# Management of Acute Heart Failure

# 11

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## Case Presentation

A 55 year old male with history of coronary artery disease (CAD), chronic systolic heart failure, and chronic obstructive pulmonary disease (COPD) presented to the hospital with 5 days of cough, exertional dyspnea, and fatigue. The patient's past medical history was notable for a remote history of emergent percutaneous coronary intervention for an acute anterior myocardial infarction complicated by systolic heart failure. His left ventricular ejection fraction (LVEF) was most recently noted to be 25 %. He had an implantable cardioverter-defibrillator (ICD) for primary prevention. He had not been seen by his cardiologist in several years.

Upon arrival to the emergency department, the patient was found to have a white blood cell count of 15 K, serum sodium of 123 mEq/L, creatinine of 1.6 mg/dL, and NT-pro-B-type natriuretic peptide level of 4800 ng/mL. An electrocardiogram showed sinus tachycardia with a chronic left bundle branch block. Initial cardiac enzymes were negative. He was short of breath and mildly hypoxic, with a room air oxygen saturation of 90 %. A chest x-ray showed a right-sided pleural effusion and some subtle interstitial infiltrates bilaterally. The patient was admitted to the inpatient hospitalist service, where he was treated with intravenous (IV) ceftriaxone for community-acquired pneumonia, bronchodilators and oral prednisone for a COPD flare, and given some IV fluids to treat acute renal failure presumed to have been pre-renal in etiology.

Over the course of several days, the patient became increasingly more short of breath. He was also noted to be more lethargic and less responsive. Laboratory analysis revealed an increasing serum creatinine and persistent hyponatremia. Serial electrocardiograms (ECGs) revealed no dynamic changes suggestive of ischemia, and cardiac biomarkers demonstrated a low-level elevation in cardiac-specific troponin. He was transferred to the intensive care unit (ICU) for management of hypotension and respiratory distress. There he was tachypneic and a blood gas analysis revealed new metabolic acidosis with associated respiratory compensation. His extremities were cool. A Foley catheter was placed with no return of urine.

The patient was placed on supplemental oxygen, given intermittent IV furosemide, and started

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on a dopamine infusion for hypotension. Despite increasing dosages of dopamine and furosemide, the patient remained hypotensive and anuric. Given an increasing work of breathing, he was intubated and mechanically ventilated.

**Question** What complications should be considered when instituting invasive mechanical ventilation for this patient?

**Answer** Worsening acidosis and progressive cardiovascular collapse.

The decision to pursue intubation and mechanical ventilation for a patient with cardiogenic shock should not be taken lightly. While hemodynamic instability and refractory respiratory failure may make invasive ventilation unavoidable, complications should be anticipated. The patient was given benzodiazepines and neuromuscular blockade to facilitate intubation. Shortly after this, he became considerably more hypotensive. He was placed on the ventilator with an assist-control mode and 100 % $FIO_2$. His dopamine dosing was rapidly escalated and he was given an ampule of sodium bicarbonate. His respiratory rate was initially set at 15 breaths per minute, but when an ABG showed a pH of 7.2 and worsening metabolic acidosis, his ventilator rate was quickly increased to provide more appropriate respiratory compensation.

Given his unrelenting cardiogenic shock, an intra-aortic balloon pump (IABP) was placed emergently at the bedside. This resulted in an immediate improvement in the patient's mean arterial blood pressure. A dobutamine infusion was then added to his pharmacologic regimen for simultaneous afterload reduction and inotropic support. An hour after balloon counterpulsation and inotropic therapy, the patient's metabolic acidosis had completely resolved. A serum lactate – which was initially markedly elevated – had returned to the normal range. Serial ABGs demonstrated resolution of his systemic acidosis and improvement in his hypoxemia, thus allowing his ventilator to be weaned. Additionally, the patient's urine output improved over several hours, supported by high-dose parenteral diuretic therapy.

A swan-ganz catheter was placed in order to assess the patient's invasive hemodynamics, on his present level of circulatory support, and revealed a pulmonary artery (PA) pressure of 50/30, mean PA pressure of 37 mmHg, central venous pressure of 13 mmHg, Fick cardiac output of 6.2 L/min, Fick cardiac index of 2.8 L/min/$m^2$, and a mixed venous oxygen saturation of 68 %. Over the next 3 days, IABP support was gradually weaned from a 1:1 to 1:3 assist ratio to ensure the patient would maintain stable hemodynamics off mechanical support. Subsequently, the device was removed while systemic anticoagulation was held. On the fifth ICU day, the patient was successfully liberated from mechanical ventilation and transitioned to a nasal cannula. Unfortunately, multiple attempts to wean his dobutamine infusion resulted in hemodynamic perturbation and worsening renal dysfunction. He was ultimately transferred out of the ICU for ongoing care, with plans to consider more durable advanced heart failure therapies including home inotropic support, implantable left ventricular assist device, or heart transplantation.

## Principles of Management

### Diagnosis

Acute Heart Failure (AHF) is a complex clinical syndrome which results from any structural or functional impairment of ventricular filling or ejection of blood. AHF may occur either due to heart failure with reduced ejection fraction (HFrEF) or heart failure with preserved ejection fraction (HFpEF). While HFrEF is simply characterized by decreased cardiac contractility, HFpEF is commonly a result of diastolic dysfunction represented by impaired left ventricular relaxation and/or increased left ventricular filling pressures. HFpEF is often seen in association with comorbidities such as chronic hypertension and diabetes, and its prevalence increases with age. Diagnosis of HFpEF is aided

by echocardiography which can show abnormal trans-mitral valve and/or pulmonary vein flow hemodynamics or impaired mitral annular relaxation.

Dietary indiscretions, medication non-compliance, uncontrolled hypertension, arrhythmias, infections, catecholamine surge, valvular dysfunction, and ischemia are just a few of the known triggers of acute decompensation. Elevated cardiac filling pressures classically produce symptoms of dyspnea, orthopnea, and paroxysmal nocturnal dyspnea. Patients may also have evidence of peripheral or pulmonary edema. Potential etiologies for AHF include, but are not limited to, myocardial ischemia/infarction, acute on chronic HFpEF or HFrEF, acute or fulminant myocarditis, myocardial contusion, septic shock with myocardial depression, acute valvular heart disease, cardiac arrhythmias, drug-related cardiotoxicity, profound metabolic derangements, peripartum cardiomyopathy, or stress-induced cardiomyopathy [1, 2].

A thorough history and physical examination are necessary to determine a cause of acute heart failure in order to develop a comprehensive diagnostic and management plan for each affected patient. Complementary studies include laboratory evaluation to risk-stratify the individual with AHF (Fig. 11.1), ECG, and imaging modalities (including echocardiography [Video 11.1] and chest radiography). An ischemic evaluation with myocardial perfusion imaging or cardiac catheterization can often be helpful in determining whether ischemia is contributing to cardiac decompensation. Interrogating a patient's ICD, if present, can also help to elucidate if arrhythmias may be precipitating or preceding heart failure.

## Diuretic Therapy

Fluid removal through intravenous diuresis is an essential management strategy for AHF patients that present with congestion (2013 American College of Cardiology (ACC)/American Heart Association (AHA) Heart Failure Management Guidelines Class I, Level of Evidence (LOE) B). If unable to achieve effective diuresis with escalating doses of loop diuretics, a second diuretic agent (e.g. metolazone, chlorothiazide) may be added (ACC/AHA Class IIA, LOE B). Use of a continuous diuretic infusion has not been shown to be more effective than bolus therapy but may be considered for ease of dosing. Potential diuretic-related side effects that can negatively impact patient outcomes include electrolyte disturbances (hyponatremia, hypokalemia, and hypomagnesemia), metabolic alkalosis, ototoxicity, hyperuricemia, and hypotension. It is important to serially monitor clinical signs, daily weights, urine output, and electrolytes during treatment to determine the adequacy of decongestion and to avoid the untoward consequences of volume contraction (ACC/AHA Class I, LOE C). Under-treatment is common among hospitalized patients as seen in the Acute Decompensated Heart Failure National Registry (ADHERE), and failure to achieve adequate volume removal can be considered an important risk factor for hospital readmission [3].

## Intravenous Vasodilators

Nitrates, such as nitroglycerin (10–350 mcg/minute) and sodium nitroprusside (5–300 mcg/minute) promote smooth muscle relaxation, resulting in decongestion and reduced cardiac filling pressures. Unpredictable patient responses to therapy and the risk for associated hypotension, however, mandate careful hemodynamic monitoring during treatment and the consideration of ICU admission for all individuals receiving parenteral nitrates. Nitroprusside has been shown to improve cardiac output, maintain adequate mean arterial pressures, and improve clinical outcomes in patients with acutely decompensated heart failure [4]. Nitroglycerin has a relatively short half-life and rapid onset of action. In AHF with significant pulmonary congestion, nitroglycerin can improve arterial oxygenation and hemodynamics through venous vasodilation. Duration of vasodilator therapy may be limited by hypotension, drug tachyphylaxis (nitroglycerin), and thiocyanate toxicity (nitroprusside).

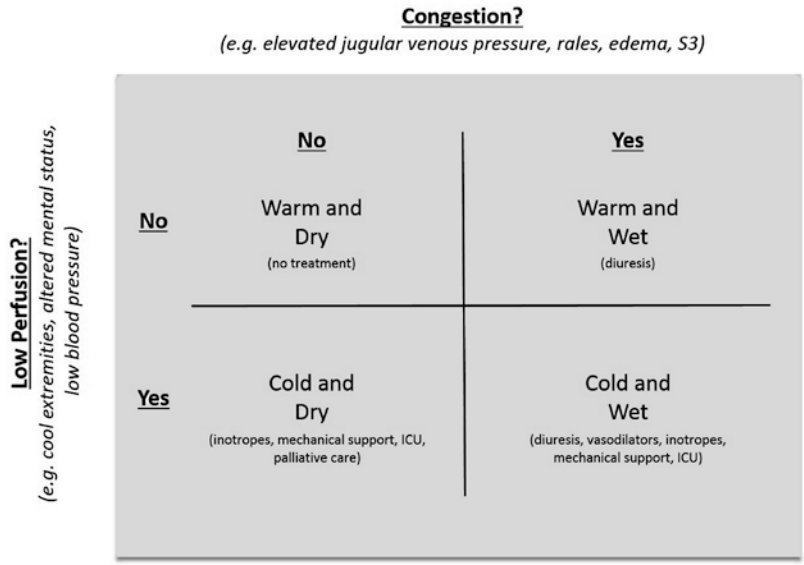


**Fig. 11.1** Acute decompensated heart failure patient classification (Adapted from Nohria and Lewis [20], with permission)

## Emergent Mechanical Circulatory Support

In situations of hemodynamic instability and reduced cardiac output that is refractory to pharmacologic intervention, mechanical circulatory support may be needed to reduce afterload and augment diastolic perfusion pressure (see Chap. 10, Management of Cardiogenic Shock).

## Evidence Contour

### Pulmonary Artery (PA) Catheters

PA catheterization allows direct measurement of cardiac filling pressures, pulmonary arterial pressures, cardiac output, and calculation of both systemic and pulmonary vascular resistance. Widespread adoption of this technology in all critically ill patients was tempered by findings which suggested an increased cost, mortality, and length of stay [5]. Specific to the heart failure population, the Evaluation Study of Congestive Heart Failure and Pulmonary Artery Catheterization Effectiveness (ESCAPE) trial was conducted to assess the role of PA catheter-guided therapy in hospitalized individuals with AHF. Similar to other studies, there was no suggestion that PA catheters improved mortality; it did, however, result in increased adverse events such as infection, pulmonary infarction, and bleeding [6]. It has widely been assumed that the morbidity of PA catheterization is primarily related to operator experience [7]. Despite their unproven mortality benefit, PA catheters remain a viable diagnostic tool particularly in challenging cases of AHF. The 2013 ACC/AHA guidelines for heart failure management recommend PA catheter use in cases of refractory hypotension, difficult volume status determination, renal function deterioration despite therapy, and to guide inotrope therapy titration (Class IIA (LOE C)) [2].

### Inotropic Agents

Management of AHF is often limited by low blood pressure and systemic hypoperfusion. Inotropic agents (e.g. dopamine, dobutamine, and milrinone) can augment contractility and chronotropy, resulting in increased stroke volume and cardiac output (Table 11.1). These goals are often accomplished with a tradeoff of increasing myocardial oxygen demand, increased heart rate, and increased risk for tachyarrhythmias. Improved hemodynamic response, however, has

**Table 11.1** Intravenous inotropic agents used in management of HF

| Adrenergic agonists | Typical infusion dose (mcg/kg/min) | CO | HR | SVR | PVR | Possible adverse effects |
|---|---|---|---|---|---|---|
| Dopamine | 5–10 | ↑ | ↑ | ↔ | ↔ | Headache, nausea, arrhythmia |
| | 10–15 | ↑ | ↑ | ↑ | ↔ | |
| Dobutamine | 2.5–5 | ↑ | ↑ | ↓ | ↔ | Hyper- or hypotension, headache, arrhythmia, hypersensitivity |
| | 5–20 | ↑ | ↑ | ↔ | ↔ | |
| **PDE inhibitor** | | | | | | |
| Milrinone | 0.125–0.75 | ↑ | ↑ | ↓ | ↓ | Hypotension, arrhythmia |

Adapted from Yancy et al. [21]. With permission from Wolters Kluwer Health, Inc.
*Abbreviations*: *CO* cardiac output, *HR* heart rate, *PDE* phosphodiesterase, *PVR* pulmonary vascular resistance, *SVR* systemic vascular resistance

not always translated into improved patient survival. The Outcomes of a Prospective Trial of Intravenous Milrinone for Exacerbations of Chronic Heart Failure (OPTIME-CHF) investigators and data from the ADHERE registry showed that these agents may actually increase mortality when compared to standard diuretic or vasodilator therapies in AHF patients [8–10]. Therefore, inotropes are best used for short periods in the ICU in situations suggestive of emerging cardiogenic shock and end-organ failure. Inotropes can also be employed as a bridge to other definitive management strategies or used for palliative care purposes.

## Diuretic Dosing – Intermittent Versus Continuous

Patients presenting with AHF and congestion should receive intravenous loop diuretics as progressive bowel wall edema may limit oral diuretic absorption and efficacy. Less well understood is the differences between adopting a continuous infusion or interval dosing diuretic strategy. The Diuretic Optimization Strategies Evaluation (DOSE) trial compared intermittent IV diuresis to a continuous infusion strategy, and found them to have a similar effect on subjective symptoms and renal function [11]. A more recent meta-analysis evaluating ten randomized control trials similarly found no difference in resulting renal function, electrolyte disturbances, length of hospitalization, or cardiac or all-cause mortality between these two approaches [12].

## Ultrafiltration

The use of ultrafiltration (UF) to enhance cardiac decongestion has been examined extensively as an adjunct to diuresis. UF can remove excess fluid and small solutes via a dialysis circuit. Initial small randomized controlled trials have supported the utility and safety of UF when compared to traditional loop diuretics [13]. A follow-up trial, the Ultrafiltration Versus Intravenous Diuretics for Patients Hospitalized for Acute Decompensated Heart Failure (UNLOAD) study, found that UF achieved greater net weight loss and reduced re-hospitalization rates at 90 days [14]. However, subsequent studies have not consistently corroborated these findings [15], and have suggested a potentially greater adverse-event rate and cost-of-care among UF-treated individuals. The financial implications and potential morbidity of UF must therefore be weighed carefully in any decision to initiate therapy. The most recent AHA/ACC guidelines maintain a Class IIA (LOE B) recommendation for UF in patients refractory to standard diuresis.

## Nesiritide

Nesiritide, a form of synthetic B-type natriuretic peptide (BNP), is a potent vasodilating agent that may reduce cardiac filling pressures and improve ventricular unloading. Reported side-effects of this drug have included hypotension and acute renal failure. In a large, multicenter, randomized trial, the Acute Study of the Clinical Effectiveness of

Nesiritide in Decompensated Heart Failure (ASCEND-HF) study found that use of this drug did not improve patient survival, reduce readmission rates, or augment end-organ function when compared to placebo [16]. Therefore, while still available, its routine use has been discouraged, and it is often only considered for patients with substantially elevated systemic vascular resistance in whom intensive vasodilation may be advantageous.

## Renal-Dose Dopamine

At lower doses (1–2.5 mg/kg/min), dopamine predominantly activates renal dopamine receptors, with little systemic adrenergic stimulation. Diuresis in AHF is often limited by deteriorating renal function, hypokalemia, and hyponatremia. Therefore, a low-dose dopamine strategy has been considered a possible treatment for diuretic-refractory patients. In 2010, results of the Dopamine in Acute Decompensated Heart Failure (DAD-HF) trial showed that low-dose furosemide plus low-dose dopamine resulted in less hypokalemia and less renal insufficiency, but with similar 60-day mortality, rates of readmission, and hospital lengths-of-stay [17]. A follow-up investigation – the Dopamine in Acute Decompensated Heart Failure II (DAD-HF II) trial – was stopped prematurely after finding that the dopamine arm had a greater incidence of tachycardia with no demonstrable effect on the primary endpoint of all-cause mortality or re-hospitalization [18]. More recently, the Renal Optimization Strategies Evaluation (ROSE-AHF) trial similarly evaluated the use of low-dose dopamine (2 mcg/kg/min) in patients hospitalized with AHF [19]. In this case, low-dose dopamine failed to improve urine output or renal function. Despite limited supporting evidence in AHF, however, low-dose dopamine continues to be used clinically and carries a Class IIB (LOE B) designation.

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