

Acute Congestive Heart Failure in the Emergency Department

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Acute congestive heart failure (CHF) and pulmonary edema is a clinical entity commonly encountered in the emergency department. It is estimated that more than 5 million people in the United States have CHF, and it is expected that as the population ages the incidence of CHF and emergency department visits for acutely decompensated CHF and pulmonary edema will rise [1,2]. As survival rates for acute myocardial infarction continue to increase, the incidence of heart failure is expected to increase as well. The estimated prevalence of CHF in adults over the age of 75 years is 10%, with a lifetime risk of almost 20% [3]. In the Acute Decompensated Heart Failure National Registry (ADHERE), a large, national database of demographic, clinical, and outcomes data for patients hospitalized for decompensated CHF, the emergency department is the initial site of care for more than 78% of patients who have acute symptomatic heart failure [4].

The syndrome of CHF is most commonly defined as a state in which cardiac abnormalities cause cardiac dysfunction so that the heart is unable to meet the circulatory demands of the body or does so with elevated filling pressures. Clinically, this syndrome causes symptoms of reduced exercise tolerance or signs of fluid retention. Congestive heart failure commonly is

a result of systolic dysfunction but can also occur in the setting of normal systolic dysfunction.

The presentation of decompensated CHF is variable and ranges from mild dyspnea on exertion to acute, severe pulmonary edema. Critically ill patients who have acute, cardiogenic pulmonary edema pose the greatest clinical challenge. The primary role of the emergency physician is to perform a rapid assessment of the patient, develop an initial differential diagnosis for entities that could have led to the decompensation, and determine what therapies are indicated. Patients in extremis from acute pulmonary edema require the most aggressive care. In the emergency department, treatment strategies are tailored to the acuity and severity of the CHF exacerbation.

Evaluation and management in the emergency department

The emergency physician's role in the stabilization, evaluation, and treatment of the patient who has decompensated CHF is critical. Although no data exist for a "golden hour" in treating CHF, a thorough workup, triage, and treatment strategy initiated by the emergency physician is likely to have a significant impact on patient morbidity and mortality. To emphasize this point, a study by Sacchetti and colleagues [5] has shown that pharmacologic interventions started in the emergency department reduce the need for ICU admission and endotracheal intubation. Thus, emergency department treatment of

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the CHF patient has the potential to save money and lives.

A careful analysis of past medical history and chief complaint is crucial for accurately diagnosing acute CHF and its potential cause. A clear understanding of the categories and specific causes of cardiomyopathies is essential. Broad categories include dilated, hypertrophic, restrictive, and arrhythmogenic right ventricle. Specific causes are ischemic, valvular, hypertensive, inflammatory, metabolic, toxic, peripartum, genetic, and idiopathic (Box 1).

The interview of a patient who has potential heart failure should include several crucial questions. The interviewer can quickly and accurately discover whether the patient has a history of CHF or risk factors for the development of heart failure: coronary artery disease, diabetes, hypertension, arrhythmias, valvular disease. It is also important to verify whether the patient has symptoms consistent with angina, which could indicate an acute coronary syndrome as an inciting event triggering CHF. In addition, a survey in search of inciting factors for acute decompensation is warranted. Common factors leading to CHF include myocardial ischemia or infarct, new-onset arrhythmias (especially atrial fibrillation),

medical noncompliance, and dietary indiscretion. Less common but certainly well-known inciting factors include infection and diuretic resistance.

Evaluation of the patient who has acute CHF (pulmonary edema) begins with a thorough assessment of the patient's airway, respiratory status, and circulation. An assessment of the patient's airway should be the first step in management, because patients who have hypoxemia or altered mental status may require immediate endotracheal intubation before further workup can proceed. Patients who are compromised but not in need of emergent intubation can be treated with noninvasive means of ventilation such as continuous positive airway pressure (CPAP) or bilevel positive airway pressure (BiPAP) as a temporizing measure. Large-bore intravenous catheters should be placed. Once it has been established that the airway is secure, an assessment of the patient's breathing and circulation can begin.

Acute medical therapy for heart failure should be considered as distinct from treatment for chronic heart failure. In the acute treatment of decompensated heart failure the goals are threefold: to stabilize the patient clinically, to normalize filling pressures, and to optimize perfusion to vital organs. Diuretics, vasodilators, and positive inotropic agents can be used to achieve these goals. In severely compromised patients mechanical support with an intra-aortic balloon pump may be warranted. In contrast, the goals for the chronic management of heart failure include improvement of morbidity and mortality.

Stabilization measures, diagnostic testing, and medical management begin in the emergency department. Vital signs should be assessed immediately, supplemental oxygen should be administered, and the patient should be placed on a cardiac monitor. All patients should have a 12-lead ECG obtained upon arrival. A complete blood cell count, renal function, and electrolytes should be obtained on all patients. Patients who have an unclear cause of their dyspnea should have a B-type natriuretic peptide (BNP) drawn, because this test may help differentiate CHF from other pulmonary disease. Patients who have the potential for ischemia should have cardiac biomarkers drawn in the emergency department to assess for myocardial infarction as the precipitant of decompensated heart failure. If available, bedside transthoracic echocardiography can be performed to assess left ventricular function and to evaluate for entities such as pericardial effusion

Box 1. Differential diagnosis of acute CHF/pulmonary edema

Coronary artery disease

- Acute myocardial infarction
- Myocardial ischemia
- Mechanical complications of acute myocardial infarction (papillary muscle rupture)

Valvular disease

- Aortic stenosis
- Aortic regurgitation
- Mitral regurgitation
- Mitral stenosis

Myocardial disease

- Hypertrophic cardiomyopathy
- Dilated cardiomyopathy (eg, idiopathic, familial)
- Myocarditis
- Hypertension
- Peripartum
- Toxic and metabolic (eg, alcohol, cocaine)

and valvular dysfunction. There are limited data on emergency physician–performed bedside ultrasound to estimate left ventricular function. A study by Randazzo and colleagues [6] evaluated the use of echocardiography performed by emergency physicians. It was found that after a small amount of focused training emergency physicians could assess left ventricular ejection fraction accurately in the emergency department. After stabilization of the patient, a search for the cause and precipitant of CHF/pulmonary edema should be undertaken, because detection of specific cause might have a significant impact on treatment.

Currently there are no guidelines for the management of acutely decompensated heart failure in the emergency department. DiDomenico and colleagues [7] published a set of guidelines in 2004 for the initial therapy of CHF in the emergency department. The proposed algorithm relies on a rapid assessment of the patient's overall volume status with the initial treatment approach aimed at alleviating pulmonary congestion and improving cardiac output. Patients with milder degrees of volume overload may respond to intravenous diuretics, whereas patients who have low cardiac output and moderate to severe volume overload need an approach that combines volume management, preload and afterload reduction, and inotropic support.

Noninvasive airway management

In many instances, patients do not require immediate control of their airway by endotracheal intubation but might need additional assistance to decrease their work of breathing. It has been established that noninvasive ventilation (CPAP or BiPAP) is an effective means of providing ventilatory support for critically ill patients who have acutely decompensated CHF and pulmonary edema [8]. Noninvasive ventilatory strategies using modes like CPAP work by limiting decline in functional residual capacity, improving respiratory mechanics and oxygenation, and decreasing left ventricular preload and afterload [9–11]. Two randomized studies have also found beneficial physiologic effects by showing a significant reduction in endotracheal intubation rates in patients who had acute cardiogenic pulmonary edema [12,13].

Previously, studies examining noninvasive ventilation have been performed in the ICU when respiratory failure was already present. In a study by Nava and colleagues [11], noninvasive pressure

support ventilation (NPSV) was compared with conventional oxygen therapy in the treatment of acute cardiogenic pulmonary edema. In this multicenter emergency department study, 130 patients who had acute respiratory failure secondary to cardiogenic pulmonary edema were randomly assigned to traditional medical therapy including oxygen (65 patients) or NPSV (65 patients). The main outcome measured was the need for intubation. NPSV provided faster improvement in the ratio of arterial oxygen saturation to inspired oxygen concentration ($\text{PaO}_2/\text{FIO}_2$), respiratory rate, and dyspnea. Although the rates of intubation, hospital mortality, and duration of hospitalization were similar in the two groups, a subgroup of hypercapnic patients did benefit from the therapy and had a decreased intubation rate (2 of 33 versus 9 of 31). This study lends credence to the anecdotal evidence that noninvasive ventilation is effective in relieving the work of breathing and in some cases in preventing endotracheal intubation [11].

B-type natriuretic peptide as a diagnostic tool in the emergency department

Among the tools available to the emergency physician for the assessment of the patient who has undifferentiated dyspnea or suspected heart failure, no test has been proven as useful as BNP. This peptide is released into the circulation when ventricular stress is present and has been shown to assist in the diagnosis of CHF and to help differentiate it from other syndromes [14]. The ability to measure this peptide to aid diagnosis and to use as a prognostic indicator represents a major advance in the diagnosis and management of CHF. Some studies have shown that measurement of BNP can reduce hospitalization rates, reduce length of stay, and may help resource use and possibly even improve survival [15].

There are some limitations of using BNP as a diagnostic aid in the emergency department. Interpretation of the test should be used in conjunction with other clinical data and judgment and as an adjunct only [16]. Also, a number of other conditions have been shown to elevate BNP levels. It should never be assumed that elevated BNP levels alone indicate CHF. **Box 2** reviews the reasons for a falsely elevated BNP (in the absence of heart failure) and the reasons for a falsely low BNP.

Box 2. Conditions that affect BNP levels*Conditions that can elevate BNP levels*

Right-sided heart failure
 Pulmonary embolism
 Myocardial infarction
 Advanced age
 Renal failure

Conditions that cause lower-than-expected BNP levels

Obesity
 Acute pulmonary edema
 Mitral stenosis
 Acute mitral regurgitation

Several studies have investigated the use of BNP as a diagnostic test. The Breathing Not Properly (BNP) trial showed that, in patients presenting to the emergency department with acute dyspnea, the diagnostic accuracy of BNP measurement was 81% for a BNP level greater than 100 pg/mL compared with an accuracy of 74% for clinical judgment [17]. In fact, a BNP level of 100 pg/mL or greater provides a sensitivity of 90%, specificity of 76%, positive predictive value of 79%, and a negative predictive value of 89%. The overall accuracy in the study was determined to be 81%. A BNP level of 500 pg/mL or greater has been shown to indicate a 95% probability of heart failure [18]. Recent results from the Rapid Emergency Department Heart Failure Outpatient Trial (REDHOT) showed that BNP levels might also be useful in the assessment of disease severity and prognosis. This study evaluated 464 patients presenting to the emergency department with dyspnea and BNP levels greater than 100 pg/dL. BNP was found to be a predictor of events and mortality [19].

Volume management

Diuretics are the first-line therapeutic modality to consider in acute treatment of CHF. Although diuretics have no proven mortality benefit, they effectively relieve symptoms of congestion, pulmonary edema, extremity swelling, and hepatic congestion. The acute effect of diuretics in patients who have heart failure-related volume overload is to reduce left ventricular filling pressures. There is no acute increase in cardiac output.

Many patients who have chronic heart failure are taking stable doses of loop diuretics as outpatients. Therefore, it is important in the acute setting to administer a dose of intravenous diuretic to achieve the desired therapeutic effect. In general, with normal renal function, two times the oral dose is given intravenously in the acute setting. With abnormal renal function, two and half times the oral dose is generally required to achieve the desired effect.

It should be obvious within 2 hours whether a patient will respond to initial intravenous diuretic therapy. If not, and if diuretic resistance is suspected, it is likely that the patient will require hospital admission for other fluid removal therapy. These measures may include escalating doses and combination diuretic therapy, ultrafiltration, or parenteral therapy.

Vasodilator therapy

For the patient who presents to the emergency department with acutely decompensated CHF, vasodilator therapy should be initiated to achieve reduction in preload and afterload. The use of intravenous vasodilators to treat acute heart failure and pulmonary edema makes sound physiologic sense, because the underlying mechanism of dyspnea and respiratory distress relates to elevated filling pressures. Several different forms of vasodilators are currently available. Most act to reduce filling pressures and systemic vascular resistance, thereby increasing cardiac function. Therapy should be individualized [20,21].

Nitroglycerin

Nitroglycerin traditionally has been the vasodilator of choice in the treatment of acutely decompensated heart failure and pulmonary edema. Nitroglycerin acts primarily to lower preload by increasing venous capacitance. The lowered preload in turn reduces ventricular filling pressure and volume and leads to a decrease in myocardial oxygen consumption. Nitrates also cause coronary vasodilatation, which may be beneficial if ischemia is the underlying precipitant of acute heart failure. Nitroglycerin's effect on the arterial side is seen mainly when high doses are used, in excess of 30 µg per minute. In cases of acutely decompensated heart failure and pulmonary edema, nitroglycerin can be given sublingually while an intravenous drip is prepared [22]. Use of nitroglycerin should be considered for any patient who presents with

acutely decompensated CHF, particularly in cases of pulmonary edema and respiratory distress. Drawbacks to its use include its contraindication in patients taking phosphodiesterase-5 inhibitors for erectile dysfunction (sildenafil, tadalafil, vardenafil) and side effects such as headache.

Angiotensin-converting enzyme inhibitors

The use of angiotensin-converting enzyme (ACE) inhibitors to treat acutely decompensated CHF and pulmonary edema has been a controversial topic among cardiologists and emergency physicians. There are anecdotal reports of rapid improvements in patients who had acute cardiogenic pulmonary edema after of sublingual or intravenous administration of ACE inhibitors. Is there, however, any evidence in the literature to support these reports?

In a study of 24 patients who had acute cardiogenic pulmonary edema, Haude and colleagues [23] showed that significant hemodynamic changes were induced by the acute administration of sublingual captopril. Captopril caused an increase in stroke volume and was also found to decrease systemic vascular resistance. Although no firm conclusions can be drawn from this study, it did indicate that ACE inhibitors could affect parameters shown to be problematic in patients who have acute pulmonary edema, namely elevated peripheral vascular resistance. Hamilton and colleagues [24] studied the effects of adding an ACE inhibitor to the usual therapy of oxygen, nitrates, morphine, and diuretics (furosemide) in the treatment of acute pulmonary edema. He found that the addition of an ACE inhibitor produced more rapid clinical improvement than the standard treatment. Again, this study was small and evaluated only 48 patients. In a placebo-controlled, randomized, double-blind trial of intravenous enalapril in patients who had acute cardiogenic pulmonary edema, Annane and colleagues [25] showed that early administration of intravenous enalapril was effective and well tolerated in patients who had acutely decompensated heart failure. Of course, vasodilation may have been the cause of the benefit seen in these small studies. Acute ACE inhibition can cause renal dysfunction in patients who are intravascularly depleted, however, and therefore should not be the vasodilator of choice in patients who have unknown renal function or intravascular volume status. To date, there has not been a large, randomized study of ACE inhibitor use in acute

pulmonary edema or comparisons with other vasodilators.

Nitroprusside

Nitroprusside is a potent arterial and venous vasodilator and can be used to treat acutely decompensated heart failure in specific circumstances. Nitroprusside was one of the first vasodilators used in the management of acute heart failure. Patients who have acute mitral or aortic regurgitation may benefit from the use of nitroprusside. In addition, the drug is useful in patients who have cardiogenic pulmonary edema in the setting of severely elevated blood pressure. Caution should be exercised, however, if ischemia is a possible underlying mechanism, because nitroprusside administration has been shown to induce a "coronary steal" phenomenon and worsen cardiac ischemia. Drawbacks of nitroprusside include the need for invasive hemodynamic monitoring and the side effects of accumulation of cyanide and thiocyanate.

Nesiritide

Nesiritide is a vasodilator that has been shown to decrease pulmonary artery and pulmonary capillary wedge pressures in patients who have heart failure [26]. It has also been advocated as an acute treatment in the emergency department with the goal of decreasing hospitalization rates. The argument is that starting active therapy earlier will lead to quicker resolution of symptoms and shorter hospital stays.

Unfortunately, beneficial outcomes of nesiritide have never been documented in a randomized, blinded, controlled study. Indeed, recent studies have suggested that nesiritide may actually decrease survival [27] and increase the rate of renal dysfunction [28]. Despite a common belief that renal function and urine output improve with nesiritide, this improvement has never been documented in heart failure patients receiving currently used doses [29].

It is clear that the vasodilation caused by nesiritide can lead to clinically significant hypotension. Thus, it is contraindicated in patients who have a systolic blood pressure less than 90 mm Hg. It should be used very cautiously in patients who have ischemic heart disease, especially those suspected of having myocardial infarction, because hypotension can be particularly detrimental in these patients.

As a vasodilator, nesiritide can clearly decrease symptoms associated with increased volume and left ventricular filling pressures. Diuretics and other vasodilators have the same potential actions, however. Analyses of large databases have suggested better outcomes with nesiritide [30], but these uncontrolled studies with many potential biases should not be misused to support conclusions that can be provided only by well-designed investigations. Indeed, the findings of one analysis that patients not receiving nesiritide were more likely to be discharged to extended care facilities suggests that the patients receiving nesiritide were healthier and different from patients who received other care.

At present, nesiritide can be used in patients who have adequate blood pressure and symptomatic heart failure until the effects of more definitive therapy can take hold. It is expensive, however, and physicians should not assume that it improves outcomes or affects renal function.

Inotropes

Inotropic therapy is commonly used to treat the sickest patients. Although its potential adverse effects are now well accepted, the mainstay of treatment of patients who have worsening renal function or suggestion of other end-organ damage continues to include dobutamine or milrinone. This use arises mostly from lack of other options and has not been supported by studies; inotropic therapy which increases cAMP by receptor stimulation (dobutamine) or phosphodiesterase inhibition (milrinone) has never been shown to be beneficial. Fortunately, studies of newer interventions are being undertaken and may provide pharmacologic options for the sickest patients.

The few randomized studies of inotropic therapy have been disappointing. Chronic therapy has been shown to be detrimental [31,32], and in-hospital use has also been shown to be of no benefit. The Outcomes of a Prospective Trial of Intravenous Milrinone for Exacerbations of Chronic Heart Failure (OPTIME-CHF) study tested the hypothesis that milrinone given to patients hospitalized because of heart failure would lead to shorter hospitalizations and improved outcomes as compared with placebo [33]. The study demonstrated no improvement in patients receiving milrinone, however, and mortality, arrhythmia, and myocardial infarction rates tended to be worse. Furthermore, adverse events and the incidence of sustained hypotension were statistically worse

in patients receiving active drug. OPTIME-CHF clearly demonstrated that milrinone should not be used routinely in patients hospitalized for heart failure.

The applicability of OPTIME-CHF to sicker patients, however, is uncertain. Investigators did not randomize patients who were thought to need inotropic therapy; these patients were given active drug. Thus, the impact of milrinone in patients who have worsening renal function or refractory symptoms is unknown. Although the randomized studies of chronic inotropic use and the OPTIME-CHF study led to concern that inotropic therapy may be detrimental, the OPTIME-CHF data cannot be extrapolated to the sickest patients. There are few studies of these patients. Nevertheless, retrospective data also raise concern about the utility of conventional inotropic therapy. Of course, such data are limited by differences between groups of patients that cannot be controlled for by any statistical analysis.

Recent controlled data do support the concept that adrenergic agents and phosphodiesterase inhibitors may be harmful. Levosimendan is a novel agent that increases calcium sensitivity. In one study, the comparison of levosimendan and dobutamine showed improved survival with levosimendan [34]. Whether this improved survival reflects benefits of levosimendan or harm of dobutamine (or both) is not known. Some studies demonstrate better outcome with levosimendan than with placebo and provide hope that levosimendan will prove to increase survival and decrease symptoms [35]. The composite outcome in the ongoing Randomized, Multicenter Evaluation of Intravenous Levosimendan Efficacy Versus Placebo in the Short Term Treatment of Decompensated Chronic Heart Failure (REVIVE) study may help illuminate whether levosimendan is truly beneficial.

One problem regarding analyses of older studies of inotropic therapy is that concomitant therapies were very different. Those studies were not performed with patients taking beta-adrenergic blocking agents or even ACE inhibitors. It is certainly possible that the effects of an inotropic agent will be different in patients receiving modern therapy. For this reason studies of enoximone are in process and may lead to a better understanding of the effects of inotropic therapy.

Despite these concerns, with present knowledge and available agents, physicians appropriately still find it necessary to use dobutamine and milrinone in selected patients. When these agents

are used, a few factors should be considered. First, because many patients arrive at the emergency department taking chronic β -blocking therapy, an agent that is still effective may be preferable. The effects of dobutamine are more likely to be impacted by β -blocking agents [36], and milrinone may be the preferred drug in these patients.

Tolerance to these drugs should also be considered in patients who have received them for a prolonged period. Decreased expression of receptors may lead to decreased contractility (as compared with before initiation of dobutamine) if the drug is abruptly stopped. Therefore, any patient who has been taking dobutamine for more than 1 day should be weaned off it slowly. In the sickest patients, weaning may take many days. Although changes in receptors do not affect the efficacy of milrinone, drug weaning may also be needed in patients receiving this drug.

Beta-adrenergic blockers

With the multiple studies showing marked benefit when beta-adrenergic blockers are given chronically to patients who have heart failure, these drugs are occasionally prescribed for acutely decompensated patients. These patients often have a tachycardia, which is tempting to treat. Beta-blockers are negative inotropic, however, and will decrease contractility. Although their chronic effect is to improve cardiac function, a dose of a beta-blocker will impair cardiac performance. In a decompensated patient, they are likely to lead to deterioration and should not be used.

A common question is what to do with beta-adrenergic blockers in patients who present with worsening heart failure. Although their negative inotropic properties can certainly decrease contractility in compromised patients, it is also known that abrupt withdrawal of these agents can lead to adverse consequences. Furthermore, if the drugs are not given for a prolonged period, retitration may take weeks or months. Unfortunately, there are no studies indicating how to deal with this situation.

Each case must be evaluated individually. A patient who presents with fluid overload and an anticipation of rapid improvement with diuresis probably does not need to have the beta-blocker withheld. Conversely, giving a beta-blocker to someone in cardiogenic shock will undoubtedly make the situation worse. At times, halving the dose may provide acute help while making it

simple to titrate back to a therapeutic dose when the patient stabilizes.

Of course, someone who deteriorates with initiation or increasing titration of a beta-blocker (usually occurring approximately 1 week after the change) [37] may be helped by decreasing the dose. Even in some of these patients, however, all that is needed is diuresis and time to accommodate to the new dose.

Some patients present to the emergency room with primary tachycardia [38]. Atrial fibrillation with a rapid ventricular response or a supraventricular tachycardia in a patient who has poor cardiac function may be particularly difficult to treat. Although a slower rate may improve hemodynamic parameters, agents that are negative inotropic (such as calcium-channel blockers or beta-blockers) might cause deterioration. In such patients, the risk of these agents must be remembered. This situation is ideal for the use of esmolol, which can be tried but discontinued with immediate reversal of its effects. If improvement is seen in clinical status and heart rate, a longer-acting beta-blocker can be given. In contrast, deterioration can be easily reversed. If the primary problem is cardiac dysfunction, calcium-channel blockers such as diltiazem must be used cautiously, if at all.

Another agent that can be considered in these patients is amiodarone, remembering that the intravenous formulation is a vasodilator and that blood pressure must be followed carefully. Although it might be difficult to know if the tachycardia is the cause of the heart failure or its consequence, cardioversion should always be considered in a compromised patient who is presumed to have primary atrial fibrillation or supraventricular tachycardia.

Vasoconstrictors

In patients who have heart failure, low blood pressure is usually the consequence of a decreased cardiac output. Increasing the blood pressure with a vasoconstrictor results in further lowering of cardiac output and worsening of the primary problem. Thus, vasoconstrictors should be used only in a patient whose blood pressure is clearly affecting organ systems, particularly the brain. A patient who has chronic heart failure without symptoms of dizziness or lightheadedness rarely needs a vasoconstrictor. If a higher blood pressure is clearly needed, vasopressin may increase blood pressure without directly affecting the heart.

When hypotension is present, it is necessary to see if other problems might be leading to the deterioration. Sepsis should be considered, and volume must be assessed. In a patient who has heart failure, however, the routine administration of large volumes of fluid for hypotension may exacerbate the heart failure without increasing blood pressure. Volume should be given judiciously and in small boluses to ensure a positive response.

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