Trainee Section

Problem-based review: The patient with acute heart failure

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Abstract

Acute heart failure is a common and potentially life threatening presentation to hospitals in the UK. Acute Physicians at the front door of the hospital will often be involved with the initial management of these patients. Despite its many underlying causes, certain general treatment principles exist. We present a typical clinical scenario followed by an overview of the pathophysiology and management of acute heart failure and cardiogenic pulmonary oedema. The aim is to cover a broad spectrum of therapies ranging from medical treatment up to invasive devices, thereby discussing the available options from the Emergency Department to the Intensive Care Unit.

Keywords

Acute, heart failure

Key Points

- Acute heart failure is one of the leading causes of hospital admission in the UK
- Mortality rates for patients with acute heart failure remain high
- Furosemide has the potential to cause harm in some patients, in whom nitrates may be more beneficial
- Non-invasive respiratory support can be a useful adjunct in the treatment of acute heart failure
- Cardiogenic shock has a very high mortality, management on the Intensive Care Unit involves use of vasopressors, inotropes and ultrafiltration

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Case Scenario

A 64 year old patient with no previous medical history presents to the Emergency Department (ED) with central chest pain. Observations show a respiratory rate of 25 breaths per minute, oxygen saturations of 93% whilst breathing room air, the heart rate is 110 beats per minute and the non-invasive blood pressure is 140/90 mmHg. A 12 lead ECG shows Sinus rhythm and depressed ST segments. On examination the patient appears restless and clammy. The jugular venous pressure is raised, auscultation reveals normal heart sounds and bilateral inspiratory crepitations, extending to the midzones. The Chest radiograph (Figure 1) shows evidence of cardiomegaly, pulmonary congestion and pleural effusions bibasally. The working diagnosis is Acute Coronary Syndrome (ACS) and acute heart failure with pulmonary oedema. Initial treatment consists of aspirin, clopidogrel and low molecular weight heparin. The patient is referred to the Acute Medical Unit for further assessment and treatment.

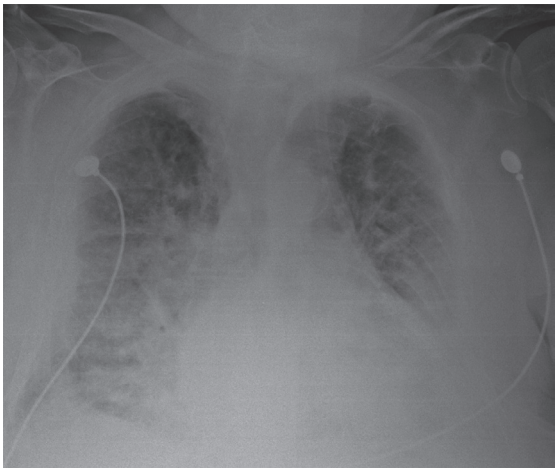

Figure 1. Chest radiograph showing cardiomegaly, pulmonary congestion and pleural effusions bibasally

What investigations should be ordered?

A number or conditions could explain this patient's symptoms, including cardiac or respiratory events (ACS, acute heart failure, cardiac tamponade or severe arrhythmia; exacerbation of COPD/asthma, infection, massive pulmonary embolism or pneumothorax). A number of investigations are available to support the clinician in establishing a differential diagnosis in conjunction with the history and examination findings. (see Table 1).

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Table 1. Investigating acute-onset dyspnoea.

Investigations	
Bloods	**Looking For:**
Full blood count	Anaemia, leucocytosis
Electrolytes, urea and creatinine	Renal failure, hyperkalaemia, hyponatraemia, hypocalcaemia
Liver function tests	Liver failure, hepatic congestion
CRP, ESR	Infection (infective endocarditis, COPD), sepsis
Thyroid function tests	Hypo/hyperthyroidism
Cardiac markers (trop I)	ACS
Arterial blood gases	Hypoxia, hypercapnea, acidosis/alkalosis
Imaging	
ECG	ACS, arrhythmia, electrolyte imbalance
Chest xray	Pulmonary oedema, infection, COPD, pneumothorax, cardiomegaly
Echocardiography	Valvular incompetence, tamponade, LVH

Is acute trans-thoracic echocardiography (TTE) indicated?

An acute TTE, performed in the Emergency Department can be helpful in the diagnosis or exclusion of a number of causes of breathlessness.

Echocardiography is the investigation of choice to diagnose a pericardial effusion (Figure 2) if clinically suspected (especially if there is haemodynamic compromise).

Aortic dissection may be identified if there is an intimal flap or an aortic root annulus of over 35mm. Such findings should prompt the clinician to consider dissection and proceed to CT scanning or transoesophageal echocardiography.

Echocardiography can also provide a noninvasive assessment of haemodynamic status (Table 2). Estimation of preload can be measured by assessing the size of the inferior vena cava (IVC). Right atrial pressure is measured on the size and collapse of the IVC.[1] The IVC is measured with the patient supine and placing ultrasound probe in the midline just below the xiphoid. The probe is angled slightly to the right to visualize the IVC.

A dilated IVC will help to rule out other causes of hypotension such as hypovolaemic and septic shock.

What is acute heart failure (AHF)?

Acute heart failure (AHF) is defined as rapid onset or change in the signs and symptoms of heart failure, resulting in the need for urgent therapy.[2] Clinically, AHF is characterized by the development of dyspnoea and often rapid accumulation of fluid in the interstitial and alveolar spaces of the lung.[3]

In a large European survey, the most frequently identified reason for the presentation was decompensated chronic heart failure, although more than a third of patients presented with de novo AHF.[4] In this patient group, the main factor leading to AHF is an ACS, however, a multitude of other factors can often interact. (Table 3). Extrapolating from the NHS heart failure survey from 2007, it appears that more than 17,000 patients present to NHS hospitals in England, Wales and Northern Ireland with AHF every year.[5] The importance of a sound understanding of the management principles of AHF is demonstrated by two other observations: the median length of stay was up to 9 days in the European survey,[4] and mortality rates are 40-50% in patients with cardiogenic shock.[6,7]

What are the likely causes of the patient's signs and symptoms?

The initial step in the development of AHF and cardiogenic pulmonary oedema is a rise in left ventricular filling pressure.[3] This results in increased left atrial and pulmonary venous pressures, and depending on the extent, ultimately leads to a rise in pulmonary capillary pressure.[2] As the epithelium of the pulmonary capillaries is not primarily affected in cardiogenic pulmonary oedema, it maintains its barrier function. The consequence is filtration of protein poor fluid, a transudate, into the pulmonary interstitium and alveolar spaces.[3] Up to a certain point, this can be compensated for by the lymphatic system, which removes the fluid from the interstitium and returns it into the systemic

Table 2. TTE findings in patients with shock.

Hypovolaemic shock	Narrow IVC that collapses with respiration
Cardiogenic shock	Dilated IVC with little or no collapsing with respiration

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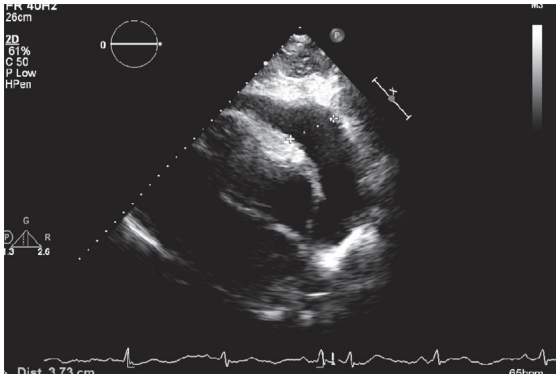

Figure 2. Trans-thoracic echocardiogram showing a 3.73cm pericardial effusion (indicated by + …..+ markings)

Table 3. Aetiology of Acute Heart Failure.

Aetiology of AHF
Decompensation of chronic heart failure
Acute coronary syndrome
Severe hypertension
Acute arrhythmia
Valvular incompetence
Cardiac tamponade
Aortic dissection
Non-cardiovascular causes (iatrogenic, volume overload, renal failure, infection, alcohol/drug abuse, surgery, anaemia, thyrotoxicosis, septicaemia, etc)

circulation. Pulmonary oedema develops once this compensatory mechanism is overwhelmed.[3] This explains the bilateral crepitations heard on auscultation and typical features on a chest x-ray (Figure 1).

Gas transfer in the lung is subject to diffusion, and this process, as described by Fick's law, is directly proportional to the area available.[8] Based on this, it seems easily understandable that accumulation of fluid in the extravascular aspects of the lung (pulmonary oedema) directly interferes with oxygenation, resulting in hypoxia and breathlessness.

The pathophysiological processes described usually trigger further neurohumoral actions such as activation of the renin-angiotensin and sympathetic nervous systems. The resulting increase in afterload and myocardial oxygen demand secondary to an increase in systemic vascular resistance, along with the shortening of diastole due to the tachycardia, have the potential to make a bad situation worse.

Pulmonary hypertension leads to an increase in right atrial pressure which explains the raised JVP. It has been found that a raised JVP is a poor prognostic marker in heart failure and has been independently associated with an increase in hospitalisation and mortality rates among AHF patients.[9]

How should this patient be managed?

Although certain underlying conditions lend themselves to specific therapeutic interventions, i.e. rate control or cardioversion when AHF is precipitated by an arrhythmia, there are some basic principles in its management regardless of its aetiology.

The main initial treatment goals are to relieve symptoms, reduce congestion, render the patient haemodynamically stable and prevent (further) myocardial and renal injury.[10]

Oxygen/Respiratory Support:

Following assessment of the airway, the next step in resuscitating a patient with AHF should be to assure safe levels of oxygenation. This is usually initiated by increasing the fraction of inspired oxygen using different devices ranging from nasal cannulae to reservoir masks.

Clear guidance is available from the British Thoracic Society Guidelines; the recommended target saturations for patients with AHF are 94-98%, ideally achieved using nasal cannulae, in an attempt to maximise patient comfort.[11] The exceptions to this are a minority of patients who are at risk of developing type 2 respiratory failure, in which case the target saturations should lie between 88-92%, achieved by a Venturi mask, and patients in cardiogenic shock, who should be treated with reservoir masks or bag-valve devices.[11]

The patient is given 6L of oxygen via a nasal cannula and his saturations are monitored. A repeat ABG is undertaken, which shows that he remains hypoxaemic.

In those situations, where oxygen supplementation does not ensure adequate oxygenation, more advanced respiratory support should be considered at an early stage.[2] The therapeutic options range from non-invasive techniques such as Continuous Positive Airway Pressure (CPAP) and Non-invasive positive pressure ventilation (NPPV) to invasive positive pressure ventilation (IPPV).

The use of CPAP in AHF has been shown to augment cardiac output, oxygen delivery and functional residual capacity whilst reducing work of breathing and left ventricular afterload.[12,13,14] NPPV has been found to be more effective at unloading respiratory muscles than CPAP.[15]

The benefit of using both CPAP and NPPV in the context of AHF has been demonstrated in various clinical trials and meta-analyses. Both techniques result in reduced rates of intubation and mortality.[16,17]

The recent UK based multicenter "3CPO" trial compared medical management with either form of non-invasive respiratory support and demonstrated accelerated improvement in patient comfort and physiological parameters, without showing a difference in mortality.[18] Although the 3CPO trial was well conducted, it is important to consider that a significant proportion of patients did not complete

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their assigned treatment, and the low flow ventilators used may have influenced the outcome of the study.[19,20]

The patient is started on CPAP and his oxygen saturation increases to 98%.

From a practical point of view, it is important for acute physicians to be aware that the use of non-invasive respiratory support for AHF is not provided outside critical care areas in up to 30% of hospitals in England, potentially delaying this beneficial treatment option, whilst also putting strain on the Critical Care Services.[19]

Diuretics

Diuretics, most commonly loop diuretics such as furosemide, are often amongst the first drugs to be administered in AHF. They can be administered in the form of a bolus or infusion. This approach certainly appears logical in the patient with fluid overload and is supported by the major guidelines.[2]

Before using these drugs in patients without evidence of fluid overload, however, it is important to note that loop diuretics have a venodilatory effect which can be seen as soon as 15 minutes following injection of the drug.[21] Given the later onset (approximately 30 minutes post injection) and delayed peak (around 1-2 hours post injection) of the diuretic effect, it is possible that an initial improvement in symptoms can be followed by hypoperfusion-induced organ failure, as a consequence of reduced circulating volume.

Potentially adding insult to injury, furosemide activates the sympathetic nervous and the Renin-Angiotensin systems, which may further stress the myocardium.[22]

Nitrates

Nitrate induced vasodilatation reduces pre-load and consequently pulmonary capillary wedge pressure, directly targeting the pathophysiological processes leading to pulmonary oedema, as outlined above. In addition to this, there is a reduction in afterload, improving cardiac output and reducing oxygen consumption.

Another very useful effect of nitrates, particularly when AHF is due to or associated with myocardial ischemia, is the dilating effect on coronary arteries, improving flow to vulnerable myocardium.

Treatment with intravenous nitrates has been demonstrated to be superior when compared with loop diuretics. It is associated with less need for IPPV and fewer myocardial infarctions.[23]

The peak effect of nitrates occurs around 5 minutes post injection.[24] The limiting factor in the short-term use of nitrates is hypotension; the European Society of Cardiology guidelines recommend its use in patients without symptomatic hypotension and systolic blood pressures between 110 - 90mmHg.[1] Tachyphylaxis is a phenomenon associated with nitrate use and can occur within hours of its administration.[24]

Morphine

Cautious use of intravenous morphine can result in relief of breathlessness and is particularly indicated early in the management of patients presenting with AHF associated with chest pain and anxiety.[2] A retrospective analysis found that morphine use in AHF was associated with a greater need for IPPV, increased length of stay and a higher mortality.[25] Although the paucity of evidence for the use of morphine in AHF is acknowledged in the ESC guidelines its use is still recommended, albeit with caution.[2]

Despite furosemide and intravenous nitrate administration the patient's condition deteriorates further and his BP drops to 90 systolic with a urine output of approximately 20mL/hr. He is diagnosed with cardiogenic shock secondary to AHF.

What management options exist for this patient's cardiogenic shock?

Occasionally, patients with AHF will develop cardiogenic shock, a life-threatening condition characterized by systolic hypotension and evidence of systemic hypoperfusion. When AHF and cardiogenic shock present secondary to an acute myocardial infarction, it has shown that early revascularisation (preferably with PCI) results in reduced mortality compared to medical therapy with late or no revascularisation.[26]

The medical treatment of cardiogenic shock is difficult and will most often take place on the Intensive Care Unit. It involves the use of vasoactive medication, invasive cardiac and devices renal support.

Vasoactive medication

In the context of AHF, both inotropes (i.e. dobutamine, milrinone) and vasopressors (i.e. noradrenaline, dopamine) have the potential to further stress the myocardium and increase ischemia, as well as mortality. The use of inotropes has been demonstrated in a retrospective analysis of the Acute Decompensated Heart Failure National Registry (ADHERE). Patients with AHF but preserved cardiac output treated with nitrates had significantly lower mortality rates compared to patients treated with inotropes.[27]

Vasopressors on the other hand can increase myocardial workload because their action results in a rise of (the often already elevated) systemic vascular resistance and therefore afterload.

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Inotropes

Dobutamine stimulates β-1 receptors and can lead to an increase in heart rate and the development of arrhythmias, thereby potentially increasing ischemia.[28]

Milrinone is a phosphodiesterase inhibitor. Its action is mediated via reduced degradation of cyclic AMP, which leads to increased inotropy and lower systemic and pulmonary vascular resistance.[29] The fact that milrinone does not require β-1 receptor action for its effect would suggest that it may be more effective than dobutamine in patients taking β –blockers.

Dobutamine is only recommended in patients with low systolic blood pressure and evidence of hypoperfusion or congestion, if therapy using the above described approach of vasodilatation and volume reduction has failed.[2]

Vasopressors

Noradrenaline predominantly stimulates α-1 receptors and is therefore commonly used as a vasopressor.[30]

Dopamine acts on different receptors at different doses. Through its action on β-1 receptors at low doses it works as an inotrope; at higher doses, however, it displays predominantly α-adrenergic effects and therefore functions as a vasopressor.[31]

Dopamine and Noradrenaline were both commonly used in the treatment of hypotension for many years.[32] A recent study, comparing the two drugs in the treatment of shock, did not show a difference in overall outcome. The rate of adverse events, though, was significantly higher in patients treated with dopamine. More importantly for the discussion of the management of AHF, use of dopamine resulted in increased mortality in the subgroup of patients treated for cardiogenic shock.[32]

Noradrenaline has a role in patients with cardiogenic shock complicated by sepsis, while the results of the aforementioned study would indicate that Dopamine should not be used in the management of AHF and cardiogenic shock.[2,32]

Mechanical devices

Intra-aortic balloon pumps (IABPs)

Outside the peri- and postoperative setting, the IABP is generally used to support the circulation in the setting of therapy refractory unstable angina and/or cardiogenic shock.[33] It requires insertion of a balloon into the proximal descending aorta, usually via the femoral artery. Using the arterial pressure trace and the electrocardiogram to synchronize inflation, the balloon is filled with helium gas immediately following closure of the aortic valve, and deflated just before it opens again in systole. The main effects are improved coronary perfusion due to the "pushing" of blood in a retrograde fashion towards the aortic valve and coronary sinuses in diastole; and the reduction of afterload through the vacuum effect created by deflation of the balloon just before systole.[34]

Apart from the usual complications associated with invasive procedures such as bleeding, infection and thromboembolism, the main limitation of the IABP is that it is dependant on a degree of residual left ventricular function.[35]

The use of IABPs is recommended in international guidelines.[36, 37] However, despite this and the aforementioned theoretical benefits of the device, there is little objective evidence to support the use of IABPs. A recently published, well designed cardiogenic shock following myocardial infarction.[38] Comparison of 300 patients in each group did not reveal a mortality difference.[38] This study has certain limitations despite its sound design: Low mortality figures in the trial population (around 40%) differ from what has previously been described in cardiogenic shock[6,7] and may indicate a less ill patient group. A closer look at the inclusion criteria suggests that patients in the trial may not have been as unwell as most patients in the UK who are currently treated with IABPs.[38]

Left Ventricular Assist Devices (LVADs)

These are relatively new, percutaneously inserted pumps that can temporarily take over myocardial function. Different devices exist connecting the left atrium with the femoral artery or the left ventricle with the ascending aorta. LVADs have the potential to reverse cardiogenic shock and are not dependant on intrinsic cardiac activity.[35]

A recent meta-analysis comparing LVADs with IABPs demonstrated improved haemodynamic parameters following the use of LVADs, without any difference in mortality.[35] Of further note is the nearly ten fold higher cost of LVADs and a higher complication rate including leg ischemia and bleeding.[35] The meta-analysis concluded that LVADs cannot yet replace the IABP as the device of choice for the management of refractory cardiogenic shock.[35]

Ultrafiltration

Ultrafiltration (UF) mimics the physiological processes in the kidney and results in removal of sodium and water. In patients with AHF and renal insufficiency or diuretic resistance, the use of venovenous continuous renal replacement therapy can achieve fluid removal safely and very efficiently.[39]

Compared with diuretic use, UF allows the clinician better control over the volume of fluid to be removed and the speed at which this happens. It also avoids the side effects associated with diuretic use, i.e. serum electrolyte abnormalities or the neurohumeral mechanisms outlined above.

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The benefit of UF was demonstrated in the UNLOAD trial, which randomized patients with AHF to either early UF or intravenous diuretics. In this study, UF was associated with higher fluid losses, without affecting the serum creatinine. Over the next 90 days, rates of hospital admissions and unscheduled clinic attendances were reduced.[39]

The current ESC guidelines recommend UF to reduce fluid overload in selected patients as well as for the correction of hyponatraemia in patients resistant to diuretics.[2]

Calcium Sensitizers

Levosimendan sensitizes myofilaments to calcium and has K-ATP channel opening effects.[40] This results in increased cardiac contractility without the increase in myocardial oxygen consumption seen with other inotropic drugs, whilst at the same time promoting coronary artery vasodilatation.[40] Levosimendan is not dependant on increased calcium influx into the myocytes and the risk of arrhythmias is reduced.[41] Furthermore, due to its independence from β -receptor signalling, it is an alternative to milrinone in patients on β-blocker therapy.[2]

When levosimendan was compared with dobutamine in the LIDO study, it was associated with better hemodynamics and a retrospective analysis indicated improved mortality figures.[41]

The SURVIVE trial also compared the use of levosimendan with dobutamine in patients with AHF, but was larger than LIDO and analysed mortality rates prospectively.[42] Treatment with levosimendan resulted in significantly lower levels of B-type Natriuretic Peptide (BNP), a marker of left ventricular dysfunction, without leading to a mortality benefit. Interestingly, side effects such as atrial fibrillation, headache and hypokalaemia were also more common in the levosimendan group.[42]

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