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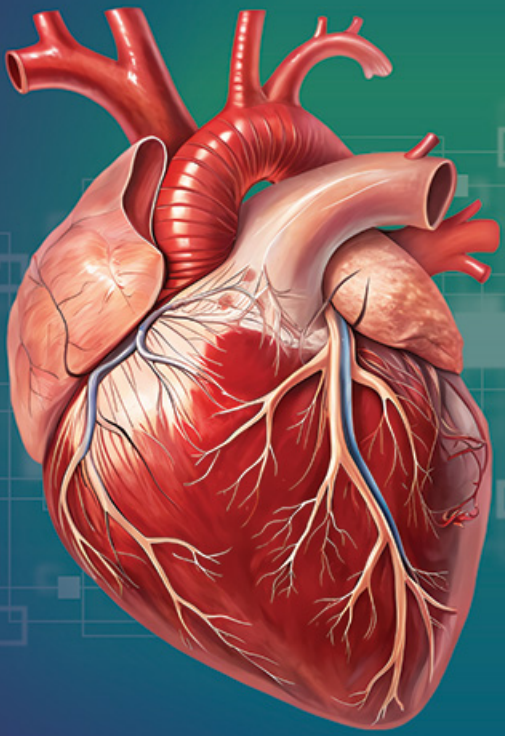

Alan S Maisel
Gerasimos S Filippatos

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CHAPTER

Using Natriuretic Peptides in the Emergency Department

Yang Xue, Elizabeth Lee, Jeffrey Chan, Sonal Sarkariya, Erik A Green, Alan S Maisel

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INTRODUCTION

Acute heart failure is a complex syndrome. Despite major advances in heart failure (HF) therapy, challenges still remain in the timely diagnosis of acute heart failure (AHF). This is due to the blurred lines between pulmonary and cardiac causes of acute dyspnea, which can lead to delayed or erroneous diagnosis for AHF, longer hospital stay, greater healthcare costs, higher morbidity, and mortality. For these reasons, biomarkers are used for rapid and accurate diagnoses of patients with acute dyspnea.

Today, natriuretic peptides are the most validated biomarkers in AHF diagnosis. Relevant biomarkers in the natriuretic peptide family are B-type natriuretic peptide (BNP), N-terminal pro-B-type natriuretic peptide (NT-proBNP), atrial natriuretic peptide (ANP), and mid-region pro-atrial natriuretic peptide (MR-proANP). In this group, ANP is made in the atria and cardiac ventricles, while BNP is made predominantly in the cardiac ventricles. Atrial natriuretic peptide and BNP counteract the physiological abnormalities of AHF by increasing glomerular filtration rate, increasing sodium and water excretion, relaxing arterioles and venules, increasing diastolic relaxation, decreasing myocardial fibrosis, inhibiting cardiac hypertrophy, as well as inhibiting renin and aldosterone secretion. Of the four natriuretic peptides, BNP, and NT-proBNP are the most widely used in today's clinical practice (Table 1).

Since ANP and BNP are mostly produced by the left cardiac ventricle, elevations of natriuretic peptide concentrations correlate well with elevated pulmonary capillary wedge pressure (PCWP)

TABLE 1: Characteristics of B-type natriuretic peptide and N-terminal prohormone B-type natriuretic peptide

	BNP	NT-proBNP
Components	BNP molecule	NT fragments (1–76) NT-proBNP (1–108)
Molecular weight	4 kD	8.5 kD
Genesis	Cleavage from NT-proBNP	Release from ventricular myocytes
Half-life	20 min	120 min
Clearance mechanism	Neutral endopeptidase clearance receptors	Renal clearance
Increase with normal aging	+	++++
Correlation with estimated glomerular filtration rate	–0.20	–0.60
Approved cutoff(s) for CHF diagnosis	100 pg/mL	Age <75: 125 pg/mL Age >75: 450 pg/mL
Studies completed	1,370	39
Entry on US market	November, 2000	December, 2002

B-type natriuretic peptide; NT-proBNP, N-terminal of the prohormone brain natriuretic peptide; CHF, congestive heart failure.

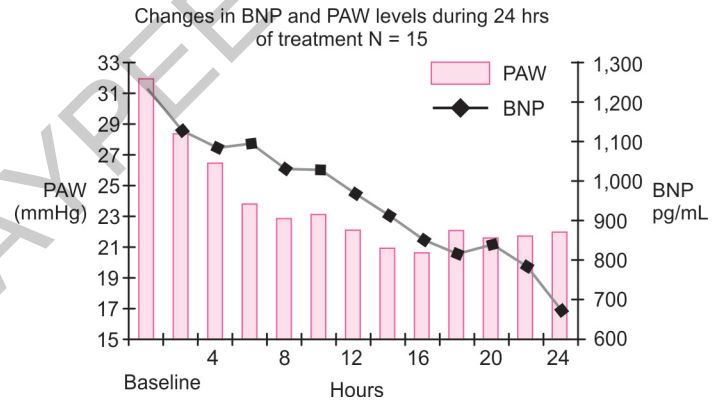

FIG. 1: Correlation between B-type natriuretic peptide and pulmonary artery wedge pressure

and increased left ventricular wall stress. This is seen in patients with severe aortic stenosis pre- and postaortic valve replacement, and in HF patients (Fig. 1). Increased ventricular wall stress leads

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to increased production of ANP and BNP by ventricular myocytes, typically in patients with hypertrophic cardiomyopathy. This correlation is the premise for using natriuretic peptide to diagnose for AHF in patients.

B-TYPE NATRIURETIC PEPTIDE: THE EVIDENCE

In 2002, the multicenter Breathing Not Properly trial demonstrated the effectiveness of BNP in the diagnosis of patients presenting to the emergency department (ED) with acute dyspnea. Patients with AHF had BNP levels of 675 ± 450 pg/mL, while patients without AHF had BNP levels of 110 ± 225 pg/mL. B-type natriuretic peptide was the single best predictor of AHF with an area under the receiver operating characteristic curve (AUC) of 0.91 (95% confidence interval: 0.90–0.93, p <0.001). A BNP cutoff of 100 pg/mL had a sensitivity of 90%, specificity of 75%, and diagnostic accuracy of 83%. B-type natriuretic peptide levels <50 pg/mL were associated with a negative predictive value (NPV) of 96%. In multiple logistic regression analysis, BNP >100 pg/mL was the strongest independent predictor of AHF with an odds ratio of 29.6.

N-TERMINAL PRO-B-TYPE NATRIURETIC PEPTIDE: THE EVIDENCE

The proBNP Investigation of Dyspnea in the Emergency Department (PRIDE) study, similar to the BNP trial, was intended to evaluate the diagnostic power of NT-proBNP. The average NT-proBNP level in AHF patients was 4,054 pg/mL (AUC 0.94, p <0.0001), while the average NT-proBNP level in patients without AHF was 131 pg/mL. Patients less than 50 years of age had an NT-proBNP cutoff of 450 pg/mL (sensitivity of 93%, specificity of 95%, diagnostic accuracy 95% for AHF). Patients more than 50 years of age, had an NT-proBNP cutoff of 900 pg/mL (sensitivity 91%, specificity 80%, diagnostic accuracy of 85% for AHF). In general, a concentration less than 300 pg/mL had a sensitivity of 99% and NPV of 99%. By multivariate analysis, NT-proBNP was the strongest predictor of AHF with an odds ratio of 44.0 (p <0.0001) and was better than clinician estimated likelihood for the diagnosis of AHF (AUC = 0.94 vs. AUC = 0.90). Adding NT-proBNP to clinician estimated likelihood of AHF improved the AUC from 0.90 to 0.96. Different optimal cutpoints of NT-proBNP were analyzed among patients with the physician estimated AHF likelihood of 0–25% (sensitivity

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96%, specificity 88% for AHF), 25–75% (sensitivity 93%, specificity 85% for AHF), more than 75% (sensitivity 93%, specificity 84% for AHF). Overall, NT-proBNP is a significant predictor of AHF.

ATRIAL NATRIURETIC PEPTIDE AND MID-REGION PRO-ATRIAL NATRIURETIC PEPTIDE: THE EVIDENCE

Although elevations of both BNP and ANP have been associated with AHF, ANP is inferior to BNP. Cowie et al. illustrated this difference between BNP [AUC 0.96, sensitivity 97%, specificity 84%, positive predictive value (PPV) 70%] and ANP (AUC 0.93, sensitivity 97%, specificity 72%, PPV 55%). The suboptimal result for ANP was due in part to its rapid clearance, thus limiting ANP's clinical application.

In comparison to ANP, mid-region (MR)-proANP is a much more stable and degradation resistant molecule. The diagnostic utility of MR-proANP in AHF was demonstrated in the Biomarker in Acute Heart Failure (BACH) trial. Midregional-proANP at cut point of 120 pmol/L (sensitivity 97%, specificity 59.9%, diagnostic accuracy 72.7%, PPV 56%, NPV 97.4) was superior to BNP at 100 pg/mL (sensitivity 95.6%, specificity 61.9%, diagnostic accuracy 73.6%, PPV 57%, NPV 96.4%) (Table 2). Furthermore, elevated MR-proANP added significantly to elevated BNP, increasing the C-statistic from 0.787 to 0.816 ($p < 0.001$). When both MR-proANP and BNP were elevated, the overall diagnostic accuracy increased from 73.6% for BNP alone to 76.6%. In patients with intermediate BNP levels and obesity, MR-proANP added incremental predictive value to BNP for the prediction of AHF. In patients with intermediate NT-proBNP levels, renal insufficiency (creatinine >1.6 mg/dL), obesity, age more than 70, and edema, MR-proANP also added incremental predictive

TABLE 2: Mid-region pro-atrial natriuretic peptide (MR-proANP) versus B-type natriuretic peptide for diagnosis of acute heart failure in the Biomarkers in Acute Heart Failure trial

Measure	Sensitivity	Specificity	Accuracy
MR-proANP 120 pmol/L	95.56	59.85	72.64
BNP 100 pg/mL	96.98	61.90	73.50
Difference	1.42	2.05	0.86
Upper 95% limit	2.82	3.84	2.10
Noninferiority p	<0.0001	<0.0001	<0.0001

MR-proANP, mid-region pro-atrial natriuretic peptide; BNP, B-type natriuretic peptide.

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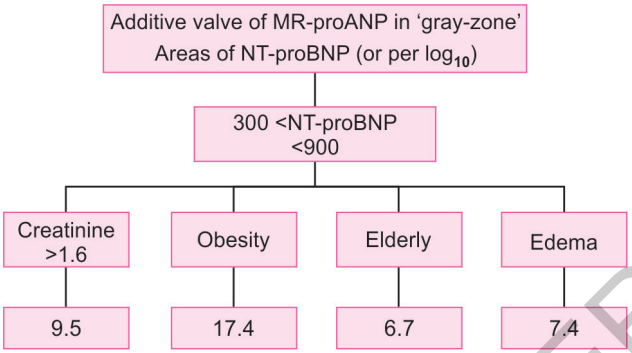

MR-proANP, mid-region pro-atrial natriuretic peptide; NT-proBNP, N-terminal pro-B-type natriuretic peptide.

ALGORITHM 1: Incremental predictive value of adding mid-region pro-atrial natriuretic peptide to gray zone N-terminal pro-B-type natriuretic peptide for the diagnosis of acute heart failure

value to NT-proBNP for the prediction of AHF (Algorithm 1). In the subgroup of patients where the ED physicians were uncertain of the diagnosis, defined as 20–80% probability of AHF on a visual analog scale, the addition of MR-proANP reduced indecision by 29%.

USING NATRIURETIC PEPTIDES IN THE EMERGENCY DEPARTMENT

We propose the following algorithm in conjunction with history and physical examination for diagnostic evaluation. Patients with BNP levels less than 100 pg/mL or NT-proBNP less than 300 pg/mL would less likely have AHF (<2% likelihood). These patients should then be further evaluated for an alternative etiology for their acute dyspnea. In patients with acute dyspnea and BNP levels more than 500 pg/mL or NT-proBNP levels above an age dependent cutoff (>450 pg/mL in patients <50 years old or >900 pg/mL in patients 50–75 years of age, or >1,800 pg/mL in patients >75 years of age), AHF is very likely (>95% likelihood).

Acute heart failure therapy should be initiated immediately with diuretics to reduce the intravascular volume and left ventricular preload. If the patient has no cardiogenic shock, vasodilators can be added when hypertensive. Inotropes can also be considered in these patients if they need aid in diuresis. In patients with cardiogenic shock, both inotrope and vasodilators may be necessary to improve cardiac output by increasing contractility

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and decreasing afterload. For patients with natriuretic peptide levels in the gray zone (all ages: BNP 100–500 pg/mL; age >50: NT-proBNP 300–450 pg/mL; ages 50–75: NT-proBNP 300–900 pg/mL; age >75: NT-proBNP 300–1,800 pg/mL), history of HF, and left ventricular dysfunction, AHF is highly probable (90% likelihood). Consequently, these patients should receive empiric treatment for AHF with diuretics and vasodilators as needed and observed closely. If there is no history of HF or left ventricular dysfunction, then an evaluation for acute coronary syndrome, cor pulmonale, or acute pulmonary embolism should be considered and treated accordingly. If there is evidence of other cardiac issues, then the gray zone natriuretic peptide levels are unlikely to represent AHF (<25% likelihood), as these patients usually have higher natriuretic peptide levels during AHF. These patients should be closely observed and evaluated for an alternative diagnosis. In inconclusive patients, gray zone natriuretic peptide levels may still represent AHF (>75% likelihood) and therapy should be initiated (Algorithm 2).

Although not widely available, MR-proANP can also be used for the diagnostic evaluation of patients with acute dyspnea. Patients with MR-proANP levels less than 120 pg/mL are unlikely to have AHF. Patients with MR-proANP levels more than 600 pg/mL are very highly to have AHF. The gray zone for MR-proANP is 120–600 pg/mL. When available, MR-proANP levels should be measured in patients with BNP or NT-proBNP levels in the diagnostic gray zone to increase the diagnostic accuracy of natriuretic peptides in patients with obesity (intermediate BNP levels), renal insufficiency (intermediate NT-proBNP levels), and advanced age (intermediate NT-proBNP levels) (Algorithm 1).

In patients with chronic HF, diagnosing AHF using natriuretic peptides can be intricate. Patients with preexisting HF can have significantly elevated natriuretic peptide levels at baseline owing to chronically elevated PCWP from severe underlying HF and renal dysfunction. Thus, it is not unusual to see BNP levels more than 500 pg/mL and NT-proBNP levels more than 1,800 pg/mL in patients with existing HF who do not have AHF. In these patients, it would be very helpful to know their optivolemic or "dry" natriuretic peptide levels when they are clinically euvolemic. If their presenting natriuretic peptide levels are elevated more than 50% from baseline, then AHF is likely. Empiric therapy for AHF should be implemented as soon as possible. However, if their presenting natriuretic peptides levels are not elevated more than 50% from baseline, then AHF is unlikely. These patients should be observed (Algorithm 3).

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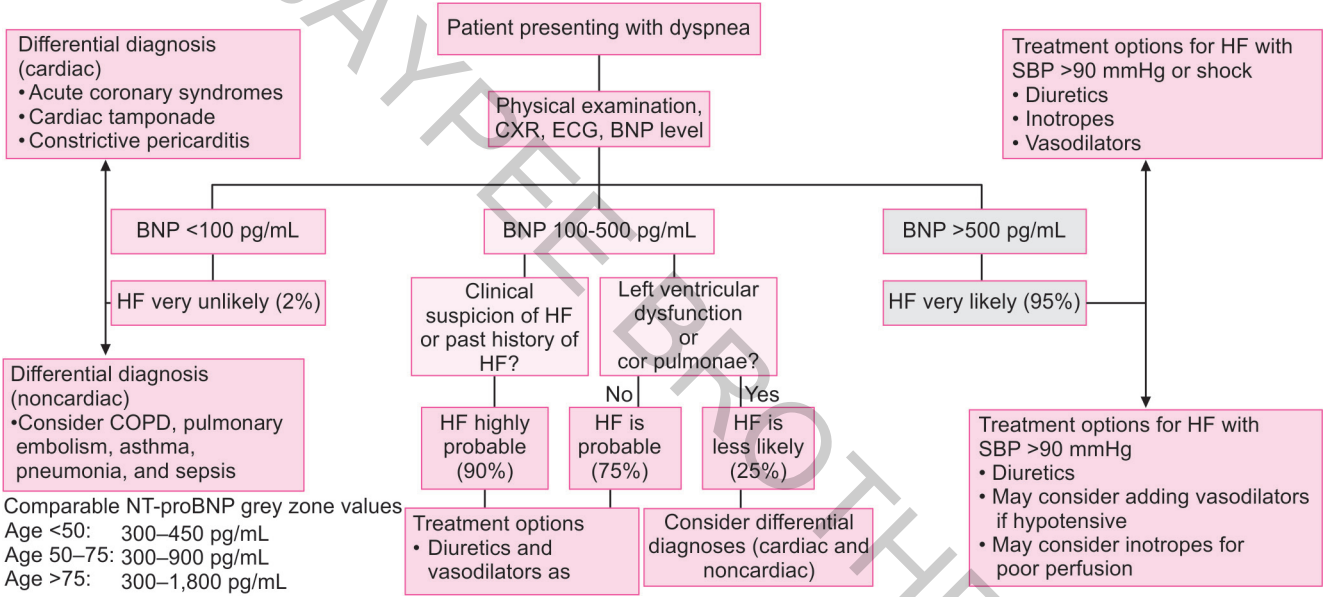

CXR, chest X-ray; BNP, B-type natriuretic peptide; ECG, electrocardiogram; HF, heart failure; ; COPD, chronic obstructive pulmonary disease; systolic blood pressure.

ALGORITHM 2: Algorithm on using B-type natriuretic peptide and N-terminal B-type natriuretic peptide (NT-proBNP) levels to rule in and rule out acute heart failure.

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Once AHF is diagnosed, serial measurements of natriuretic peptide can be used to guide therapy. We propose the following algorithm for natriuretic peptide guided therapy in AHF patients in the ED. In patients age less than 50 with BNP more than 1,000 pg/mL or NT-proBNP less than 900 pg/mL, ages 50–75 with BNP more than 1,800 pg/mL, and age more than 75 with BNP more than 3,600 pg/mL, the AHF is likely severe and these patients would benefit from inpatient therapy. However, if the patient's BNP is 500–1,000 pg/mL or NT-proBNP between 300 pg/mL and an age dependent upper limit (>900 pg/mL for age <50, >1,800 pg/mL for ages 50–75, and >3,600 pg/mL for age >75), an intensive treatment approach with diuretics and vasodilators in the ED can be considered. Meanwhile, natriuretic peptide levels should be checked every 3 hours. If the patient experiences improvement and a reduction in natriuretic peptide levels, then they can be discharged with close outpatient follow-up. Conversely, if the patient does not experience any improvement and stable natriuretic peptide levels, then the patient should be admitted for further therapy. For patients with known HF presenting with acute dyspnea and natriuretic peptide levels 50% higher than baseline, inpatient therapy is often necessary, especially if their presenting BNP level is more than 1,000 pg/mL or NT-proBNP level is greater than an age-dependent cutoff (>900 for age <50, >1,800 for ages 50–75, and >3,600 for age >75). Finally, for patients with gray zone NP levels (BNP 100–500 pg/mL, age <50: NT-proBNP 300–450 pg/mL, ages 50–75: NT-proBNP 300–900 pg/mL, age >75: NT-proBNP 300–1,800 pg/mL) who do not have an alternative explanation for their acute dyspnea, empiric therapy for AHF should be attempted in the ED. If they experience improvement in their symptoms with empiric AHF therapy, then they can be discharged with close outpatient follow-up and further evaluation for HF. If they do not experience improvement in their symptoms, then they should be admitted for continued observation and evaluation (Algorithm 3).

When using natriuretic peptides, there are some important caveats that clinicians must keep in mind. First, natriuretic peptide elevations are not pathognomonic for AHF. They should never be used in isolation during the diagnostic evaluation of patients with acute dyspnea. As shown by prior studies, natriuretic peptide levels can increase due to variety of other reasons such as age, weight, gender, renal dysfunction, and other cardiac and noncardiac ailments. Another aspect of natriuretic peptide levels that the clinician must keep in mind is that although there is a correlation between PCWP and natriuretic peptide levels, NP levels do not

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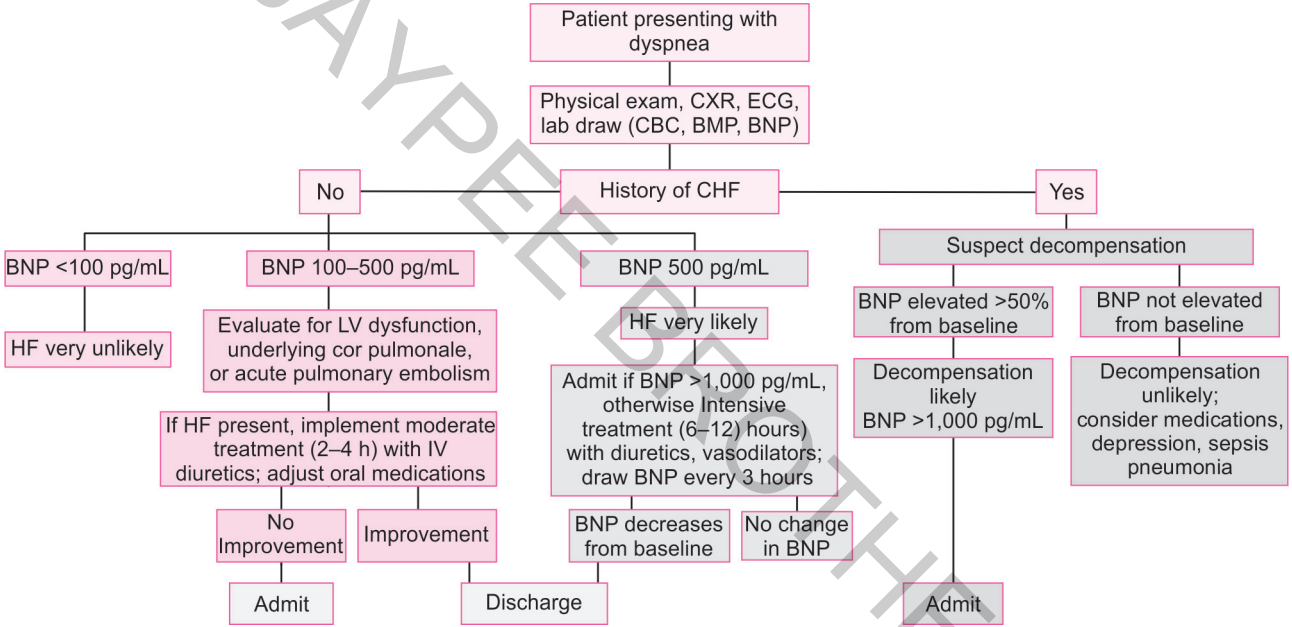

BMP, basic metabolic panel; BNP, B-type natriuretic peptide; CBC, complete blood count; ECG, electrocardiogram; HF, heart failure; LV, left ventricular.

ALGORITHM 3: Algorithm for the management of heart failure in an emergency department setting

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change "instantaneously". In situations of acute increases in left ventricular filling pressure, there is a delay in the rise of NPs as the intracellular production of NPs is ramped up. Thus, in patients with clear evidence of flash pulmonary edema, a low natriuretic peptide level cannot be used to rule out AHF. Lastly, not all HF is caused by increases in left ventricular filling pressures. Conditions such as mitral stenosis and constrictive pericarditis can cause significant HF symptoms without causing elevations of left ventricular filling pressures. Thus, the natriuretic peptide levels may be low in these cases.

CONCLUSION

Natriuretic peptides with their low cost, objectivity, reproducibility, and accessibility are excellent adjuncts to physical examination, standard laboratory, and imaging studies in diagnosing both acute systolic heart failure and acute diastolic heart failure quickly in the ED. Besides having a high sensitivity and specificity for AHF, they have high discriminatory power in cases where the diagnosis is indeterminate. Additionally, natriuretic peptide assays are fast and reliable, thereby reducing ED evaluation time, hospital admission rates, hospital length of stay, and overall healthcare cost without increasing mortality or morbidity. Hence, we suggest the incorporation of natriuretic peptide to the standard evaluation of all patients presenting to the ED with acute dyspnea.

KEY POINTS

- Acute heart failure is a common diagnosis among hospitalized patients
- Although acute dyspnea is a common presenting symptom among patients with AHF, differentiating between patients with pulmonary diagnosis and AHF remains a challenge
- Natriuretic peptides are highly effective in assisting the diagnostic evaluation of patients with AHF in the emergency department
- Natriuretic peptide help not only in increasing the diagnostic accuracy of AHF and also decrease diagnostic uncertainty in the emergency department (ED)
- They can also decrease ED and hospital length of stay without increasing risk for adverse outcomes
- Furthermore, level of natriuretic peptides can be used to guide therapy for AHF patients in the ED.

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