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Review

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Utilization of Ultrasound to Assess Volume Status in Heart Failure

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Abstract

Heart failure (HF) represents a significant financial burden to the US health care system, affecting approximately 5.7 million Americans. By 2030, the prevalence of HF is expected to increase by 23%. Clinicians generally evaluate volume status in patients with HF by visualizing jugular venous distension to estimate right atrial pressure; a method with an estimated accuracy of only 50%. Currently, the only endorsed methods for acute HF diagnosis in the 2017 American College of Cardiology (ACC) guidelines are brain natriuretic peptide (BNP) or N-terminal pro-B-type natriuretic peptide (NT-proBNP), pre-discharge BNP or NT-proBNP, and myocardial fibrosis markers. However, serial testing of BNP to monitor therapy remains controversial. Moreover, an elevated BNP cannot be attributed solely to a cardiac cause. Given the limitations of the current methods, a robust tool is needed to reliably assess volume status in HF patients. It is now known that hemodynamic congestion from increases in intracardiac pressure occurs days to weeks prior to the onset of typical HF symptoms, such as weight gain and shortness of breath. It has been postulated that assessing the inferior vena cava (IVC) diameter with a portable ultrasound, may be the simple, reliable, and cost-effective method of evaluating right atrial pressure, and thus, the severity of HF. Given this exciting new tool in assessing volume status in patients with HF, we pose the question of whether this imaging modality can be used to risk-stratify patients and guide management. The aim of this paper is to highlight the many benefits of portable ultrasound in assessing volume status in this population, and to discuss whether this imaging modality can help guide physicians in the management of their HF patients.

Keywords: Heart failure; Portable ultrasound; Readmission

Introduction

Heart failure (HF) represents a significant financial burden to the US health care system, affecting approximately 5.7 million Americans [1]. By 2030, the prevalence of HF is expected to increase by 23% [2]. In 2012, the estimated annual cost for the management of HF patients was $30.7 billion, which may increase to $70 billion by 2030 [1]. Most of this cost is attributable to hospital admissions and readmissions [1]. It has been shown that patients hospitalized for HF have a 1-month readmission rate as high as 25% [3]. Acute HF can be classified into three forms: chronic HF exacerbation, which makes up about 75% of hospital admissions, new-onset HF, which makes up 20% of hospital admissions, and refractory HF with severely reduced ejection fraction, which represents approximately 5% of cases [4].

Diagnosing HF

It is now known that hemodynamic congestion from increases in intracardiac pressure occurs days to weeks prior to the onset of typical HF symptoms, such as weight gain and shortness of breath. Further complicating the matter is the fact that a large proportion of this population has increased lymphatic drainage as a compensatory response to chronic congestive HF (CHF). This, in turn, prevents the development of clinical signs of volume overload, such as edema, even when the patient is in a hemodynamically congested state. Currently, the only endorsed methods for acute HF diagnosis in the 2017 American College of Cardiology (ACC) guidelines are brain natriuretic peptide (BNP) levels or N-terminal pro-B-type natriuretic peptide (NT-proBNP) (class 1A), pre-discharge BNP or NT-proBNP (class IIA), and myocardial fibrosis markers (class IIB) [5]. McQuade et al revealed improved mortality outcomes and a decrease in hospitalization for a BNP level of 250 pg/mL or less, and for 30% decrease in serum levels of NT-proBNP prior to discharge [6]. However, serial testing of BNP to monitor response to therapy remains controversial. Moreover, an elevated BNP cannot be attributed solely to a cardiac cause; it is widely known that an elevated BNP may be related to advanced age, renal failure, obstructive sleep apnea, and critical illness. Similarly, elevated BNP may be seen in patients taking angiotensin receptor-neprilysin inhibitors, which are gaining popularity following the PARADIGM HF Trial [7]. These factors limit the utilization of BNP levels for guiding management. A receiver-operator curve comparing BNP to the maximum diameter of the inferior vena cava (IVC) have shown that the maximum diameter of the IVC has a greater likelihood of correctly predicting the need for repeat hospitalization after inpatient therapy for acutely decompensated CHF [8].

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Evaluation of HF

Clinicians generally evaluate volume status in patients with HF by visualizing jugular venous distension to estimate right atrial pressure; a method with an estimated accuracy of only 50% and is a class IB recommendation by the American Heart Association (AHA) [9]. This technique suffers from several issues, including difficulty of assessment in obese individuals. Additionally, an imaging study found that the distance between the right atrium (RA) and the sternal angle varies between individuals and with patient position [10]. More recently, wireless implantable pulmonary arterial hemodynamic monitoring devices can be placed in the pulmonary arteries to determine intracardiac pressures. Results from the CHAMPIONS trial have shown 37% relative reduction in HF hospital admissions ($P < 0.001$) in patients who were treated based on data from these devices [11]. However, this technique is invasive, expensive, and may not be possible for high risk for patients. In summary, these methods are not ideal for assessing volume status in HF patients.

It has been shown that the IVC diameter strongly correlates with central venous pressure, and that distention of the IVC reflects an elevated right atrial pressure [12]. Assessment of the IVC diameter with a portable ultrasound has proven to be a simple, reliable, and cost-effective method of evaluating right atrial pressure. It is routinely used in multiple emergency departments across the country to elucidate volume status and guide management in HF patients [13]. A European study found that in patients admitted for HF exacerbations the IVC diameter at discharge was a better predictor of readmission than NT-proBNP [14]. Furthermore, another study showed that for every 0.5-cm increase in IVC diameter, the risk of readmission increased by 38% [15].

In addition to IVC diameter, IVC collapsibility is another measurement of interest from which the IVC collapsibility index (CI) is derived. CI is defined as the percent change in diameter of the IVC through a respiratory cycle, calculated as (IVC expiration - IVC inspiration)/IVC expiration × 100% [12]. A prospective study compared multiple techniques including IVC diameter, lung ultrasound, bioimpedance analysis, and NT-proBNP to monitor a cohort of HF patients. On multivariate analysis, they found that IVC collapse, NT-proBNP, and lung ultrasound, but not bioimpedance analysis, were useful in predicting patients at high rates of readmission [16]. New prospective data were recently published, which studied IVC diameter and CI at discharge and hospital follow-up, concluded that larger IVC diameters with less collapsibility were significantly associated with 90-day readmission [17]. This lends credence to the utility of following ultrasound measurement of the IVC at outpatient follow-up appointments in predicting hospital readmission. Despite this promising data, some drawbacks of this method include anatomical variations, such as obesity. It is also subjected to observer variability and quality of the ultrasound device being used.

Treatment

The mainstay of treatment for acute decompensated HF is rescue therapy with diuretics, with monitoring of volume status. Nonetheless, there is no standardized method to assess the volume status of these patients which is reliable, reproducible, and non-invasive. Studies have shown there is no reduction in hospital readmission rates when relying on physician's subjective findings alone [18]. IVC diameter and CI have been shown to reliably assess the effectiveness of diuretic therapy in patients with HF [3]. Patient education is also an important factor in the management of HF. The patients need to be counseled on lifestyle modifications and advised about the importance of self-monitoring, to look for the warning signs that might signal acute failure. They can be instructed to take an extra dose of diuretics if they are gaining weight, becoming short of breath on exertion or noticing an increase in lower extremity edema. The recent trend of wearable activity monitors, and smartphone applications may improve patient involvement and patient insight towards their condition, however they did not show any reduction in hospitalization rates [19].

Conclusions

In conclusion, patients hospitalized for a HF exacerbation remain at high risk for readmission. Efforts to reduce HF readmissions have become a large focus of national initiatives such as the "Get with the Guidelines®" program, supported by the AHA. It has become evident that we need a more robust tool to reliably assess volume status in HF patients, both at hospital discharge and during routine follow-up. It has been postulated that assessing the IVC diameter with a portable ultrasound, may be answer to this problem. As more clinical data on the use of portable ultrasound in HF patients become available, there should be ongoing clarification regarding how best to utilize and implement this new tool at a population level.

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Conflict of Interest

The authors of this manuscript have no conflict of interest to disclose.

Author Contributions

All listed authors participated in drafting the article or revising it critically for important intellectual content.

Data Availability

The authors declare that data supporting the findings of this study are available within the article.

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