedge pressure in patients being treated for ADHF [25]. Others have shown that IVC size change correlates with BNP reduction during ADHF treatment [26]. A potential advantage over BNP is that the IVC has been shown to respond more quickly to IV diuresis than BNP [27].

A prior report showed that a dilated IVC predicted rehospitalization, but this was the status of the IVC on admission echocardiogram, not at discharge [28]. This result may simply reflect that a larger IVC represents a group of heart failure patients with a poorer prognosis

[29–32]. Another paper found that IVC size at discharge predicted readmission in ADHF patients, but failed to compare other bedside parameters [33]. If IVC is to be useful in ADHF patients it will need to outperform simpler methods such as physical examination and patient symptoms. A prior paper noted IVC at discharge predicted readmission but did not leverage the ease of a pocket-sized ultrasound device [34]. These devices while small enough to be carried in a lab coat pocket to the bedside, have proven clinical value [35–37].

Limitations for this study include the fact that it is a single center study. Further, the use of the IVC, as a marker of patient volume status is certainly imperfect. Patients with right heart failure, tricuspid regurgitation and mechanical ventilation can be problematic. Adequate images of the IVC can be difficult in obese patients. FCU IVC is used to assess right atrial pressure, not LV filling pressures, however in ADHF these tend to track each other [23, 24]. Whether a more aggressive or targeted therapeutic plan (other than more diuresis) would alter the prognosis of these patients was not addressed in this study.

Conclusion

FCU of the IVC may assist in identifying patients at risk for rehospitalization after admission for ADHF.

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Table 1

Baseline demographics

Age (years)	69 ± 14
Male	44%
LV EF (%)	35 ± 17
LV EF > 40%	34%
Hypertension	77%
Diabetes	47%
CAD	44%

FCU focused cardiac ultrasound, *LV* left ventricular, *EF* ejection fraction, *CAD* coronary artery disease

Table 2

Baseline and discharge clinical and laboratory parameters

	Admit	DC
Weight (kg)	88 ± 23	83 ± 24
Systolic BP (mmHg)	122 ± 21	114 ± 18 *
Diastolic BP (mmHg)	73 ± 16	66 ± 14
Heart rate (bpm)	88 ± 23	83 ± 15
Elevated JVP	66%	25% *
Lower extremity edema	77%	42% *
Rales	51%	23% *
Dyspnea (% improved)	—	60%
Orthopnea (% improved)	—	40%
PND (% improved)	—	37%
Creatinine (mg/dl)	1.7 ± 0.9	1.7 ± 0.8
eGFR (ml/min/BSA)	43 ± 19	43 ± 18
logBNP	3.8 ± 0.6	—

FCU focused cardiac ultrasound, *BP* blood pressure, *JVP* jugular venous pressure, *eGFR* estimated glomerular filtration rate, *BNP* brain natriuretic peptide, *PND* paroxysmal nocturnal dyspnea

*
p < 0.05 versus admit

Table 3

Baseline and discharge IVC parameters

	Admit	DC
Maximum IVC diameter (cm)	2.2 ± 0.6	1.9 ± 0.5 *
IVC > 2 cm	67%	29% *
IVC non collapsible	70%	42% *
Low/normal estimated RAP	19%	52% *
Elevated estimated RAP	56%	23% *

RAP right atrial pressure

*
p < 0.05 versus admit