Understanding and treating heart failure in children

Dilveer Panesar
Michael Burch

Abstract

Heart failure in the paediatric setting encompasses a range of disease processes and pathophysiological mechanisms. The clinical symptoms are commonly seen in the setting of pulmonary overcirculation as well as myocardial pump failure. A significant proportion of patients with congenital heart disease present with or develop heart failure during treatment. The management of this condition differs with aetiology and it is important to understand the direct effects of hypoperfusion and those of (often maladaptive) compensatory mechanisms. The use of ventricular assist devices has heralded a new era in heart failure management and soon it will be possible to move away from transplantation and towards long-term mechanical support as a bridge to recovery and even as destination therapy in itself. This article describes the different types of heart failure seen in children, providing the reader with an improved understanding of the pathophysiology which should inform treatment decisions.

Keywords cardiomyopathy; heart failure; management; mechanism; paediatric

Introduction

Heart failure is a symptomatic state which can be caused by many disease processes. Understanding heart failure in children can at first seems a daunting prospect for paediatricians and healthcare professionals. It can be subdivided into left or right, acute or chronic, systolic or diastolic and with or without left-rigsht shunting lesions. The importance of recognising these distinct entities is that treatment differs with aetiology. The presence or absence of associated features including infection (as a cause of myocarditis), syndromes and acquired or congenital heart disease have important prognostic implications in these patients and must be actively sought. Management of these patients can be difficult, but this article attempts to draw out some general themes which are likely to be helpful in acute and chronic settings.

Dilveer Panesar *BM BCh MRCPCH is a Clinical Research Fellow at Great Ormond Street Hospital, London, UK. Conflict of interest: none declared.*

Michael Burch *MD FRCP FRCPCH is Clinical Lead of Cardiology and Paediatric Transplantation and Consultant Paediatric Cardiologist at Great Ormond Street Hospital, London, UK. Conflict of interest: none declared.*

Definition

The definition of heart failure in the paediatric population is disputed. The authors find the Heart Failure Society of America guidelines helpful. These state that: "In physiological terms, heart failure is a syndrome characterised by either or both pulmonary and systemic venous congestion and/or inadequate peripheral oxygen delivery, at rest or during stress, caused by cardiac dysfunction." In recent times the syndrome of heart failure is known to encompass neurohormonal activation, abnormal ventricular–vascular coupling, vascular dysfunction and other organ abnormalities (including renal dysfunction). Aside from the 'classical' syndrome of heart failure described above (due mainly to primary pump failure), patients may present with signs and symptoms of acute heart failure with pulmonary overcirculation (e.g. with large ventricular septal defect) as well as diastolic dysfunction (e.g. with restrictive cardiomyopathy).

Incidence

Heart failure in children is common and frequently encountered in paediatric practice. Moderate to severe congenital heart disease occurs in less than 0.6% of live births. Estimates of the incidence of heart failure in the modern era vary. In a series of 1196 paediatric patients with cardiovascular disease at a tertiary centre in Belgium reported in 2008, heart failure occurred in just over 10% (6.2% of those with congenital heart disease and 13.5% with rhythm disturbance). However, rates of heart failure vary depending upon the precise definitions used and the populations studied. A German study from 2005 found heart failure occurred in 33% of paediatric patients with heart disease (including but not exclusively congenital). Overall mortality was 6.3% in this group. Both studies showed that the risk of heart failure was greatest in the first year of life.

Cardiomyopathy (CM) occurs in 8 per 100,000 infants per year. 70% of patients are diagnosed in the first year of life and dilated cardiomyopathy (DCM) is the most commonly seen phenotype. Up to 80% of patients with cardiomyopathy develop symptomatic heart failure. Many children with mild LV dysfunction recover fully. Of those with more severe dysfunction (LVEF less than 35%); 25% progress to death or transplantation, 50% develop chronic DCM and the rest recover fully.

Pathophysiology

There are two main disease processes causing the symptoms of heart failure. Primary pump failure is the commonly understood mechanism. However, in young children it is more common to encounter heart failure with normal or hyperdynamic pump function. This is usually in the setting of a large left-to-right shunt causing pulmonary overcirculation.

Heart failure due to a large left-to-right shunt

At birth, the pressure difference between the systemic and pulmonary circulations is usually small. Pulmonary vascular resistance falls in the first weeks of life and will eventually allow increased blood flow from an unrestrictive lesion (such as large ventricular septal defect (VSD) or persistent ductus arteriosus (PDA)) to enter the lungs. This results in increased left atrial and

left ventricular end-diastolic volumes and left ventricular enlargement. Blood flows preferentially to the low resistance pulmonary circulation. The resulting lung parenchymal stiffness and increased left atrial pressure results in the characteristic breathlessness seen in these patients if left untreated. If untreated, increased pulmonary blood flow will eventually result in progressive pulmonary vascular disease leading to reversal of the shunt and Eisenmenger syndrome (usually seen in the second decade if the lesion remains unrepaired).

Heart failure due to low cardiac output

In 'classical' heart failure, there is low cardiac output, usually secondary to myocardial cell death. Mechanical obstruction to the left ventricular outflow, for example in critical aortic stenosis or severe coarctation of the aorta, may also cause a low output state.

The (mal)adaptive response to heart failure

Acutely, the compensatory mechanisms in cardiac failure may be adaptive, for example increased stroke volume and/or heart rate maintain cardiac output and organ perfusion. In young children there is only a very limited increase in stroke volume possible and therefore the dominant effect is one of increased heart rate. This increases energy demands and may exacerbate any tachypnoea and lead to faltering growth even in the presence of adequate feeding. Peripheral vasoconstriction also occurs to maintain perfusion pressure to the systemic vasculature. The child may be pale and clammy. However, mechanisms to sustain cardiac output soon become maladaptive (Figure 1).

The renin-angiotensin-aldosterone system (RAAS) is activated by decreased perfusion of the juxtaglomerular cells in the kidneys. Thus angiotensin II is formed in the lungs causing peripheral vasoconstriction and release of aldosterone by the adrenal cortex which acts on the renal tubules to retain water and sodium. This eventually leads to systemic fluid overload and oedema as well as increased afterload on the heart and adverse myocardial remodelling.

Increased sympathetic tone leads to increased peripheral vascular resistance and positive ionotropic and chronotropic effects on the myocardium. This mechanism also eventually fails, with high levels of circulating catecholamines causing down-regulation of receptors, increased afterload and increased risk of arrhythmias. Other neurohormonal mechanisms are also activated including arginine-vasopressin which potentiates peripheral vasoconstriction and natriuretic peptides which oppose these mechanisms and cause vasodilation and diuresis.

The right ventricle (RV) is often overlooked in the mechanism of heart failure. However, its importance is now better understood with RV function being linked to survival in cardiomyopathy. An important cause of right ventricular systolic dysfunction is long-term pressure-loading due to pulmonary hypertension. This results in RV dilatation, increased filling pressures and diastolic dysfunction. There is some evidence that right ventricular dysfunction is compounded in left ventricular failure by septal dyskinesia and stretching of the limited pericardial compartment in the face of a progressively dilating left ventricle.

Both ventricles are at risk of diastolic dysfunction, with a decrease in LV filling seen in tachycardia as the length of diastole decreases.

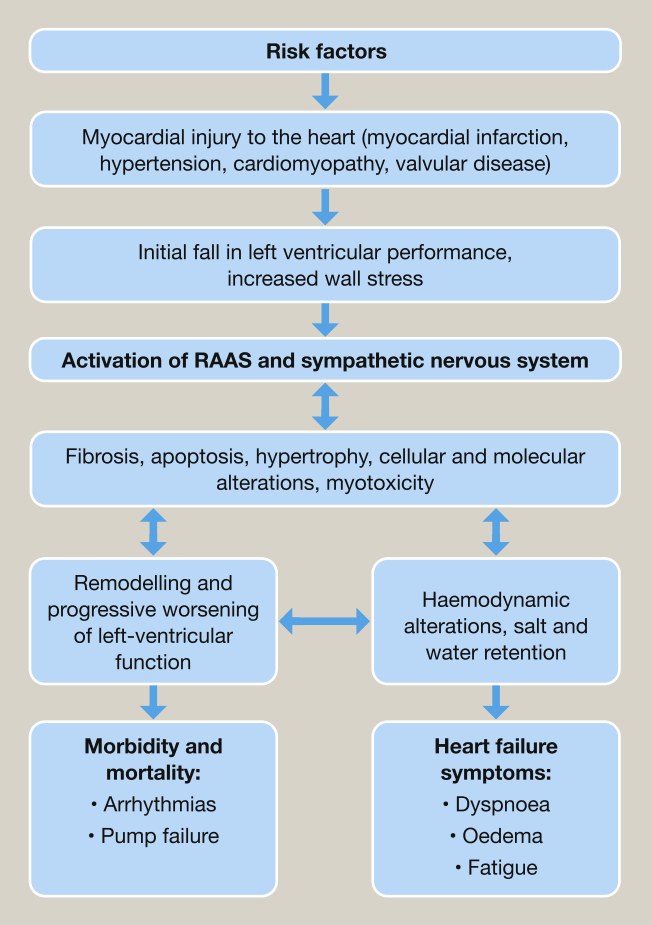

Figure 1 Simplified view of heart failure pathophysiology.

Aetiology as a form of classification

Heart failure can also be classified by causative mechanism. The heart must be able to eject an adequate stroke volume (the amount of blood pumped by the ventricle per contraction) by overcoming systemic vascular resistance and accept venous return in diastole. Many of the following mechanisms occur in the same patient at different times, especially following surgery for congenital heart disease.

Decreased ventricular contractility

True pump failure occurs in dilated cardiomyopathy. This form of heart failure is also seen as a result of cardiotoxic drugs (e.g. anthracyclines), genetic disorders (e.g. muscular dystrophy), inborn errors of metabolism (e.g. Barth syndrome) and even hypocalcaemic rickets. Primary myocyte cell death followed by adverse remodelling results in increased replacement fibrosis and decreased cardiac output. The ventricle becomes dilated as a result of decreased stroke volume and increased end-diastolic volume, thus resulting in further decreased function as described by the Frank–Starling law. Determination of the underlying aetiology is important (although only possible in 30–40% of patients) as myocarditis has a better prognosis and some conditions (e.g. hypocalcaemia and vitamin D deficiency) are treatable.