ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure 2008

The Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2008 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association of the ESC (HFA) and endorsed by the European Society of Intensive Care Medicine (ESICM)

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‡Important note: The originally published version contained errors in Table 22 on p. 2412 and Table 28 on p. 2427. This version has been corrected and the errors are identified in red.

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These guidelines were first published on the European Society of Cardiology Web Site on 30 August 2008. This article has been copublished in the European Journal of Heart Failure, doi:10.1016/j.ejheart.2008.08.005.

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Preamble

Guidelines and Expert Consensus Documents summarize and evaluate all currently available evidence on a particular issue with the aim of assisting physicians and other healthcare providers in selecting the best management strategies for a typical patient, suffering from a given condition, taking into account the impact on outcome, as well as the risk–benefit ratio of particular diagnostic or therapeutic means. Guidelines are no substitutes for textbooks. The legal implications of medical guidelines have been discussed previously.

A great number of Guidelines and Expert Consensus Documents have been issued in recent years by the European Society of Cardiology (ESC) as well as by other societies and organizations. Because of the impact on clinical practice, quality criteria for development of guidelines have been established in order to make all decisions transparent to the user. The recommendations for formulating and issuing ESC Guidelines and Expert Consensus Documents can be found on the ESC Web Site in the guidelines section (www.escardio.org).

In brief, experts in the field are selected and undertake a comprehensive review of the published evidence for management and/or prevention of a given condition. A critical evaluation of diagnostic and therapeutic procedures is performed, including assessment of the risk–benefit ratio. Estimates of expected health outcomes for larger societies are included, where data exist. The level of evidence and the strength of recommendation of particular treatment options are weighed and graded according to pre-defined scales, as outlined in Tables 1 and 2.

The experts of the writing panels have provided disclosure statements of all relationships they may have which might be perceived as real or potential sources of conflicts of interest. These

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**Table 1 Classes of recommendations**

<table>
<thead>
<tr>
<th>Classes of Recommendations</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>Evidence and/or general agreement that a given treatment or procedure is beneficial, useful, effective.</td>
</tr>
<tr>
<td>Class II</td>
<td>Conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of the given treatment or procedure.</td>
</tr>
<tr>
<td>Class IIa</td>
<td>Weight of evidence/opinion is in favour of usefulness/efficacy.</td>
</tr>
<tr>
<td>Class IIb</td>
<td>Usefulness/efficacy is less well established by evidence/opinion.</td>
</tr>
<tr>
<td>Class III</td>
<td>Evidence or general agreement that the given treatment or procedure is not useful/effective, and in some cases may be harmful.</td>
</tr>
</tbody>
</table>

**Table 2 Levels of evidence**

<table>
<thead>
<tr>
<th>Level of Evidence A</th>
<th>Data derived from multiple randomized clinical trials or meta-analyses.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of Evidence B</td>
<td>Data derived from a single randomized clinical trial or large non-randomized studies.</td>
</tr>
<tr>
<td>Level of Evidence C</td>
<td>Consensus of opinion of the experts and/or small studies, retrospective studies, registries.</td>
</tr>
</tbody>
</table>
Introduction

Heart failure guidelines

The aim of this document is to provide practical guidelines for the diagnosis, assessment, and treatment of acute and chronic heart failure (HF). These guidelines are a development and revision of guidelines published in 1995, 1997, 2001, and 2005. Much new information relating to the treatment of HF has emerged. This has necessitated a revision of some previous recommendations. The recommendations are relevant to clinical practice, epidemiological surveys, observational studies, and clinical trials. Particular attention in this revision has been given to the simplification and clarity of recommendations, and to the problems associated with implementation. The intention has been to merge and modify previous documents relating to HF. The guidelines are intended as a support for practicing physicians and other healthcare professionals providing advice on how to manage these patients, including recommendations for referral. Documented and published evidence on diagnosis, efficacy, and safety of therapeutic interventions is the main basis for these guidelines. Where evidence is lacking or does not resolve a clinical issue, a consensus opinion is presented.

ESC Guidelines are relevant to 51 member states with diverse economies and, therefore, recommendations based on cost-effectiveness have, in general, been avoided. National health policy as well as clinical judgement may dictate the order of priorities in implementation. The recommendations in these guidelines should always be considered in the light of national policies and local regulatory guidance on the use of any diagnostic procedure, medicine, or device.

This report was drafted by a Writing Group of the Task Force (see title page) appointed by the CPG of the ESC. Within this Task Force, statements of conflicts of interests were collected, which are available at the ESC Office. The draft was sent to the CPG and the document reviewers (see title page). After consideration of their input, the document was updated, reviewed, and then approved for publication by the entire Task Force. An evidence-based approach has been used to generate the grade of any recommendation in the guidelines, with an additional assessment of the quality of the evidence. For the diagnosis of HF, evidence is incomplete. Where that is so, recommendations and statements are based on a consensus of expert opinions.

Definition and diagnosis

Definition of heart failure

Many definitions of HF have been put forward over the last 50 years. These highlight one or several features of this complex syndrome such as haemodynamics, oxygen consumption, or exercise capacity. In recent years, most definitions have emphasized the need for both the presence of symptoms of HF and physical signs of fluid retention.

HF is a syndrome in which the patients should have the following features: symptoms of HF, typically shortness of breath at rest or during exertion, and/or fatigue; signs of fluid retention such as pulmonary congestion or ankle swelling; and objective evidence of an abnormality of the structure or function of the heart at rest (Table 3). A clinical response to treatment directed at HF alone is not sufficient for the diagnosis, but is helpful when the diagnosis remains unclear after appropriate diagnostic investigations. Patients with HF would usually be expected to show some improvement in symptoms and signs in response to those treatments from which a relatively fast symptomatic improvement could be anticipated (e.g., diuretic or vasodilator administration). The major and common clinical manifestations of HF are shown in Table 4.

Asymptomatic structural or functional abnormalities of the heart are considered as precursors of symptomatic HF and are associated with a high mortality. Treatment is available for these
conditions, when diagnosed, and for that reason these conditions are included in these guidelines.

An advantage of the definition of HF used here is that it is practical and allows a more precise approach both in clinical practice and when undertaking observational surveys, epidemiological studies, or clinical trials. HF should never be a sole diagnosis. The cause should always be sought.

**Descriptive terms in heart failure**

**Acute and chronic heart failure**

Many additional words or phrases are used to characterize patients with HF. These terms can overlap, and physicians do sometimes use words with a slightly different meaning. The word ‘acute’ in the context of acute HF has become confusing because some clinicians use the word to indicate severity (the medical emergency of life-threatening pulmonary oedema) and others use the word to indicate decompensated, recent-onset, or even new-onset HF. The word is then an indicator of time rather than severity. The words acute, advanced, and decompensated should not be used interchangeably when applied to HF. A useful classification of HF based on the nature of the clinical presentation is shown in Table 5. A distinction is made between new-onset HF, transient HF, and chronic HF. New-onset HF is self-explanatory and refers to the first presentation. Transient HF refers to symptomatic HF over a limited time period, although long-term treatment may be indicated. Examples would be patients with mild myocarditis from which recovery is near complete, patients with a myocardial infarction (MI) who need diuretics in the coronary care unit but in whom long-term treatment is not necessary, or transient HF caused by ischaemia and resolved by revascularization. Worsening HF on a background of chronic HF (decompensation) is by far the most common form of HF leading to hospital admission, accounting for 80% of cases. Treatment should be based on the clinical presentation for which specific therapy is indicated (e.g. pulmonary oedema, hypertension emergency, acute MI).

**Systolic vs. diastolic heart failure**

A distinction is frequently made between systolic and diastolic HF. The distinction is somewhat arbitrary. Patients with diastolic HF have symptoms and/or signs of HF and a preserved left ventricular ejection fraction (LVEF) >40–50%. There is no consensus concerning the cut-off for preserved EF. The EF is the stroke volume divided by the end-diastolic volume for the relevant ventricular chamber of the heart and is therefore largely determined by the end-diastolic volume of the ventricular chamber (i.e. a dilated heart). An EF below or above 40%, distinguishes between large or normal left end-diastolic ventricular volumes. The distinction has arisen largely because in the past most patients admitted to hospitals for investigation or entered into clinical trials have had dilated hearts with a reduced EF, 35 or 40%. Most patients with HF have evidence of both systolic and diastolic dysfunction at rest or on exercise. Diastolic and systolic HFs should not be considered as separate entities. Other phrases have been used to describe diastolic HF, such as HF with preserved ejection fraction (HFPEF), HF with normal ejection fraction (HFNEF), or HF with preserved systolic function (HFPFSF). We have elected to use the abbreviation HFPEF in this document.

**Table 3 Definition of heart failure**

Heart failure is a clinical syndrome in which patients have the following features:

- Symptoms typical of heart failure
  - Breathlessness at rest or on exercise, fatigue, tiredness, ankle swelling
- Signs typical of heart failure
  - Tachycardia, tachypnoea, pulmonary rales, pleural effusion, raised jugular venous pressure, peripheral oedema, hepatomegaly
- Objective evidence of a structural or functional abnormality of the heart at rest
  - Cardiomegaly, third heart sound, cardiac murmurs, abnormality on the echocardiogram, raised natriuretic peptide concentration

**Table 4 Common clinical manifestations of heart failure**

<table>
<thead>
<tr>
<th>Dominant clinical feature</th>
<th>Symptoms</th>
<th>Signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peripheral oedema/congestion</td>
<td>Breathlessness</td>
<td>Peripheral oedema</td>
</tr>
<tr>
<td></td>
<td>Tiredness, fatigue</td>
<td>Raised jugular venous pressure</td>
</tr>
<tr>
<td></td>
<td>Anorexia</td>
<td>Pulmonary oedema</td>
</tr>
<tr>
<td>Pulmonary oedema</td>
<td>Severe breathlessness at rest</td>
<td>Hepatomegaly, ascites</td>
</tr>
<tr>
<td>Cardiogenic shock (low output syndromes)</td>
<td>Confusion</td>
<td>Fluid overload (congestion)</td>
</tr>
<tr>
<td></td>
<td>Weakness</td>
<td>Cachexia</td>
</tr>
<tr>
<td></td>
<td>Cold periphery</td>
<td>Crackles or rales over lungs, effusion</td>
</tr>
<tr>
<td>High blood pressure (hypertensive heart failure)</td>
<td>Breathlessness</td>
<td>Tachycardia, tachypnoea</td>
</tr>
<tr>
<td>Right heart failure</td>
<td>Breathlessness</td>
<td>Poor peripheral perfusion</td>
</tr>
<tr>
<td></td>
<td>Fatigue</td>
<td>SBP &lt; 90 mmHg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anuria or oliguria</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Usually raised BP, LV hypertrophy, and preserved EF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evidence of RV dysfunction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Raised JVP, peripheral oedema, hepatomegaly, gut congestion</td>
</tr>
</tbody>
</table>
Other descriptive terms in heart failure
Many other phrases have been used in describing patients with HF that do not have aetiological significance. Forward and backward HF are old terms used to express the concept that perfusion of tissue and an increase in the left atrial pressure can under some circumstance such as acute HF and cardiogenic shock contribute to the pathophysiology. Preload and afterload are terms linked to the left and/or right atrial pressures (often reflecting volume overload) and the work of the myocardium (often reflecting pressure overload or high impedance). However, measures of these parameters are often imprecise. Right and left HF refer to syndromes presenting predominantly with congestion of the systemic or pulmonary veins, leading to signs of fluid retention with ankle swelling or pulmonary oedema, respectively. The most common cause of right ventricular failure is a raised pulmonary artery pressure due to failure of the LV leading to poor perfusion of the kidney, retention of salt and water, and accumulation of fluid in the systemic circulation. High and low output HF refer to the observation that a number of specific medical conditions lead to a clinical picture which mimics the signs and symptoms of HF. Common causes of high output states mimicking HF are anaemia, thyrotoxicosis, septicaemia, liver failure, arteriovenous shunts, Paget’s disease, and beri-beri. In these conditions, the primary abnormality is not disease of the heart and the conditions are reversible with treatment. The conditions are better labelled as HF secondary to circulatory high output conditions and are important because they are treatable and should be excluded when diagnosing HF.

Mild, moderate, or severe HF is used as a clinical symptomatic description, where mild is used for patients who can move around with no important limitations of dyspnoea or fatigue, severe for patients who are markedly symptomatic and need frequent medical attention, and moderate for the remaining patient cohort. Two classifications (Table 6) of the severity of HF are commonly employed. One is based on symptoms and exercise capacity [the New York Heart Association (NYHA) functional classification21,22]. The NYHA functional classification has proved to be clinically useful and it is employed routinely in most randomized clinical trials. The other describes HF in stages based on structural changes and symptoms. All patients with overt HF are in stages C and D.7

Epidemiology
Much is now known about the epidemiology of HF.23–27 The ESC represents countries with a population of >900 million, and there are at least 15 million patients with HF in those 51 countries. The prevalence of asymptomatic ventricular dysfunction is similar, so that HF or asymptomatic ventricular dysfunction is evident in ~4% of the population. The prevalence of HF is between 2 and 3% and rises sharply at ~75 years of age, so the prevalence in 70- to 80-year-old people is between 10 and 20%. In younger age groups HF is more common in men because the most common cause, coronary heart disease, occurs in earlier decades. In the elderly, the prevalence is equal between the sexes.

The overall prevalence of HF is increasing because of the ageing of the population, the success in prolonging survival in patients suffering coronary events, and the success in postponing coronary events by effective prevention in those at high risk or those who have already

Table 5 Classification of heart failure

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>New onset</td>
<td>First presentation</td>
</tr>
<tr>
<td>Transient</td>
<td>Acute or slow onset</td>
</tr>
<tr>
<td>Chronic</td>
<td>Persistent</td>
</tr>
</tbody>
</table>

Table 6 Classification of heart failure by structural abnormality (ACC/AHA), or by symptoms relating to functional capacity (NYHA)

<table>
<thead>
<tr>
<th>ACC/AHA stages of heart failure</th>
<th>NYHA functional classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage of heart failure based on structure and damage to heart muscle</td>
<td>Severity based on symptoms and physical activity</td>
</tr>
<tr>
<td>Stage A: At high risk for developing heart failure. No identified</td>
<td>Class I: No limitation of physical activity. Ordinary physical activity does not cause undue fatigue, palpitation, or dyspnoea.</td>
</tr>
<tr>
<td>structural or functional abnormality; no signs or symptoms.</td>
<td>Class II: Slight limitation of physical activity. Comfortable at rest, but ordinary physical activity results in fatigue, palpitation, or dyspnoea.</td>
</tr>
<tr>
<td>Stage B: Developed structural heart disease that is strongly</td>
<td>Class III: Marked limitation of physical activity. Comfortable at rest, but less than ordinary activity results in fatigue, palpitation, or dyspnoea.</td>
</tr>
<tr>
<td>associated with the development of heart failure, but without signs</td>
<td>Class IV: Unable to carry on any physical activity without discomfort. Symptoms at rest. If any physical activity is undertaken, discomfort is increased.</td>
</tr>
<tr>
<td>or symptoms.</td>
<td></td>
</tr>
<tr>
<td>Stage C: Symptomatic heart failure associated with underlying</td>
<td></td>
</tr>
<tr>
<td>structural heart disease.</td>
<td></td>
</tr>
<tr>
<td>Stage D: Advanced structural heart disease and marked symptoms of</td>
<td></td>
</tr>
<tr>
<td>heart failure at rest despite maximal medical therapy.</td>
<td></td>
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</tbody>
</table>
survived a first event (secondary prevention).\textsuperscript{28,29} In some countries the age-adjusted mortality from HF is falling at least in part due to modern treatment.\textsuperscript{28,30–32} The mean age of patients with HF in the community in developed countries is 75 years. HFPEF is more common in the elderly, women, and those with hypertension or diabetes. HF is the cause of 5% of acute hospital admissions, is present in 10% of patients in hospital beds, and accounts for \( \sim 2\% \) of national expenditure on health, mostly due to the cost of hospital admissions.\textsuperscript{33} Substantial under-reporting is probably due to clinicians’ preference for aetiological diagnoses (e.g. aortic stenosis) or the diagnosis of a major co-morbidity (e.g. diabetes).

The outlook is, in general, gloomy, although some patients can live for many years.\textsuperscript{23,29,34,35} Overall 50% of patients are dead at 4 years. Forty per cent of patients admitted to hospital with HF are dead or readmitted within 1 year.

Studies show that the accuracy of diagnosis of HF by clinical means alone is often inadequate, particularly in women, the elderly, and the obese.\textsuperscript{36,37} HFPEF (EF \( \sim 45–50\% \)) is present in half the patients with HF. The prognosis in more recent studies has been shown to be essentially similar to that of systolic HF.\textsuperscript{38,39}

### Aetiology of heart failure

There are only a limited number of ways in which the function of the heart can be affected. The most common causes of functional deterioration of the heart are damage or loss of heart muscle, acute or chronic ischaemia, increased vascular resistance with hypertension, or the development of a tachyarrhythmia such as atrial fibrillation (AF). Coronary heart disease is by far the most common cause of myocardial disease, being the initiating cause in \( \sim 70\% \) of patients with HF.\textsuperscript{28,40} Valve disease accounts for 10% and cardiomyopathies for another 10% (Table 7).

A cardiomyopathy is a myocardial disorder in which the heart muscle is structurally and functionally abnormal [in the absence of coronary artery disease (CAD), hypertension, valvular disease, or congenital heart disease] sufficient to cause the observed myocardial abnormality.\textsuperscript{41}

A classification of the cardiomyopathies has been published recently by the Working Group on Myocardial and Pericardial Diseases of the ESC.\textsuperscript{41} The American Heart Association has issued a scientific statement.\textsuperscript{42} Both take into account the great advances made recently in understanding the genetic origins and the biology of the cardiomyopathies. The European proposal was guided by the relevance of the new classification to everyday clinical practice and maintains the previously defined morpho-functional phenotypes which are further subdivided into familial/genetic and non-familial/non-genetic forms. The European classification abandoned the older distinction between ‘primary’ and ‘secondary’ cardiomyopathies, and does not include ion channelopathies among cardiomyopathies.

#### Table 7: Common causes of heart failure due to disease of heart muscle (myocardial disease)

<table>
<thead>
<tr>
<th>Coronary heart disease</th>
<th>Hypertension</th>
<th>Cardiomyopathies*</th>
<th>Drugs</th>
<th>Toxins</th>
<th>Endocrine</th>
<th>Nutritional</th>
<th>Infiltrative</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Many manifestations</td>
<td>Often associated with left ventricular hypertrophy and preserved ejection fraction</td>
<td>Familial/genetic or non-familial/non-genetic (including acquired, e.g. myocarditis)</td>
<td>Hypertrophic (HCM), dilated (DCM), restrictive (RCM), arrhythmogenic right ventricular (ARVC), unclassified</td>
<td>β-Blockers, calcium antagonists, antiarrhythmics, cytotoxic agents</td>
<td>Alcohol, medication, cocaine, trace elements (mercury, cobalt, arsenic)</td>
<td>Diabetes mellitus, hypo/hyperthyroidism, Cushing syndrome, adrenal insufficiency, excessive growth hormone, phaeochromocytoma</td>
<td>Deficiency of thiamine, selenium, carnitine, Obesity, cachexia</td>
<td>Sarcoïdosis, amyloidosis, haemochromatosis, connective tissue disease</td>
</tr>
</tbody>
</table>

*See text for details.

#### Table 8: Key features of the clinical history in patients with heart failure

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Cardiovascular events</th>
<th>Risk profile</th>
<th>Response to current and previous therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breathlessness</td>
<td>Coronary heart disease</td>
<td>Family history, smoking, hyperlipidaemia, hypertension, diabetes</td>
<td>(orthopnoea, paroxysmal nocturnal dyspnoea)</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Myocardial infarction</td>
<td></td>
<td>(tiredness, exhaustion)</td>
</tr>
<tr>
<td>Angina, palpitations, syncope</td>
<td>Intervention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other surgery</td>
<td>Stroke or peripheral vascular disease</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Valvular disease or dysfunction</td>
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</tbody>
</table>
**Diagnosis of heart failure**

In 1933 Sir Thomas Lewis wrote in his textbook on heart disease that ‘The very essence of cardiovascular medicine is the recognition of early heart failure’.43

**Symptoms and signs of heart failure**

The symptoms and signs of HF are the key to early detection because that is what causes patients to seek medical attention. Taking a good history and careful physical examination are skills, which are essential to master (Table 8). Breathlessness, tiredness, and fatigue are the characteristic symptoms, but eliciting and assessing these symptoms particularly in the elderly requires experience and skill.44–46 The clinical signs of HF (Table 9) should be assessed in a careful clinical examination, including observation, palpation, and auscultation.47–51

Like symptoms, the signs of early HF can be difficult to interpret, not only in elderly patients, but also in the obese. The clinical suspicion of HF must then be confirmed by more objective tests particularly targeting assessment of cardiac function.

**The causes of symptoms in heart failure**

The origins of the symptoms of HF are not fully understood.52–55 Increased pulmonary capillary pressure is undoubtedly responsible for pulmonary oedema and shortness of breath in the context of acute HF with evidence of fluid overload. In contrast, studies conducted during exercise in patients with chronic HF demonstrate only a weak relationship between capillary pressure and exercise performance. HF is a condition which eventually results in pathology in almost all body organs. Tiredness and fatigue are frequently reported symptoms, but are non-specific with multiple causes. Loss of skeletal muscle mass and strength is a late manifestation.55,56 Signals from skeletal muscle are often interpreted by the brain as breathlessness or as fatigue. This may explain why the response to treatment may be slow in patients with HF because the quality of skeletal muscle must be restored. Variation in the degree of mitral regurgitation or transitory dysrhythmia, common in HF, will also exacerbate breathlessness.

**Symptoms and severity of heart failure**

There is a poor relationship between symptoms and the severity of cardiac dysfunction. Symptoms do relate more closely to prognosis if persistent after therapy and can then be used to classify the severity of HF and to monitor the effects of therapy. However, symptoms alone should not guide the optimal titration of neurohormonal inhibitors such as angiotensin-converting enzyme inhibitors (ACEIs), angiotensin receptor blockers (ARBs), β-blockers, or aldosterone antagonists, because these drugs impact on mortality in a manner that is not closely related to symptoms. Patients should be titrated to the optimal, tolerated dose.

The severity of heart failure is most often classified using the NYHA functional classification. A more recent classification is based on both the structure of the heart and symptoms. In the context of MI, two other classifications of the severity of HF, the Killip57 and Forrester58 classifications, are used (Table 10).

**Algorithm for the diagnosis of heart failure**

An algorithm for the diagnosis of HF or LV dysfunction is shown in Figure 1. The diagnosis of HF is not sufficient alone. Appropriate investigations are required to establish the cause of the HF, because although the general treatment of HF is common to

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**Table 9** Key features of the clinical examination in patients with heart failure

<table>
<thead>
<tr>
<th>Appearance</th>
<th>Alertness, nutritional status, weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse</td>
<td>Rate, rhythm, and character</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>Systolic, diastolic, pulse pressure</td>
</tr>
<tr>
<td>Fluid overload</td>
<td>Jugular venous pressure</td>
</tr>
<tr>
<td></td>
<td>Peripheral oedema (ankles and sacrum)</td>
</tr>
<tr>
<td></td>
<td>hepatomegaly, ascites</td>
</tr>
<tr>
<td>Lungs</td>
<td>Respiratory rate</td>
</tr>
<tr>
<td></td>
<td>Rales</td>
</tr>
<tr>
<td></td>
<td>Pleural effusion</td>
</tr>
<tr>
<td>Heart</td>
<td>Apex displacement</td>
</tr>
<tr>
<td></td>
<td>Gallop rhythm, third heart sound</td>
</tr>
<tr>
<td></td>
<td>Murmurs suggesting valvular dysfunction</td>
</tr>
</tbody>
</table>

**Table 10** Two classifications of the severity of heart failure in the context of acute myocardial infarction

<table>
<thead>
<tr>
<th>Killip classification</th>
<th>Forrester classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed to provide a clinical estimate of the severity of circulatory derangement in the treatment of acute myocardial infarction.</td>
<td>Designed to describe clinical and haemodynamic status in acute myocardial infarction.</td>
</tr>
<tr>
<td>Stage I No heart failure. No clinical signs of cardiac decompenation</td>
<td>1. Normal perfusion and pulmonary wedge pressure (PCWP—estimate of left atrial pressure)</td>
</tr>
<tr>
<td>Stage II Heart failure. Diagnostic criteria include rales, S3 gallop, and pulmonary venous hypertension. Pulmonary congestion with wet rales in the lower half of the lung fields.</td>
<td>2. Poor perfusion and low PCWP (hypovolaemic)</td>
</tr>
<tr>
<td>Stage III Severe heart failure. Frank pulmonary oedema with rales throughout the lung fields</td>
<td>3. Near normal perfusion and high PCWP (pulmonary oedema)</td>
</tr>
<tr>
<td>Stage IV Cardiogenic shock. Signs include hypotension (SBP &lt; 90 mmHg), and evidence of peripheral vasoconstriction such as oliguria, cyanosis and sweating</td>
<td>4. Poor perfusion and high PCWP (cardiogenic shock)</td>
</tr>
</tbody>
</table>


most patients, some causes require specific treatments and may be correctable.

## Diagnostic techniques

### Diagnostic tests in heart failure

Several diagnostic tests are employed routinely to confirm or rule out the diagnosis of HF (Table 11). Diagnostic tests are usually most sensitive for the detection of patients with HF and reduced EF. Diagnostic findings are often less pronounced in patients with HFPEF. Echocardiography is the most useful method for evaluating systolic and diastolic dysfunction.

The following investigations are considered appropriate in patients with HF. However, the recommendations largely represent expert consensus opinion without adequate documented evidence. Level of evidence C applies unless otherwise stated.

### Electrocardiogram

An electrocardiogram (ECG) should be performed in every patient with suspected heart failure.

Electrocardiographic changes are common in patients suspected of having HF (Table 12). An abnormal ECG has little predictive value for the presence of HF. If the ECG is completely normal, HF, especially with systolic dysfunction, is unlikely (<10%).

### Chest X-ray

Chest X-ray is an essential component of the diagnostic work-up in heart failure. It permits assessment of pulmonary congestion and may demonstrate important pulmonary or thoracic causes of dyspnoea.

The chest X-ray (in two planes) is useful to detect cardiomegaly, pulmonary congestion, and pleural fluid accumulation, and can demonstrate the presence of pulmonary disease or infection causing or contributing to dyspnoea (Table 13). Apart from congestion, findings are predictive of HF only in the context of typical signs and symptoms. Cardiomegaly can be absent not only in acute but also in chronic HF.

### Laboratory tests

A routine diagnostic evaluation of patients with suspected HF includes a complete blood count (haemoglobin, leukocytes, and
platelets), serum electrolytes, serum creatinine, estimated glomerular filtration rate (GFR), glucose, liver function tests, and urinalysis. Additional tests should be considered according to the clinical picture (Table 14). Marked haematological or electrolyte abnormalities are uncommon in untreated mild to moderate HF, although mild anaemia, hyponatraemia, hyperkalaemia, and reduced renal function are common, especially in patients treated with diuretics and ACEI/ARB/aldosterone antagonist therapy. Appropriate laboratory monitoring is essential during the initiation, titration, and follow-up phases in patients receiving drug therapy for HF.

**Natriuretic peptides**

Plasma concentrations of natriuretic peptides are useful biomarkers in the diagnosis of HF and in the management of patients with established chronic HF. Evidence exists supporting their use for diagnosing, staging, making hospitalization/discharge decisions, and identifying patients at risk for clinical events. The evidence for their use in monitoring and adjusting drug therapy is less clearly established. A normal concentration in an untreated patient has a high negative predictive value and makes HF an unlikely cause of symptoms. This may play an important role especially...

### Table 12 Common ECG abnormalities in heart failure

<table>
<thead>
<tr>
<th>Abnormality</th>
<th>Causes</th>
<th>Clinical implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus tachycardia</td>
<td>Decompensated HF, anaemia, fever, hyperthyroidism</td>
<td>Clinical assessment</td>
</tr>
<tr>
<td>Sinus bradycardia</td>
<td>β-Blockade, digoxin, Anti-arrhythmics</td>
<td>Evaluate drug therapy</td>
</tr>
<tr>
<td>Atrial tachycardia/flutter/fibrillation</td>
<td>Hyperthyroidism, infection, mitral valve diseases</td>
<td>Slow AV conduction, medical conversion, electroversion, catheter ablation, anticoagulation</td>
</tr>
<tr>
<td>Ventricular arrhythmias</td>
<td>Ischemia, infarction, cardiomyopathy, myocarditis</td>
<td>Exercise test, perfusion studies, coronary angiography, electrophysiology testing, ICD</td>
</tr>
<tr>
<td>Ischaemia/Infarction</td>
<td>Coronary artery disease</td>
<td>Echo, troponins, coronary angiography, revascularization</td>
</tr>
<tr>
<td>Q waves</td>
<td>Infarction, hypertrophic cardiomyopathy</td>
<td>Echo, coronary angiography</td>
</tr>
<tr>
<td>LV hypertrophy</td>
<td>Hypertension, aortic valve disease, hypertrophic cardiomyopathy</td>
<td>Echo/Doppler</td>
</tr>
<tr>
<td>AV block</td>
<td>Infarction, drug toxicity, myocarditis, sarcoidosis, Lyme disease</td>
<td>Evaluate drug therapy, pacemaker, systemic disease</td>
</tr>
<tr>
<td>Microvoltage</td>
<td>Obesity, emphysema, pericardial effusion, amyloidosis</td>
<td>Echo, chest X-ray</td>
</tr>
<tr>
<td>QRS length &gt;120 ms of LBBB morphology</td>
<td>Electrical and mechanical dysynchrony</td>
<td>Echo, CRT-P, CRT-D</td>
</tr>
</tbody>
</table>

### Table 13 Common chest X-ray abnormalities in heart failure

<table>
<thead>
<tr>
<th>Abnormality</th>
<th>Causes</th>
<th>Clinical Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiomegaly</td>
<td>Dilated LV, RV, atria, Pericardial effusion</td>
<td>Echo/Doppler</td>
</tr>
<tr>
<td>Ventricular hypertrophy</td>
<td>Hypertension, aortic stenosis, hypertrophic cardiomyopathy</td>
<td>Echo/Doppler</td>
</tr>
<tr>
<td>Normal pulmonary findings</td>
<td>Pulmonary congestion unlikely</td>
<td>Reconsider diagnosis (if untreated)</td>
</tr>
<tr>
<td>Pulmonary venous congestion</td>
<td>Elevated LV filling pressure</td>
<td>Left heart failure confirmed</td>
</tr>
<tr>
<td>Interstitial oedema</td>
<td>Elevated LV filling pressure</td>
<td>Left heart failure confirmed</td>
</tr>
<tr>
<td>Pleural effusions</td>
<td>Elevated filling pressures, HF likely if bilateral</td>
<td>Consider non-cardiac aetiology if abundant</td>
</tr>
<tr>
<td>Kerley B lines</td>
<td>Increased lymphatic pressures</td>
<td>If abundant, consider diagnostic or therapeutic centres</td>
</tr>
<tr>
<td>Hyperlucent lung fields</td>
<td>Emphysema or pulmonary embolism</td>
<td>Mitral stenosis or chronic HF</td>
</tr>
<tr>
<td>Pulmonary infection</td>
<td>Pneumonia may be secondary to pulmonary congestion</td>
<td>Spiral CT, spirometry, Echo</td>
</tr>
<tr>
<td>Pulmonary infiltration</td>
<td>Systemic disease</td>
<td>Treat both infection and HF</td>
</tr>
<tr>
<td>Echo/Doppler</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
in primary care. High levels of natriuretic peptides despite optimal treatment indicate a poor prognosis. B-type natriuretic peptide (BNP) and N-terminal pro-BNP (NT-proBNP) measurements were introduced as tools for diagnosis and management of HF. They rise in response to an increase in myocardial wall stress. Usually, lower levels are observed in patients with preserved LV systolic function. There is no definitive cut-off value recognized for either of the two natriuretic peptides commonly assessed for the diagnosis of HF in the emergency department. Due to the relatively long half-lives of natriuretic peptides, abrupt changes in LV filling pressures may not be reflected by rapid changes in peptides. Conditions other than HF associated with elevated natriuretic peptide levels include: LV hypertrophy, tachycardia, right ventricular overload, myocardial ischaemia, hypoxaemia, renal dysfunction, advanced age, liver cirrhosis, sepsis, and infection. Obesity and treatment may decrease natriuretic peptide levels. Natriuretic peptides may also be useful in assessing prognosis prior to hospital discharge and in monitoring the effectiveness of HF therapy.

<table>
<thead>
<tr>
<th>Abnormality</th>
<th>Cause</th>
<th>Clinical implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased serum creatinine (&gt;150 µmol/L)</td>
<td>Renal disease, ACEI/ARB, aldosterone blockade</td>
<td>Calculate GFR, Consider reducing ACEI/ARB, or aldosterone blocker dose, Check potassium and BUN</td>
</tr>
<tr>
<td>Anaemia (&lt;13 g/dL in men, &lt;12 in women)</td>
<td>Chronic HF, haemodilution, iron loss or poor utilization, renal failure, chronic disease</td>
<td>Diagnostic work-up, Consider treatment</td>
</tr>
<tr>
<td>Hyponatraemia (&lt;135 mmol/L)</td>
<td>Chronic HF, haemodilution, AVP release, diuretics</td>
<td>Consider water restriction, reducing diuretic dosage</td>
</tr>
<tr>
<td>Hypernatraemia (&gt;150 mmol/L)</td>
<td>Hyperglycaemia</td>
<td>Assess water intake, Diagnostic work-up</td>
</tr>
<tr>
<td>Hypokalaemia (&lt;3.5 mmol/L)</td>
<td>Diuretics, secondary hyperaldosteronism</td>
<td>Risk of arrhythmia, Consider potassium supplements, ACEIs/ARB, aldosterone blockers</td>
</tr>
<tr>
<td>Hyperkalaemia (&gt;5.5 mmol/L)</td>
<td>Renal failure, potassium supplement, renin–angiotensin–aldosterone system blockers</td>
<td>Stop potassium-sparing treatment (ACEIs/ARB, aldosterone blockers)</td>
</tr>
<tr>
<td>Hyperglycaemia (&gt;6.5 mmol/L)</td>
<td>Diabetes, insulin resistance</td>
<td>Evaluate hydration, treat glucose intolerance</td>
</tr>
<tr>
<td>Hyperuricaemia (&gt;500 µmol/L)</td>
<td>Diuretic treatment, gout, malignancy</td>
<td>Allopurinol, Reduce diuretic dose</td>
</tr>
<tr>
<td>BNP &gt;400 pg/mL, NT-proBNP &gt;2000 pg/mL</td>
<td>Increased ventricular wall stress</td>
<td>HF likely, Indication for echo, Consider treatment</td>
</tr>
<tr>
<td>BNP &lt;100 pg/mL, NT-proBNP &lt;400 pg/mL</td>
<td>Normal wall stress</td>
<td>Re-evaluate diagnosis, HF unlikely if untreated</td>
</tr>
<tr>
<td>Albumin high (&gt;45 g/L)</td>
<td>Dehydration, myeloma</td>
<td>Rehydrate</td>
</tr>
<tr>
<td>Albumin low (&lt;30 g/L)</td>
<td>Poor nutrition, renal loss</td>
<td>Diagnostic work-up</td>
</tr>
<tr>
<td>Transaminase increase</td>
<td>Liver dysfunction, Right heart failure, Drug toxicity</td>
<td>Diagnostic work-up, Liver congestion, Reconsider therapy</td>
</tr>
<tr>
<td>Elevated troponins</td>
<td>Myocyte necrosis, Prolonged ischaemia, severe HF, myocarditis, sepsis, renal failure, pulmonary embolism</td>
<td>Evaluate pattern of increase (mild increases common in severe HF), Coronary angiography, Evaluation for revascularization</td>
</tr>
<tr>
<td>Abnormal thyroid tests</td>
<td>Hyper/hypothyroidism, Amiodarone</td>
<td>Treat thyroid abnormality</td>
</tr>
<tr>
<td>Urinalysis</td>
<td>Proteinuria, glycosuria, bacteria</td>
<td>Diagnostic work-up, Rule out infection</td>
</tr>
<tr>
<td>INR &gt;2.5</td>
<td>Anticoagulant overdose, Liver congestion</td>
<td>Evaluate anticoagulant dosage, Assess liver function, Assess anticoagulant dose</td>
</tr>
<tr>
<td>CRP &gt;10 mg/L, neutrophilic leukocytosis</td>
<td>Infection, inflammation</td>
<td>Diagnostic work-up</td>
</tr>
</tbody>
</table>
Troponins
Troponin I or T should be sampled in suspected HF when the clinical picture suggests an acute coronary syndrome (ACS). An increase in cardiac troponins indicates myocyte necrosis and, if indicated, the potential for revascularization should be considered and an appropriate diagnostic work-up performed. An increase in troponin also occurs in acute myocarditis. Mild increases in cardiac troponins are frequently seen in severe HF or during episodes of HF decompensation in patients without evidence of myocardial ischaemia due to ACS and in situations such as sepsis. An elevated troponin is a strong prognostic marker in HF, especially in the presence of elevated natriuretic peptides.63

Neurohormonal markers
HF is accompanied by an increase in various other neurohormonal markers (norepinephrine, renin, aldosterone, endothelin, arginine vasopressin). Although useful in research, evaluation of neuroendocrine activation is not required for diagnostic or prognostic purposes in individual patients.

Echocardiography
The term echocardiography is used to refer to all cardiac ultrasound imaging techniques, including pulsed and continuous wave Doppler, colour Doppler and tissue Doppler imaging (TDI).

Table 15 Common echocardiographic abnormalities in heart failure

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Abnormality</th>
<th>Clinical implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV ejection fraction</td>
<td>Reduced (&lt;45–50%)</td>
<td>Systolic dysfunction</td>
</tr>
<tr>
<td>LV function, global and focal</td>
<td>Akinesis, hypokinesis, dyskinesis</td>
<td>Myocardial infarction/ischaemia</td>
</tr>
<tr>
<td>End-diastolic diameter</td>
<td>Increased (&gt;55–60 mm)</td>
<td>Volume overload</td>
</tr>
<tr>
<td>End-systolic diameter</td>
<td>Increased (&gt;45 mm)</td>
<td>HF likely</td>
</tr>
<tr>
<td>Fractional shortening</td>
<td>Reduced (&lt;25%)</td>
<td>Systolic dysfunction</td>
</tr>
<tr>
<td>Left atrial size</td>
<td>Increased (&gt;40 mm)</td>
<td>Increased filling pressures</td>
</tr>
<tr>
<td>Left ventricular thickness</td>
<td>Hypertrophy (&gt;11–12 mm)</td>
<td>Hypertension, aortic stenosis, hypertrophic cardiomyopathy</td>
</tr>
<tr>
<td>Valvular structure and function</td>
<td>Valvular stenosis or regurgitation (especially aortic stenosis and mitral insufficiency)</td>
<td>May be primary cause of HF or complicating factor Assess gradients and regurgitant fraction Assess haemodynamic consequences Consider surgery</td>
</tr>
<tr>
<td>Mitral diastolic flow profile</td>
<td>Abnormalities of the early and late diastolic filling patterns</td>
<td>Indicates diastolic dysfunction and suggests mechanism</td>
</tr>
<tr>
<td>Tricuspid regurgitation peak velocity</td>
<td>Increased (&gt;3 m/s)</td>
<td>Increased right ventricular systolic pressure Suspect pulmonary hypertension</td>
</tr>
<tr>
<td>Pericardium</td>
<td>Effusion, haemopericardium, thickening</td>
<td>Consider tamponade, uraemia, malignancy, systemic disease, acute or chronic pericarditis, constrictive pericarditis</td>
</tr>
<tr>
<td>Aortic outflow velocity time integral</td>
<td>Reduced (&lt;15 cm)</td>
<td>Reduced low stroke volume</td>
</tr>
<tr>
<td>Inferior vena cava</td>
<td>Dilated Retrograde flow</td>
<td>Increased right atrial pressures</td>
</tr>
</tbody>
</table>

Assessment of left ventricular diastolic function
Assessment of diastolic function using evaluation of the ventricular filling pattern is important for detecting abnormalities of diastolic function or filling in patients with HF. This can be the predominant functional abnormality of the heart, thus fulfilling the third component necessary for the diagnosis of heart failure. This is
Table 16 Doppler-echocardiographic indices and ventricular filling

<table>
<thead>
<tr>
<th>Doppler indices</th>
<th>Pattern</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>E/A waves ratio</td>
<td>Restrictive (&gt;2, short deceleration time &lt;115 to 150 ms)</td>
<td>High filling pressures</td>
</tr>
<tr>
<td></td>
<td>Slowed relaxation (&lt;1)</td>
<td>Normal filling pressures</td>
</tr>
<tr>
<td></td>
<td>Normal (&gt;1)</td>
<td>Poor compliance</td>
</tr>
<tr>
<td>E/Ea</td>
<td>Increased (&gt;15)</td>
<td>High filling pressures</td>
</tr>
<tr>
<td></td>
<td>Reduced (&lt;8)</td>
<td>Low filling pressures</td>
</tr>
<tr>
<td></td>
<td>Intermediate (8–15)</td>
<td>Conclusive as may be pseudo-normal</td>
</tr>
<tr>
<td>(A mitral–A pulm) duration</td>
<td>&gt;30 ms</td>
<td>Normal filling pressures</td>
</tr>
<tr>
<td>Pulmonary S wave</td>
<td>&lt;30 ms</td>
<td>High filling pressures</td>
</tr>
<tr>
<td></td>
<td>&gt;D wave</td>
<td>Low filling pressures</td>
</tr>
<tr>
<td>Vp</td>
<td>&lt;45 cm/s</td>
<td>Slow relaxation</td>
</tr>
<tr>
<td>E/Vp</td>
<td>&gt;2.5</td>
<td>High filling pressures</td>
</tr>
<tr>
<td></td>
<td>&lt;2</td>
<td>Low filling pressures</td>
</tr>
<tr>
<td>Valsalva manoeuvre</td>
<td>Change of the pseudonormal to abnormal filling pattern</td>
<td>Unmasks high filling pressure in the setting of systolic and diastolic dysfunction</td>
</tr>
</tbody>
</table>

Doppler echocardiography allows estimation of the systolic pulmonary artery pressure. This is derived from calculation of the right ventricular systolic pressure estimated from the peak velocity of the tricuspid regurgitant jet velocity present in most subjects. It also permits an assessment of stroke volume and cardiac output by measurement of the velocity time integral (VTI) of the aortic flow.

Assessment of heart failure with preserved ejection fraction (HFPEF)

Echocardiography plays a major role in confirming the diagnosis of HFPEF. The diagnosis of HFPEF requires three conditions to be satisfied:

1. Presence of signs and/or symptoms of chronic HF.
2. Presence of normal or only mildly abnormal LV systolic function (LVEF ≥45–50%).
3. Evidence of diastolic dysfunction (abnormal LV relaxation or diastolic stiffness).

Transoesophageal echocardiography

Transoesophageal echocardiography (TOE) is recommended in patients who have an inadequate transthoracic echo window (obesity, ventilated patients), in complicated valvular patients (especially aortic, mitral, and mechanical valves), in suspected endocarditis, in congenital heart disease, or to exclude a thrombus in the left atrial appendage in patients with AF.

Stress echocardiography

Stress echocardiography (dobutamine or exercise echo) is used to detect ventricular dysfunction caused by ischaemia and to assess myocardial viability in the presence of marked hypokinesia or akinthesis. It may also be useful in identifying myocardial stunning, hibernation, and in relating HF symptoms to valvular abnormalities. In patients with HF, stress echo may have a lower sensitivity and specificity due to LV dilatation or the presence of bundle branch block.

Additional non-invasive imaging tests

In patients in whom echocardiography at rest has not provided adequate information and in patients with suspected CAD, further non-invasive imaging may include cardiac magnetic resonance imaging (CMR), cardiac CT, or radionuclide imaging.

Cardiac magnetic resonance imaging (CMR)

CMR is a versatile, highly accurate, reproducible, non-invasive imaging technique for the assessment of left and right ventricular volumes, global function, regional wall motion, myocardial thickness, thickening, myocardial mass and tumours, cardiac valves, congenital defects, and pericardial disease. It has become the gold standard of accuracy and reproducibility for assessment of volumes, mass, and wall motion. The use of paramagnetic contrast agents such as gadolinium can provide evidence of inflammation, infiltration, and scarring in patients with infarction, myocarditis, pericarditis, cardiomyopathies, infiltrative and storage diseases. Limitations include cost, availability, patients with dysrhythmia or an implanted device and patient intolerance.

CT scan

In patients with HF, non-invasive diagnosis of coronary anatomy might be of value and assist in decisions concerning coronary
angiography. CT angiography may be considered in patients with a low or intermediate pre-test probability of CAD and an equivocal exercise or imaging stress test. The demonstration of atherosclerosis on a CT scan confirms CAD but does not necessarily imply ischaemia.

**Radionuclide ventriculography**
Radionuclide ventriculography is recognized as a relatively accurate method of determining LVEF and is most often performed in the context of a myocardial perfusion scan providing information on viability and ischaemia. It has limited value for assessing volumes or more subtle indices of systolic or diastolic function.

**Pulmonary function tests**
Measurements of pulmonary function are of limited value in the diagnosis of HF. However, these tests are useful in demonstrating or excluding respiratory causes of breathlessness and assessing the potential contribution of lung disease to the patient’s dyspnoea. Routine spirometry evaluates the extent of obstructive airways disease. The presence of pulmonary congestion may influence the test results. Blood gases are normal in well-compensated chronic HF. A reduction of arterial oxygen saturation should lead to a search for other diagnoses.

**Exercise testing**
Exercise testing is useful for the objective evaluation of exercise capacity and exertional symptoms, such as dyspnoea and fatigue. The 6-min walk test is a simple, reproducible, readily available tool frequently employed to assess maximal functional capacity and evaluate the response to intervention. A normal peak exercise test in a patient not receiving treatment excludes the diagnosis of symptomatic HF. Either a cycle ergometer or treadmill may be used with a modified HF protocol employing a slow increase in workload. Gas exchange analysis during exercise is preferable as it provides a highly reproducible measurement of exercise limitation and insights into the differentiation between cardiac or respiratory cause of dyspnoea, assesses ventilatory efficiency, and carries prognostic information. Peak oxygen uptake (peak VO₂) and the anaerobic threshold are useful indicators of the patient’s functional capacity, and peak VO₂ and the VE/VCO₂ slope (ventilatory response to exercise) is a major prognostic variable. The peak respiratory exchange ratio is a useful index of the degree of anaerobiosis achieved. There is a poor correlation between exercise capacity, EF, and most haemodynamic measures at rest.

**Ambulatory ECG monitoring (Holter)**
Ambulatory ECG monitoring is valuable in the assessment of patients with symptoms suggestive of an arrhythmia (e.g. palpitations or syncope) and in monitoring ventricular rate control in patients with AF. It may detect and quantify the nature, frequency, and duration of atrial and ventricular arrhythmias and silent episodes of ischaemia which could be causing or exacerbating symptoms of HF. Episodes of symptomatic, non-sustained ventricular tachycardia (VT) are frequent in HF and are associated with a poor prognosis.

**Cardiac catheterization**
Cardiac catheterization is unnecessary for the routine diagnosis and management of patients with HF. Invasive investigation is frequently indicated to elucidate aetiology, to obtain important prognostic information, and if revascularization is being considered.

**Coronary angiography**
Coronary angiography should be considered in HF patients with a history of exertional angina or suspected ischaemic LV dysfunction, following cardiac arrest, and in those with a strong risk factor profile for coronary heart disease, and may be urgently required in selected patients with severe HF (shock or acute pulmonary oedema) and in patients not responding adequately to treatment. Coronary angiography and LV ventriculography are also indicated in patients with refractory HF of unknown aetiology and in patients with evidence of severe mitral regurgitation or aortic valve disease potentially correctable by surgery.

**Right heart catheterization**
Right heart catheterization provides valuable haemodynamic information regarding filling pressures, vascular resistance and cardiac output. Its role in the diagnosis of HF is, in clinical practice, limited. It forms the basis for the Forrester classification and is the most accurate method to evaluate haemodynamics in patients refractory to treatment, prior to cardiac transplantation, or in clinical research evaluating interventions.

Monitoring of haemodynamic variables by means of a pulmonary arterial catheter (PAC) may be considered in hospitalized patients with cardiogenic/non-cardiogenic shock or to monitor treatment in patients with severe HF not responding to appropriate treatment. However, the use of a PAC has not been shown to improve outcomes.

**Endomyocardial biopsy**
Specific myocardial disorders may be diagnosed by endomyocardial biopsy (EMB). Clinical decisions must be made from available case-controlled studies and expert opinion statements. A recently published AHA/ACC/ESC joint statement for the indications of EMB suggested that the procedure should be considered in patients with acute or fulminant HF of unknown aetiology who deteriorate rapidly with ventricular arrhythmias and/or AV heart block, or in patients who are unresponsive to conventional HF therapy. EMB might be also considered in chronic HF with suspected infiltrative processes such as amyloid, sarcoid, and haemochromatosis, as well as in eosinophilic myocarditis and restrictive cardiomyopathy of unknown origin.

**Prognosis**
Determining prognosis in HF is complex. Diverse aetiologies, age, frequent co-morbidities, variation in individual progression and outcomes (sudden vs. progressive HF death) must be considered. The impact on prognosis of specific treatments in individual patients with HF is often difficult to predict. The variables most
consistently cited as independent outcome predictors are reported in Table 17.

**Non-pharmacological management**

**Self-care management**
- Self-care management is a part of successful HF treatment and can significantly impact on symptoms, functional capacity, well-being, morbidity, and prognosis. Self-care can be defined as actions aimed at maintaining physical stability, avoidance of behaviour that can worsen the condition, and detection of the early symptoms of deterioration.68
- Important self-care behaviours in heart failure are presented in Table 18.
- It is recommended that healthcare professionals provide comprehensive heart failure education and counselling.

The webpage heartfailurematters.org represents an internet tool provided by the Heart Failure Association of the ESC that permits patients, their next of kin, and caregivers to obtain useful, practical information in a user-friendly format.

The following management options are considered appropriate in patients with symptomatic HF. The recommendations largely represent expert consensus opinion without adequate documented evidence.

**Adherence to treatment**

*Key evidence*
Good adherence has been shown to decrease morbidity and mortality and improve well-being.69 The literature suggests that only 20–60% of patients with HF adhere to their prescribed pharmacological and non-pharmacologic treatment.70,71 Data from the EuroHeart Failure Survey demonstrate that a large proportion of patients either misunderstood or had problems recalling that they had received recommendations regarding self-care management such as instructions on medications or diet.72
- A strong relationship between healthcare professionals and patients as well as sufficient social support from an active social network has been shown to improve adherence to treatment. It is recommended that family members be invited to participate in education programmes and decisions regarding treatment and care.73
- Patients should have adequate knowledge of their medical treatment, especially regarding effects, side effects, and how the medication should be taken and titrated. This may be challenging in patients with cognitive dysfunction.74
- Patients should be aware that the beneficial effects of therapy may be delayed and not have unrealistic expectations regarding the initial response to treatment. It must be explained that side

| Table 17 Conditions associated with a poor prognosis in heart failure |
|--------------------------|-----------------|-------------------------|-----------------|-----------------|-----------------|
| Demographics              | Clinical        | Electrophysiological    | Functional/exertional | Laboratory     | Imaging         |
| Advanced age*             | Hypotension*    | Tachycardia Q waves     | Reduced work, low peak VO₂* | Marked elevation of BNP/NT pro-BNP* | Low LVEF*       |
| Ischaemic aetiology*      | NYHA functional class III–IV* | Wide QRS* | LV hypertrophy Complex ventricular arrhythmias* | Hyponatraemia* | Elevated troponin* |
| Resuscitated sudden death*| Prior HF hospitalization* |                  |                  | Elevated biomarkers, neurohumoral activation* | Increased LV volumes |
| Poor compliance           | Tachycardia     | Low heart rate variability Atrial fibrillation T-wave alternans | Poor 6 min walk distance High VE/VCO₂ slope Periodic breathing | Elevated creatinine/BUN | Low cardiac index |
| Renal dysfunction         | Pulmonary rales |                  |                  | Elevated bilirubin Anaemia |                  |
| Diabetes                  | Aortic stenosis |                  |                  | Elevated uric acid |                  |
| Anaemia                   | Low body mass index |                  |                  |                  |                  |
| COPD                      | Sleep-related breathing disorders |                  |                  |                  |                  |
| Depression                |                  |                  |                  |                  |                  |

* = powerful predictors.
effects are often transient, and it might take months to uptitrate and assess the full effects of a drug.

- Interventions to improve adherence are recommended and should be targeted by the healthcare provider.

### Class of recommendation I, level of evidence C

#### Symptom recognition

The symptoms of deterioration in HF may vary considerably. Patients and/or caregivers should learn to recognize the symptoms of deterioration and take appropriate action such as increasing the prescribed diuretic dose and/or contact the healthcare team.

- Flexible dosage of diuretics based on symptoms and fluid balance should be recommended, within pre-specified limits, after detailed instructions and education.

### Class of recommendation I, level of evidence C

#### Weight monitoring

Increases in body weight are often associated with deterioration of HF and fluid retention. Patients should be aware that deterioration without weight gain can occur.

- Patients should weigh themselves on a regular basis to monitor weight change, preferably as part of a regular daily routine. In the case of a sudden unexpected weight gain of 2 kg in 3 days, patients may increase their diuretic dose and should alert the healthcare team. The risks of volume depletion with excessive diuretic use must be explained.

### Class of recommendation Ia, level of evidence C

#### Sodium intake

Sodium restriction is recommended in symptomatic HF to prevent fluid retention. Although no specific guidelines exist, excessive intake of salt should be avoided. Patients should be educated concerning the salt content of common foods.

### Class of recommendation Ib, level of evidence C

#### Fluid intake

Fluid restriction of 1.5–2 L/day may be considered in patients with severe symptoms of HF especially with hyponatraemia. Routine fluid restriction in all patients with mild to moderate symptoms does not appear to confer clinical benefit.

### Class of recommendation Ia, level of evidence C

#### Alcohol

Alcohol may have a negative inotropic effect, and may be associated with an increase in blood pressure (BP) and the risk of arrhythmias. Excessive use may be deleterious.

- Alcohol intake should be limited to 10–20 g/day (1–2 glasses of wine/day).

### Class of recommendation Ib, level of evidence C

#### Patients suspected of having alcohol-induced cardiomyopathy should abstain from alcohol completely.

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### Table 18 Essential topics in patient education with associated skills and appropriate self-care behaviours

<table>
<thead>
<tr>
<th>Educational topics</th>
<th>Skills and self-care behaviours</th>
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<tbody>
<tr>
<td>Definition and aetiology of heart failure</td>
<td>Understand the cause of heart failure and why symptoms occur</td>
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<tr>
<td>Symptoms and signs of heart failure</td>
<td>Monitor and recognize signs and symptoms</td>
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<td>Record daily weight and recognize rapid weight gain</td>
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<td>Know how and when to notify healthcare provider</td>
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<td>Use flexible diuretic therapy if appropriate and recommended</td>
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<tr>
<td>Pharmacological treatment</td>
<td>Understand indications, dosing, and effects of drugs</td>
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<td>Recognize the common side-effects of each drug prescribed</td>
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<td>Risk factor modification</td>
<td>Understand the importance of smoking cessation</td>
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<td>Monitor blood pressure if hypertensive</td>
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<td>Maintain good glucose control if diabetic</td>
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<td>Avoid obesity</td>
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<td>Diet recommendation</td>
<td>Sodium restriction if prescribed</td>
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<td></td>
<td>Avoid excessive fluid intake</td>
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<td>Modest intake of alcohol</td>
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<td>Monitor and prevent malnutrition</td>
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<tr>
<td>Exercise recommendations</td>
<td>Be reassured and comfortable about physical activity</td>
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<td>Understand the benefits of exercise</td>
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<td>Perform exercise training regularly</td>
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<td>Sexual activity</td>
<td>Be reassured about engaging in sex and discuss problems with healthcare professionals</td>
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<td></td>
<td>Understand specific sexual problems and various coping strategies</td>
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<tr>
<td>Immunization</td>
<td>Receive immunization against infections such as influenza and pneumococcal disease</td>
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<tr>
<td>Sleep and breathing disorders</td>
<td>Recognize preventive behaviour such as reducing weight of obese, smoking cessation, and abstinence from alcohol</td>
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<td>Learn about treatment options if appropriate</td>
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<tr>
<td>Adherence</td>
<td>Understand the importance of following treatment recommendations and maintaining motivation to follow treatment plan</td>
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<tr>
<td>Psychosocial aspects</td>
<td>Understand that depressive symptoms and cognitive dysfunction are common in patients with heart failure and the importance of social support</td>
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<tr>
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<td>Learn about treatment options if appropriate</td>
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<tr>
<td>Prognosis</td>
<td>Understand important prognostic factors and make realistic decisions</td>
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<td></td>
<td>Seek psychosocial support if appropriate</td>
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</tbody>
</table>
Class of recommendation I, level of evidence C

Weight reduction
Weight reduction in obese [body mass index (BMI) >30 kg/m²] persons with HF should be considered in order to prevent the progression of HF, decrease symptoms, and improve well-being.

Class of recommendation IIa, level of evidence C
In moderate to severe HF, weight reduction should not routinely be recommended since unintentional weight loss and anorexia are common problems.

Unintentional weight loss
Clinical or subclinical malnutrition is common in patients with severe HF. The pathophysiology of cardiac cachexia in heart failure is complex and not completely understood, but altered metabolism, insufficient food intake, decreased nutritional uptake, gut congestion and inflammatory mechanisms may be important factors. Cardiac cachexia is an important predictor of reduced survival.80

- If weight loss during the last 6 months is >6% of previous stable weight without evidence of fluid retention, the patient is defined as cachectic.81 The patient’s nutritional status should be carefully assessed.

Class of recommendation I, level of evidence C
Smoking
Smoking is a known risk factor for cardiovascular disease. No prospective studies have evaluated effects of smoking cessation in patients with HF. Observational studies support the relationship between smoking cessation and decreased morbidity and mortality.82,83

- It is recommended that patients receive support and advice and be motivated to stop smoking.

Class of recommendation I, level of evidence C
Immunization
- Pneumococcal vaccination and annual influenza vaccination should be considered in patients with symptomatic HF without known contraindications.84

Class of recommendation IIa, level of evidence C
Activity and exercise training
Physical inactivity is common in patients with symptomatic HF and contributes to its progression.85 Regular, initially supervised, resistance or endurance physical training improves autonomic control by enhancing vagal tone and reducing sympathetic activation, improves muscle strength, vasodilator capacity, and endothelial dysfunction, and decreases oxidative stress. Several systematic reviews and meta-analyses of small studies have shown that physical conditioning by exercise training reduces mortality and hospitalization when compared with usual care alone, and improves exercise tolerance and health-related quality of life.86–90 Cardiac rehabilitation programmes following a cardiovascular event or episode of decompensation represent an effective treatment option for patients with HF.

- Regular, moderate daily activity is recommended for all patients with heart failure.

Class of recommendation I, level of evidence B
- Exercise training is recommended, if available, to all stable chronic HF patients. There is no evidence that exercise training should be limited to any particular HF patient subgroups (aetiology, NYHA class, LVEF, or medication). Exercise training programmes appear to have similar effects whether provided in a hospital or at home.

Class of recommendation I, level of evidence A
Sexual activity
Sexual problems related to cardiovascular disease, medical treatment (β-blockers), or psychological factors such as fatigue and depression are common in patients with HF. There is limited evidence regarding the influence of sexual activity on clinical status in patients with mild or moderate symptoms. A slightly increased risk of decompensation triggered by sexual activity in patients in NYHA class III–IV has been reported. Cardiovascular symptoms such as dyspnoea, palpitations, or angina during sex rarely occur in patients who do not experience similar symptoms during exercise levels representing moderate exertion.91

Patients may be advised to use sublingual nitroglycerine as prophylaxis against dyspnoea and chest pain during sexual activity.

- Phosphodiesterase 5 (PDE5) inhibitors (e.g. sildenafil) reduce pulmonary pressures but are not currently recommended for patients with advanced HF. They should never be used in combination with nitrate preparations.

Class of recommendation III, level of evidence B
- Individualized sensitive counselling is recommended for both male and female patients and their partners.

Class of recommendation I, level of evidence C
Pregnancy and contraception
- Pregnancy may lead to deterioration of HF due to the rise in blood volume and increase in cardiac output, as well as the substantial increase in extravascular fluid. Importantly, many medications used in HF treatment are contraindicated during pregnancy.

- The risk of pregnancy is considered greater than the risks linked to contraceptive use. It is recommended that women with heart failure discuss contraceptives and planned pregnancy with a physician in order to take an informed decision based on assessment of potential risks.

Travelling
High altitudes (>1500 m) and travel to very hot and humid destinations should be discouraged for symptomatic patients. Planned travel should be discussed with the HF team. As a rule, air travel is preferable to long journeys by other means of transportation.

Sleep disorders
Patients with symptomatic HF frequently have sleep-related breathing disorders (central or obstructive sleep apnoea). These
conditions may be associated with increased morbidity and mortality.92

- Weight loss in severely overweight persons, smoking cessation, and abstinence of alcohol can reduce risk and is recommended.

**Class of recommendation I, level of evidence C**

- Treatment with a continuous positive airway pressure (CPAP) should be considered in obstructive sleep apnoea documented by polysomnography.93

**Class of recommendation IIa, level of evidence C**

**Depression and mood disorders**

The prevalence of clinically significant depression has been found to be as high as 20% in HF patients and may be much higher in patients screened with more sensitive instruments or in patients with more advanced HF. Depression is associated with increased morbidity and mortality.94

- There is limited evidence regarding screening and assessment tools as well as of the efficacy of psychological and pharmacological interventions in patients with HF. However, screening for depression and initiating appropriate treatment should be considered in patients with suggestive symptoms.

**Class of recommendation IIa, level of evidence C**

**Prognosis**

Although challenging to discuss, it is important that patients understand the important prognostic factors. Recognition of the impact of treatment on prognosis may motivate patients to adhere to treatment recommendations. An open discussion with the family may assist in making realistic and informed decisions regarding treatment and future plans.

### Pharmacological therapy

#### Objectives in the management of heart failure

The purpose of diagnosing and treating HF is no different from any other medical condition, namely to bring about a reduction of mortality and morbidity (Table 19). Since the annual mortality of HF is so high, particular emphasis has been put on this end-point in clinical trials. However, for many patients, and notably the elderly, the ability to lead an independent life, freedom from excessively unpleasant symptoms, and avoidance of admission to hospital are goals which on occasion may be equivalent to the desire to maximize the duration of life. Prevention of heart disease or its occurrence may be as important as the impact of treatment on prognosis.

**Table 19** Objectives of treatment in chronic heart failure

| 1. Prognosis | Reduce mortality |
| 2. Morbidity | Relieve symptoms and signs, improve quality of life |
|              | Eliminate oedema and fluid retention |
|              | Increase exercise capacity |
|              | Reduce fatigue and breathlessness |
|              | Reduce need for hospitalization |
|              | Provide for end of life care |
| 3. Prevention | Occurrence of myocardial damage |
|              | Progression of myocardial damage |
|              | Remodelling of the myocardium |
|              | Reoccurrence of symptoms and fluid accumulation |
|              | Hospitalization |

### Angiotensin-converting enzyme inhibitors (ACEIs)

Unless contraindicated or not tolerated, an ACEI should be used in all patients with symptomatic HF and a LVEF ≤40%. Treatment with an ACEI improves ventricular function and patient well-being, reduces hospital admission for worsening HF, and increases survival. In hospitalized patients, treatment with an ACEI should be initiated before discharge.

**Class of recommendation I, level of evidence A**

**Key evidence**

- Two key randomized controlled trials (RCTs) (CONSENSUS and SOLVD-Treatment) assigned ~2800 patients with mild to severely symptomatic HF to placebo or enalapril.95,96 Most patients were also treated with a diuretic and digoxin, but <10% of patients in each trial were treated with a β-blocker. In CONSENSUS, which enrolled patients with severe HF, 53% of patients were treated with spironolactone.

- Each of these two RCTs showed that ACEI treatment reduced mortality [relative risk reduction (RRR) 27% in CONSENSUS and 16% in SOLVD-Treatment]. In SOLVD-Treatment there was also an RRR of 26% in hospital admission for worsening HF. These benefits were additional to those gained with conventional treatment.

- The absolute risk reduction (ARR) in mortality in patients with mild or moderate HF (SOLVD-Treatment) was 4.5% equating to a number needed to treat (NNT) of 22 to postpone one death (over an average of 41 months). The equivalent figures for severe HF (CONSENSUS) were ARR = 14.6% and NNT = 7 (over an average of 6 months), respectively.

- These findings are supported by a meta-analysis of smaller, short-term, placebo-controlled RCTs, which showed a clear reduction in mortality within only 3 months. These RCTs also showed that ACEIs improve symptoms, exercise tolerance, quality of life, and exercise performance.97

- In ATLAS, 3164 patients with mainly moderate to severe HF were randomized to low-or high-dose lisinopril. There was a RRR of...
15% in the risk of death or HF hospitalization in the high-dose lisinopril group as compared with the low-dose lisinopril group. Additional support for the use of ACEIs comes from an RCT in patients with a low LVEF but no symptoms of HF (‘asymptomatic LV systolic dysfunction’) and three large (5966 patients in total) placebo-controlled, randomized, outcome trials in patients with HF, LV systolic dysfunction, or both after acute MI. In the SOLVD-Prevention trial (which randomized 4228 patients with asymptomatic LV systolic dysfunction), there was a 20% RRR in death or HF hospitalization. In the MI trials, which used captopril (SAVE), ramipril (AIRE), and trandolapril (TRACE), there was a 26% RRR in death and 27% RRR in death or HF hospitalization. ACEIs have also been shown to reduce the risk of MI in patients with and without HF and irrespective of LVEF.

ACEIs occasionally cause worsening of renal function, hyperkalaemia, symptomatic hypotension, cough and rarely angioedema. An ACEI should only be used in patients with adequate renal function and a normal serum potassium.

Which patients should get an ACEI?
Indications, based upon the patients enrolled in the RCTs: LVEF ≤40%, irrespective of symptoms.

Contraindications
- History of angioedema
- Bilateral renal artery stenosis
- Serum potassium concentration >5.0 mmol/L
- Serum creatinine >220 μmol/L (≈2.5 mg/dL)
- Severe aortic stenosis

How to use an ACEI in heart failure (Table 20)
Initiation of an ACEI
- Check renal function and serum electrolytes
- Re-check renal function and serum electrolytes within 1–2 weeks of starting treatment.

Dose up-titration
- Consider dose up-titration after 2–4 weeks. Do not increase dose if significant worsening of renal function or hyperkalaemia. Re-check renal function and serum electrolytes 1 and 4 weeks after increasing dose. More rapid dose up-titration can be carried out in patients in hospital or otherwise closely supervised, tolerability permitting.
In the absence of above problems, aim for evidence-based target dose or maximum tolerated dose (Table 20).

- **In the absence of above problems, aim for evidence-based target dose or maximum tolerated dose (Table 20).**
- **Re-check renal function and serum electrolytes 1, 3, and 6 months after achieving maintenance dose and 6 monthly thereafter.**

**Potential adverse effects**

- **Worsening renal function**—some rise in urea (blood urea nitrogen) and creatinine is expected after initiation of an ACEI and is not considered clinically important unless rapid and substantial. Check for nephrotoxic drugs such as non-steroidal anti-inflammatory drugs (NSAIDs). If necessary, reduce ACEI dose or discontinue. An increase in creatinine of up to 50% from baseline or to an absolute concentration of 265 μmol/L (~3 mg/dL), whichever is lower, is acceptable. If the creatinine rises above 265 μmol/L (~3.0 mg/dL), but below 310 μmol/L (~3.5 mg/dL), halve dose of ACEI and monitor blood chemistry closely. If creatinine rises to 310 μmol/L (~3.5 mg/dL) or above, stop ACEI immediately and monitor blood chemistry closely.
- **Hyperkalaemia**—check for use of other agents causing hyperkalaemia, e.g. potassium supplements and potassium-sparing diuretics, e.g. amiloride, and stato. If potassium rises above 5.5 mmol/L, halve dose of ACEI and monitor blood chemistry closely. If potassium rises over 6.0 mmol/L, stop ACEI immediately and monitor blood chemistry closely.
- **Symptomatic hypotension** (e.g. dizziness) is common—often improves with time, and patients should be reassured. Consider reducing the dose of diuretics and other hypotensive agents (except ARB/β-blocker/aldosterone antagonist). Asymptomatic hypotension does not require intervention.

- **Cough**—if an ACEI causes a troublesome cough, switch to an ARB.

### β-Blockers

Unless contraindicated or not tolerated, a β-blocker should be used in all patients with symptomatic HF and an LVEF ≤ 40%. β-Blockade improves ventricular function and patient well-being, reduces hospital admission for worsening HF, and increases survival. Where possible, in hospitalized patients, treatment with a β-blocker should be initiated cautiously before discharge.

#### Class of recommendation I, level of evidence A

**Key evidence**

- More RCTs have been undertaken with β-blockers than with ACEIs in patients with HF.
- Three key trials (CIBIS II, COPERNICUS, and MERIT-HF) randomized nearly 9000 patients with mild to severely symptomatic HF to placebo or a β-blocker (bisoprolol, carvedilol, or metoprolol succinate CR). More than 90% of patients were on an ACEI or ARB. Most were also treated with a diuretic and more than half with digoxin.
- Each of these three trials showed that β-blocker treatment reduced mortality (RRR ~34% in each trial) and hospital admission for worsening heat failure (RRR 28–36%) within ~1 year of starting treatment. There was also an improvement in self-reported patient well-being in COPERNICUS and MERIT-HF. These benefits were additional to those gained with conventional treatment, including an ACEI.
- The ARR in mortality (after 1 year of treatment) in patients with mild to moderate HF (CIBIS 2 and MERIT-HF combined) was 4.3%, equating to an NNT (for 1 year to postpone 1 death) of 23. The equivalent figures for severe HF (COPERNICUS) were ARR = 7.1% and NNT = 14, respectively.
- These findings are supported by another placebo-controlled RCT (SENIORS) in 2128 elderly (>70 years) patients, 36% of which had a LVEF > 35%. Treatment with nebivolol resulted in an RRR of 14% in the primary composite end-point of death or hospital admission for a cardiovascular reason.
- The findings of these trials were also supported by an earlier programme of studies with carvedilol (US carvedilol studies), meta-analysis of other small β-blocker trials, and a placebo-controlled RCT in 1959 patients with an LVEF ≤ 0.40 after acute MI in which the RRR in mortality with carvedilol was 23% during a mean follow-up period of 1.3 years.
- One large RCT (BEST) with bucindolol, a β-blocker with partial agonist properties, did not show a significant reduction in mortality, though its findings were generally consistent with the above studies.
- Another RCT, COMET, showed that carvedilol increased survival compared with short-acting metoprolol tartrate (different from the long-acting succinate formulation used in MERIT-HF).
- β-Blockers should usually be initiated in stable patients and only with caution in recently decompensated patients (and only initiated in hospital in these patients). Recently decompensated patients were, however, safely initiated on β-blocker treatment in COPERNICUS.

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### Table 20 Dosages of commonly used drugs in heart failure

<table>
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<tr>
<th>Class of recommendation</th>
<th>T</th>
<th>Date</th>
<th>Title</th>
<th>Authors</th>
<th>Year</th>
<th>Patients</th>
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<td>ACEI</td>
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• In patients admitted to hospital due to worsening HF, a reduction in the β-blocker dose may be necessary. In severe situations, temporary discontinuation can be considered. Low-dose therapy should be re-instituted and up-titrated as soon as the patient’s clinical condition permits, preferably prior to discharge.

Which patients should get a β-blocker?
Indications, based upon patients enrolled in the RCTs:

- LVEF ≤40%.
- Mild to severe symptoms (NYHA functional class II–IV); patients with asymptomatic LV systolic dysfunction after MI also have an indication for a β-blocker.
- Optimal dose level of an ACEI or/and ARB (and aldosterone antagonist, if indicated).
- Patients should be clinically stable (e.g. no recent change in dose of diuretic). Cautious, pre-discharge, initiation is possible in a recently decompenated patient provided that the patient has improved with other treatments, is not dependent on an i.v. inotropic agent, and can be observed in hospital for at least 24 h after initiation of β-blocker treatment.

Contraindications

- Asthma [chronic obstructive pulmonary disease (COPD)] is not a contraindication.
- Second- or third-degree heart block, sick sinus syndrome (in the absence of a permanent pacemaker), sinus bradycardia (<50 b.p.m.).

How to use a β-blocker in heart failure (Table 20)
Initiation of a β-blocker

- Starting dose: bisoprolol 1.25 mg o.d., carvedilol 3.125–6.25 mg b.i.d., metoprolol CR/XL 12.5–25 mg o.d., or nebivolol 1.25 mg o.d.—under supervision in outpatient setting.
- β-Blockers may be initiated prior to hospital discharge in recently decompenated patients with caution.

Dose up-titration

- Visits every 2–4 weeks to up-titrate the dose of β-blocker (slower dose up-titration may be needed in some patients). Do not increase dose if signs of worsening HF, symptomatic hypotension (e.g. dizziness), or excessive bradycardia (pulse rate <50/min) at each visit.
- In absence of the above problems, double the dose of β-blocker at each visit until the evidence-based target dose is reached—bisoprolol 10 mg o.d., carvedilol 25–50 mg b.i.d., metoprolol CR/XL 200 mg o.d., or nebivolol 10 mg o.d.—or maximum tolerated dose.

Potential adverse effects

- Symptomatic hypotension—often improves with time; consider reducing dose of other hypotensive agents (except ACEI/ARB), e.g. diuretics, nitrates. Asymptomatic hypotension does not require intervention.
- Worsening HF—increase dose of diuretic (often only temporary requirement) and continue β-blocker (often at a lower dose) if possible.
- Excessive bradycardia—record ECG (or perform ambulatory monitoring when necessary) to exclude heart block. Consider stopping digitalis glycoside if administered. The dose of β-blocker may need to be reduced or the treatment discontinued.

Aldosterone antagonists

Unless contraindicated or not tolerated, the addition of a low-dose of an aldosterone antagonist should be considered in all patients with an LVEF ≤35% and severe symptomatic HF, i.e. currently NYHA functional class III or IV, in the absence of hyperkalaemia and significant renal dysfunction. Aldosterone antagonists reduce hospital admission for worsening HF and increase survival when added to existing therapy, including an ACEI. In hospitalized patients satisfying these criteria, treatment with an aldosterone antagonist should be initiated before discharge.

Class of recommendation I, level of evidence B

Key evidence

- A single large RCT (RALES) has been undertaken with the aldosterone antagonist spironolactone in patients with severe HF.108
- In RALES 1663 patients with an LVEF ≤35% and in NYHA functional class III were randomized to placebo or spironolactone 25–50 mg o.d. added to conventional treatment, including a diuretic, ACEI (95%), and digoxin (74%). At the time this trial was conducted, β-blockers were not widely used to treat HF, and only 11% were treated with a β-blocker.
- Treatment with spironolactone led to an RRR in death of 30% and an RRR in hospital admission for worsening HF of 35% within an average of 2 years of starting treatment. Spironolactone also improved NYHA class. These benefits were additional to those gained with conventional treatment, including an ACEI.
- The ARR in mortality (after a mean of 2 years of treatment) in patients with severe HF was 11.4%, equating to an NNT (for 2 years to postpone 1 death) of 9.
- These findings are supported by another RCT (EPHESUS) which enrolled 6632 patients 3–14 days after acute MI with an LVEF ≤40% and HF or diabetes.109 Patients were randomized to placebo or eplerenone 25–50 g o.d. added to conventional treatment including an ACEI/ARB (87%) and β blocker (75%). Treatment with eplerenone led to an RRR in death of 15%.
- Spironolactone and eplerenone can cause hyperkalaemia and worsening renal function, which were uncommon in the RCTs but may occur more frequently in ordinary clinical practice, especially in the elderly. Both should only be used in patients with adequate renal function and a normal serum potassium
Worsening renal function

Re-check renal function and serum electrolytes 1, 2, 3, and 6 months after achieving maintenance dose, and 6 monthly thereafter.

In absence of above problems, aim for evidence-based target dose—spironolactone 50 mg o.d. or eplerenone 50 mg o.d.—or maximum tolerated dose.

Re-check renal function and serum electrolytes 1, 2, 3, and 6 months after achieving maintenance dose, and 6 monthly thereafter.

Potential adverse effects

Hyperkalaemia—if potassium rises to >5.5 mmol/L, halve dose of spironolactone (or eplerenone), e.g. to 25 mg on alternate days, and monitor blood chemistry closely. If potassium rises to 6.0 mmol/L stop spironolactone (or eplerenone) immediately and monitor blood chemistry closely; specific treatment of renal dysfunction may be needed.

Worsening renal function—if creatinine rises to >220 μmol/L (~2.5 mg/dL) halve dose of spironolactone (or eplerenone), e.g. to 25 mg on alternate days, and monitor blood chemistry closely. If creatinine rises to >310 μmol/L (~3.5 mg/dL) stop spironolactone (or eplerenone) immediately and monitor blood chemistry closely; specific treatment of renal dysfunction may be needed.

Breast tenderness and/or enlargement—switch from spironolactone to eplerenone.

Angiotensin receptor blockers (ARBs)

Unless contraindicated or not tolerated, an ARB is recommended in patients with HF and an LVEF ≤40% who remain symptomatic despite optimal treatment with an ACEI and β-blocker, unless also taking an aldosterone antagonist. Treatment with an ARB improves ventricular function and patient well-being, and reduces hospital admission for worsening HF.

Class of recommendation I, level of evidence A

Treatment reduces the risk of death from cardiovascular causes.

Class of recommendation IIa, level of evidence B

An ARB is recommended as an alternative in patients intolerant of an ACEI. In these patients, an ARB reduces the risk of death from a cardiovascular cause or hospital admission for worsening HF. In hospitalized patients, treatment with an ARB should be initiated before discharge.

Class of recommendation I, level of evidence B

Key evidence

Two key placebo-controlled RCTs (Val-HEFT and CHARM-Added) randomized ~7600 patients with mild to severely symptomatic HF to placebo or an ARB (valsartan and candesartan), added to an ACEI (in 93% of patients in Val-HEFT and all in CHARM-Added).111,112 In addition, 35% of patients in Val-HEFT and 55% in CHARM-Added were treated with a β-blocker. Five per cent of patients in Val-HEFT and 17% in CHARM-Added were treated with spironolactone.

Each of these two trials showed that ARB treatment reduced the risk of hospital admission for worsening HF (RRR 24% in Val-HEFT and 17% in CHARM-Added) but not all-cause hospitalization. There was a 16% RRR in the risk of death from a cardiovascular cause with candesartan in CHARM-Added. These benefits were additional to those gained with conventional treatment, including a diuretic, digoxin, an ACEI, and a β-blocker.

The ARR in the primary composite mortality–morbidity endpoint in patients with mild to moderate HF was 4.4%, equating to an NNT (for an average of 41 months to postpone 1 event) of 23 in CHARM-Added. The equivalent figures for Val-HEFT were ARR = 3.3% and NNT = 30 (over an average of 23 months), respectively.

The CHARM trials and Val-HEFT also showed that ARBs improve symptoms and quality of life. Other trials showed that these agents improve exercise capacity.

CHARM-Alternative was a placebo-controlled RCT with candesartan in 2028 patients with a LVEF ≤40%, intolerant...
of an ACEI. Treatment with candesartan resulted in an RRR of death from a cardiovascular cause or hospital admission for worsening HF of 23% (ARR = 7%, NNT = 14, over 34 months of follow-up).

- Additional support for the use of ARBs comes from VALIANT, an RCT in which 14 703 patients with HF, LV systolic dysfunction, or both after acute MI were assigned to treatment with captopril, valsartan, or the combination. Valsartan was found to be non-inferior to captopril. A similar trial with losartan (OPTIMAAL) did not demonstrate non-inferiority as compared with captopril.

**Patients who should get an angiotensin receptor blocker**

Indications, based upon the patients enrolled in the RCTs:

- LVEF ≤40% and either
- as an alternative in patients with mild to severe symptoms (NYHA functional class II–IV) who are intolerant of an ACEI
- or in patients with persistent symptoms (NYHA functional class II–IV) despite treatment with an ACEI and β-blocker
- ARBs may cause worsening of renal function, hyperkalaemia, and symptomatic hypotension with an incidence similar to an ACEI. They do not cause cough.

**Contraindications**

- As with ACEIs, with the exception of angioedema
- Patients treated with an ACEI and an aldosterone antagonist
- An ARB should only be used in patients with adequate renal function and a normal serum potassium concentration; serial monitoring of serum electrolytes and renal function is mandatory, especially if an ARB is used in conjunction with an ACEI.

**How to use an angiotensin receptor blocker in heart failure (Table 20)**

**Initiation of an ARB**

- Check renal function and serum electrolytes
- Starting dose: either candesartan 4–8 mg o.d. or valsartan 40 mg b.i.d.
- Re-check renal function and serum electrolytes within 1 week of starting treatment.

**Dose up-titration**

- Consider dose up-titration after 2–4 weeks. Do not increase dose if worsening renal function or hyperkalaemia. Re-check renal function and serum electrolytes 1 and 4 weeks after increasing dose.
- In absence of above problems, aim for evidence-based target dose—candesartan 32 mg o.d. or valsartan 160 mg b.i.d.—or maximum tolerated dose.
- Re-check renal function and serum electrolytes 1, 3, and 6 months after achieving maintenance dose, and 6 monthly thereafter.

**Potential adverse effects**

- As with ACEIs except for cough.

**Hydralazine and isosorbide dinitrate (H-ISDN)**

In symptomatic patients with an LVEF ≤40%, the combination of H-ISDN may be used as an alternative if there is intolerance to both an ACEI and an ARB. Adding the combination of H-ISDN should be considered in patients with persistent symptoms despite treatment with an ACEI, β-blocker, and an ARB or aldosterone antagonist. Treatment with H-ISDN in these patients may reduce the risk of death.

**Class of recommendation IIa, level of evidence B**

Reduces hospital admission for worsening HF.

**Class of recommendation IIa, level of evidence B**

Improves ventricular function and exercise capacity.

**Class of recommendation IIa, level of evidence A**

**Key evidence**

- There are two placebo-controlled (V-HeFT-I and A-HeFT) RCTs and one active-controlled (V-HeFT-II) RCT with H-ISDN.
- In V-HeFT-I, 642 men were randomized to placebo, prazosin, or H-ISDN added to a diuretic and digoxin. No patients were treated with a β-blocker or an ACEI. Mortality was not different in the placebo and prazosin groups. With H-ISDN, there was a trend to a reduction in all-cause mortality during the overall period of follow-up (mean 2.3 years): RRR 22%; ARR 5.3%; NNT = 19. H-ISDN increased exercise capacity and LVEF compared with placebo.
- In A-HeFT, 1050 African-American men and women in NYHA class III or IV, were randomized to placebo or H-ISDN, added to a diuretic (in 90%), digoxin (60%), an ACEI (70%), an ARB (17%), a β-blocker (74%), and spironolactone (39%). The trial was discontinued prematurely, after a median follow-up of 10 months, because of a significant reduction in mortality (RRR 43%; ARR 4.0%; NNT = 25). H-ISDN also reduced the risk of HF hospitalization (RRR 33%) and improved quality of life.
- In V-HeFT-II, 804 men, in mainly NYHA class II and III, were randomized to enalapril or H-ISDN, added to a diuretic and digoxin. No patients were treated with a β-blocker. There was a trend in the H-ISDN group to an increase in all-cause mortality during the overall period of follow-up (mean 2.5 years): relative increase in risk 28%.
- The most common adverse effects with H-ISDN in these trials were headache, dizziness/hypotension, and nausea. Arthralgia leading to discontinuation or reduction in dose of H-ISDN occurred in ~5–10% of patients in V-HeFT I and II and sustained increase in antinuclear antibody (ANA) in 2–3% of patients (but lupus-like syndrome was rare).

**Patients who should get hydralazine and isosorbide dinitrate**

Indications, based upon the patients enrolled in the RCTs
An alternative to an ACEI/ARB when both of the latter are not tolerated
As add-on therapy to an ACEI if an ARB or aldosterone antagonist is not tolerated
Evidence is strongest in patients of African-American descent

Contraindications
- Symptomatic hypotension
- Lupus syndrome
- Severe renal failure (dose reduction may be needed)

How to use hydralazine and isosorbide dinitrate in heart failure

 Initiation
- Starting dose: hydralazine 37.5 mg and ISDN 20 mg t.i.d.
- Dose up-titration
  - Consider dose up-titration after 2–4 weeks. Do not increase dose with symptomatic hypotension.
  - If tolerated, aim for evidence-based target dose—hydralazine 75 mg and ISDN 40 mg t.i.d.—or maximum tolerated dose.

Potential adverse effects
- Symptomatic hypotension (e.g. dizziness)—often improves with time; consider reducing dose of other hypotensive agents (except ACEI/ARB/β-blocker/aldosterone antagonist). Asymptomatic hypotension does not require intervention.
- Arthralgia/muscle aches, joint pain or swelling, pericarditis/pleuritis, rash or fever—consider drug-induced lupus-like syndrome; check ANA, discontinue H-ISDN.

Digoxin
In patients with symptomatic HF and AF, digoxin may be used to slow a rapid ventricular rate. In patients with AF and an LVEF ≤40% it should be used to control heart rate in addition to, or prior to a β-blocker.

Class of recommendation I, level of evidence C
In patients in sinus rhythm with symptomatic HF and an LVEF ≤40%, treatment with digoxin (in addition to an ACEI) improves ventricular function and patient well-being, reduces hospital admission for worsening HF, but has no effect on survival.

Class of recommendation IIa, level of evidence B

Key evidence
Digoxin in patients with HF and atrial fibrillation
- Digoxin is useful for initial control of the ventricular rate in a patient with rapid AF and may be considered in decompensated HF patients prior to initiation of a β-blocker.
- In the longer term, a β-blocker, either alone or in combination with digoxin, is the preferred treatment for rate control (and other clinical outcome benefits) in patients with an LVEF ≤40%.
- While digoxin alone may control the ventricular rate at rest (target < 80 b.p.m.), it does not usually provide sufficient rate control during exercise (target heart rate ≤110–120 b.p.m.).
- In patients with an LVEF > 40%, verapamil or diltiazem may be used alone or in combination with digoxin to control the ventricular rate.

Digoxin in patients with HF, LVEF ≤40%, and sinus rhythm
- A single large prospective outcome RCT has been undertaken with digoxin in patients with symptomatic HF and a low LVEF.
- In the DIG trial, 6800 patients with an LVEF ≤45% and in NYHA functional class II–IV were randomized to placebo or digoxin (0.25 mg o.d), added to a diuretic and ACEI. This trial was performed before β-blockers were widely used for HF.
- Treatment with digoxin did not alter all-cause mortality but did lead to an RRR for hospital admission for worsening HF of 28% within an average of 3 years of starting treatment. The absolute ARR was 7.9%, equating to an NNT (for 3 years to postpone 1 patient admission) of 13.
- These findings are supported by a meta-analysis, but not supported entirely by the DIG trial where quality of life was not improved and there was no advantage in patients with HFPEF.
- Digoxin can cause atrial and ventricular arrhythmias, particularly in the context of hypokalaemia, and serial monitoring of serum electrolytes and renal function is mandatory.

Patients with heart failure who should get digoxin
Indications, based upon patients enrolled in the RCTs:

Atrial fibrillation
- With ventricular rate at rest >80 b.p.m., at exercise >110–120 b.p.m.

Sinus rhythm
- LV systolic dysfunction (LVEF ≤40%)...
- Mild to severe symptoms (NYHA functional class II–IV)
- Optimal dose of ACEI or and an ARB, β-blocker and aldosterone antagonist, if indicated

Contraindications
- Second- or third-degree heart block (without a permanent pacemaker); caution if suspected sick sinus syndrome
- Pre-excitation syndromes
- Previous evidence of digoxin intolerance

How to use digoxin in heart failure
Initiation of digoxin
- Starting dose: loading doses of digoxin are generally not required in stable patients with sinus rhythm. A single daily maintenance dose of 0.25 mg is commonly employed in adults with normal renal function. In the elderly and in those with renal impairment, a reduced dose of 0.125 or 0.0625 mg o.d. should be used.
- The digoxin concentration should be checked early during chronic therapy in those with normal renal function. Steady...
state may take longer to be achieved in those with renal impairment.

- There is no evidence that regular digoxin concentration measurements confer better outcomes. The therapeutic serum concentration should be between 0.6 and 1.2 ng/mL, lower than previously recommended.
- Certain drugs may increase plasma digoxin levels (amiodarone, diltiazem, verapamil, certain antibiotics, quinidine).

Potential adverse effects

- Sinoatrial and AV block
- Atrial and ventricular arrhythmias, especially in the presence of hypokalaemia (digoxin-specific Fab antibody fragments should be considered for ventricular arrhythmias caused by toxicity)
- Signs of toxicity include: confusion, nausea, anorexia, and disturbance of colour vision.

Diuretics (Table 21)

Diuretics are recommended in patients with HF and clinical signs or symptoms of congestion.

Class of recommendation I, level of evidence B

Key points

- Diuretics provide relief from the symptoms and signs of pulmonary and systemic venous congestion in patients with HF.123
- Diuretics cause activation of the renin–angiotensin–aldosterone system in patients with mild symptoms of HF and should usually be used in combination with an ACEI/ARB.
- The dose requirement must be tailored to the individual patient’s needs and requires careful clinical monitoring.
- In general, a loop diuretic will be required in moderate or severe HF.
- A thiazide may be used in combination with loop diuretics for resistant oedema, but with caution to avoid dehydration, hypovolaemia, hyponatraemia, or hypokalaemia.
- It is essential to monitor potassium, sodium, and creatinine levels during diuretic therapy.

Diuretics and ACEIs/ARBs/aldosterone antagonists

- Volume depletion and hyponatraemia from excessive diuresis may increase the risk of hypotension and renal dysfunction with ACEI/ARB therapy.
- If an ACEI/ARB/aldosterone antagonist is used with a diuretic, potassium replacement will usually not be required.
- Serious hyperkalaemia can occur if potassium-sparing diuretics, including aldosterone antagonists, are used in combination with ACEIs/ARBs. Non-aldosterone antagonist potassium-sparing diuretics should be avoided. The combination of an aldosterone antagonist and an ACEI/ARB should only be used under careful supervision.

Table 21  Practical considerations in treatment of heart failure with loop diuretics

<table>
<thead>
<tr>
<th>Problems</th>
<th>Suggested action</th>
</tr>
</thead>
</table>
| Hypokalaemia/hypomagnesaemia      | - Increase ACEI/ARB dosage  
                                       - Add aldosterone antagonist  
                                       - Potassium supplements  
                                       - Magnesium supplements |
| Hyponatraemia                      | Fluid restriction  
                                       - Stop thiazide diuretic or switch to loop diuretic, if possible  
                                       - Reduce dose/stop loop diuretics if possible  
                                       - Consider AVP antagonist, e.g. tolvaptan if available  
                                       - i.v. Inotropic support  
                                       - Consider ultrafiltration |
| Hyperuricaemia/gout                | - Consider allopurinol  
                                       - For symptomatic gout use colchicine for pain relief  
                                       - Avoid NSAIDs |
| Hypovolaemia/dehydration           | - Assess volume status  
                                       - Consider diuretic dosage reduction |
| Insufficient response or diuretic resistance | - Check compliance and fluid intake  
                                       - Increase dose of diuretic  
                                       - Consider switching from furosemide to bumetanide or torasemide  
                                       - Add aldosterone antagonist  
                                       - Combine loop diuretic and thiazide/metolazone |
| Renal failure (excessive rise in urea/BUN and/or creatinine) | - Administer loop diuretic twice daily or on empty stomach  
                                       - Consider short-term i.v. infusion of loop diuretic  
                                       - Check for hypovolaemia/dehydration  
                                       - Exclude use of other nephrotoxic agents, e.g. NSAIDs, trimethoprim  
                                       - Withhold aldosterone antagonist  
                                       - If using concomitant loop and thiazide diuretic stop thiazide diuretic  
                                       - Consider reducing dose of ACEI/ARB  
                                       - Consider ultrafiltration |
How to use diuretics in heart failure

Initiation of diuretic therapy

- Check renal function and serum electrolytes.
- Most patients are prescribed loop diuretics rather than thiazides due to the higher efficiency of induced diuresis and natriuresis.

Diuretic dosages (Table 22)

- Start with a low dosage and increase until clinical improvement of the symptoms and signs of congestion.
- Dose must be adjusted, particularly after restoration of dry body weight, to avoid the risk of renal dysfunction and dehydration. Aim to maintain ‘dry weight’ with lowest achievable dose.
- Self-adjustment of diuretic dose based on daily weight measurements and other clinical signs of fluid retention should be encouraged in HF outpatient care. Patient education is required.
- Management of diuretic resistance is presented in Table 21.

Other drugs used to treat cardiovascular co-morbidity in patients with heart failure

Anticoagulants (vitamin K antagonists)

Warfarin (or an alternative oral anticoagulant) is recommended in patients with HF and permanent, persistent, or paroxysmal AF without contraindications to anticoagulation. Adjusted-dose anticoagulation reduces the risk of thromboembolic complications including stroke.

Class of recommendation I, level of evidence A

Anticoagulation is also recommended in patients with intracardiac thrombus detected by imaging or evidence of systemic embolism.

Class of recommendation I, level of evidence C

Key evidence

- The evidence that anticoagulants are effective in reducing thromboembolism in patients with AF is summarized in the joint ACC/AHA/ESC guidelines.
- In a series of randomized trials in patients with AF, which included patients with HF, warfarin reduced the risk of stroke by 60–70%.
- Warfarin was more effective in reducing the risk of stroke than antiplatelet therapy and is preferred over antiplatelet therapy in patients at high risk of stroke, such as those with HF.
- There is no proven role for anticoagulation in other patients with HF, except in those with a prosthetic valve.

Antiplatelet agents

Key evidence

- Antiplatelet agents are not as effective as warfarin in reducing the risk of thromboembolism in patients with AF.
- In a pooled analysis of two small trials comparing warfarin and aspirin in patients with HF, the risk of HF hospitalization was significantly greater in aspirin-treated, compared with warfarin-treated, patients.
- There is no evidence that antiplatelet agents reduce atherosclerotic risk in patients with HF.

HMG CoA reductase inhibitors (‘statins’)

In elderly patients with symptomatic chronic HF and systolic dysfunction caused by CAD, statin treatment may be considered to reduce cardiovascular hospitalization.

Table 22 Diuretic dosages in patients with heart failure

<table>
<thead>
<tr>
<th>Diuretics</th>
<th>Initial dose (mg)</th>
<th>Usual daily dose (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Loop diuretics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Furosemide</td>
<td>20–40</td>
<td>40–240</td>
</tr>
<tr>
<td>Bumetanide</td>
<td>0.5–1.0</td>
<td>1–5</td>
</tr>
<tr>
<td>Torasemide</td>
<td>5–10</td>
<td>10–20</td>
</tr>
<tr>
<td><strong>Thiazides</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bendroflumethiazide</td>
<td>2.5</td>
<td>2.5–10</td>
</tr>
<tr>
<td>Hydrochlorothiazide</td>
<td>25</td>
<td>12.5–100</td>
</tr>
<tr>
<td>Metolazone</td>
<td>2.5</td>
<td>2.5–10</td>
</tr>
<tr>
<td>Indapamide†</td>
<td>2.5</td>
<td>2.5–5</td>
</tr>
<tr>
<td><strong>Potassium-sparing diuretics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spironolactone/eplerenone</td>
<td>12.5–25</td>
<td>50</td>
</tr>
<tr>
<td>Amiloride</td>
<td>2.5</td>
<td>5</td>
</tr>
<tr>
<td>Triamterene</td>
<td>25</td>
<td>50</td>
</tr>
</tbody>
</table>

*Dose might need to be adjusted according to volume status/weight; excessive doses may cause renal impairment and ototoxicity.

**Do not use thiazides if eGFR < 30 mL/min, except when prescribed synergistically with loop diuretics.

***Aldosterone antagonists should always be preferred to other potassium-sparing diuretics.

†Indapamide is a non-thiazide sulphonamide.
Class of recommendation IIb, level of evidence B

Key evidence

- Most trials with statins excluded patients with HF. Only one trial, CORONA, specifically studied a statin in patients with symptomatic HF, ischaemic aetiology, and reduced EF. Rosuvastatin did not reduce the primary end-point (cardiovascular death, MI, or stroke) or all-cause mortality. The number of hospitalizations for cardiovascular causes was reduced significantly.127
- The value of statins in HF patients with a non-ischaemic aetiology is unknown.

Management of patients with heart failure and preserved left ventricular ejection fraction (HFPEF)

- No treatment has yet been shown, convincingly, to reduce morbidity and mortality in patients with HFPEF. Diuretics are used to control sodium and water retention and relieve breathlessness and oedema. Adequate treatment of hypertension and myocardial ischaemia is also considered to be important, as is control of the ventricular rate in patients with AF. Two very small studies (<30 patients each) have shown that the heart rate-limiting calcium channel blocker verapamil may improve exercise capacity and symptoms in these patients.128,129
- The 3023 patient Candesartan in Heart Failure: Assessment of Reduction in Mortality and Morbidity (CHARM)-Preserved trial did not show a significant reduction in the risk of the primary composite end-point (adjudicated death from cardiovascular causes or admission with HF) but did show a significant reduction in the risk of investigator-reported admissions for HF.130 The 850 patient Perindopril for Elderly People with Chronic Heart failure (PEP-CHF) study failed to show a reduction in this composite primary end-point over the total duration of the trial, but showed a significant reduction in cardiovascular death and HF hospitalization at 1 year.131

Devices and surgery

Revascularization procedures, valvular and ventricular surgery

- If clinical symptoms of HF are present, surgically correctable conditions should be detected and corrected if indicated.
- CAD is the most common cause of HF and is present in 60–70% of patients with HF and impaired LVEF.132,133 In HFPEF, CAD is less frequent but still may be detected in up to half of these patients.39 Ischaemic aetiology is associated with a higher risk of mortality and morbidity.

Revascularization in patients with heart failure

Both a coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI) should be considered in selected HF patients with CAD. Decisions regarding the choice of the method of revascularization should be based on a careful evaluation of co-morbidities, procedural risk, coronary anatomy and evidence of the extent of viable myocardium in the area to be revascularized, LV function, and the presence of haemodynamically significant valvular disease.

Key evidence

There are no data from multicentre trials assessing the value of revascularization procedures for the relief of HF symptoms. However, single-centre, observational studies on HF of ischaemic origin suggest that revascularization may lead to symptomatic improvement and potentially improve cardiac function. Clinical trials are ongoing that address the effect of intervention on clinical outcomes.134

Evaluation for coronary artery disease in heart failure patients with unknown coronary artery status

Routine coronary angiography is not recommended.

In patients at low risk for CAD: the results of non-invasive evaluation should determine the indication for subsequent angiography (exercise ECG, stress echocardiography, stress nuclear perfusion imaging).

Coronary angiography

- is recommended in patients at high risk for CAD without contraindications to establish diagnosis and plan treatment strategy.

Class of recommendation I, level of evidence C

- is recommended in patients with HF and evidence of significant valvular disease.

Class of recommendation I, level of evidence C

- should be considered in patients with HF who experience anginal symptoms despite optimal medical therapy.

Class of recommendation IIa, level of evidence C

Detection of viable myocardium

As viable myocardium may be a target for revascularization, its detection should be considered in the diagnostic work-up in HF patients with CAD. Several imaging modalities with comparable diagnostic accuracy may be employed to detect dysfunctional but viable myocardium (dobutamine echocardiography, nuclear imaging by SPECT and/or by PET, MRI with dobutamine and/or with contrast agents, CT with contrast agents).135

Class of recommendation IIa, level of evidence C

Valvular surgery

- Valvular heart disease (VHD) may be the underlying aetiology for HF or an important aggravating factor that requires specific management.
- The ESC Guidelines on the management of valvular disease apply to most patients with HF.136 Although impaired LVEF is
an important risk factor for higher peri- and postoperative mortality, surgery may be considered in symptomatic patients with poor LV function.

- Optimal medical management of both HF and co-morbid conditions prior to surgery is imperative. Emergency surgery should be avoided if possible.
- Specific recommendations concerning surgery for patients with VHD and HF are difficult to provide. Decisions should be based on a thorough clinical and echocardiographic assessment with attention to cardiovascular and non-cardiovascular co-morbidities. Decisions concerning surgery for haemodynamically important aortic stenosis, aortic regurgitation, or mitral regurgitation require careful consideration of the patient’s motivation, biological age and risk profile.

**Aortic valve surgery**

**Aortic stenosis (AS)**

Medical treatment should be optimized but not delay the decision regarding valve surgery. Vasodilators (ACEIs, ARBs, and nitrates) may cause substantial hypotension in patients with severe AS and should be used only with great caution.

**Surgery**

- is recommended in eligible patients with HF symptoms and severe AS.

**Class of recommendation I, level of evidence C**

- is recommended in asymptomatic patients with severe AS and impaired LVEF (<50%).

**Class of recommendation I, level of evidence C**

- may be considered in patients with a severely reduced valve area and LV dysfunction.

**Class of recommendation IIb, level of evidence C**

**Aortic regurgitation (AR)**

**Surgery**

- is recommended in all eligible patients with severe AR who have symptoms of HF.

**Class of recommendation I, level of evidence B**

- is recommended in asymptomatic patients with severe AR and moderately impaired LVEF (LVEF ≤50%).

**Class of recommendation IIa, level of evidence C**

**Mitral valve surgery**

**Mitral regurgitation (MR)**

**Surgery**

- In patients with HF and severe mitral valve regurgitation, symptomatic improvement has been reported in selected patients. Surgery should be considered in patients with severe MR whenever coronary revascularization is an option. Surgical repair of the valve may represent an attractive option in carefully selected patients.\(^{136}\)

**Organic mitral regurgitation**

- In patients with severe organic MR due to a structural abnormality or damage to the mitral valve, development of HF symptoms is a strong indication for surgery.

**Surgery**

- is recommended for patients with LVEF >30% (valve repair if possible).

**Class of recommendation I, level of evidence B**

- may be considered for patients with severe MR and LVEF <30%; medical therapy should be a first choice. Only if patients remain refractory to pharmacological treatment and have a low risk profile should surgery be considered.

**Class of recommendation IIb, level of evidence C**

**Functional mitral regurgitation**

**Surgery**

- may be considered in selected patients with severe functional MR and severely depressed LV function, who remain symptomatic despite optimal medical therapy.

**Class of recommendation IIb, level of evidence C**

- Cardiac resynchronization therapy (CRT) should be considered in eligible patients as it may improve LV geometry, papillary muscle dyssynchrony and may reduce MR (see section Devices and surgery).

**Class of recommendation IIa, level of evidence B**

**Ischaemic mitral regurgitation**

**Surgery**

- is recommended in patients with severe MR and LVEF >30% when CABG is planned.

**Class of recommendation I, level of evidence C**

- should be considered in patients with moderate MR undergoing CABG if repair if feasible.

**Class of recommendation IIa, level of evidence C**

**Tricuspid regurgitation (TR)**

- Functional TR is extremely common in HF patients with biventricular dilatation, systolic dysfunction, and pulmonary
hypertension. Symptoms of right-sided HF with systemic congestion respond poorly to aggressive diuretic therapy, which may aggravate symptoms such as fatigue and exercise intolerance. Surgery for isolated functional TR is not indicated.

Class of recommendation III, level of evidence C

Left ventricular aneurysmectomy

- LV aneurysmectomy may be considered in symptomatic patients with large, discrete LV aneurysms.

Class of recommendation IIb, level of evidence C

Cardiomyoplasty

- Cardiomyoplasty and partial left ventriculectomy (Batista operation) is not recommended for the treatment of HF or as an alternative to heart transplantation.

Class of recommendation III, level of evidence C

External ventricular restoration

- External ventricular restoration is not recommended for the treatment of HF.

Class of recommendation III, level of evidence C

Pacemakers

- The conventional indications for patients with normal LV function also apply to patients with HF. In patients with HF and sinus rhythm, maintenance of a normal chronotropic response and coordination of atrial and ventricular contraction with a DDD pacemaker may be especially important.
- In HF patients with concomitant indication for permanent pacing (first implant or upgrading of a conventional pacemaker) and NYHA class II–IV symptoms, low LVEF ≤35%, or LV dilatation, CRT with pacemaker function (CRT-P) should be considered. In these patients, the use of right ventricular pacing may be deleterious and may cause or increase dyssynchrony.

Class of recommendation IIa, level of evidence C

Cardiac resynchronization therapy (CRT) (Table 23)

- CRT-P is recommended to reduce morbidity and mortality in patients in NYHA III–IV class who are symptomatic despite optimal medical therapy, and who have a reduced EF (LVEF ≤35%) and QRS prolongation (QRS width ≥120 ms).

Class of recommendation I, level of evidence A

- CRT with defibrillator function (CRT-D) is recommended to reduce morbidity and mortality in patients in NYHA III–IV class who are symptomatic despite optimal medical therapy, and who have a reduced EF (LVEF ≤35%) and QRS prolongation (QRS width ≥120 ms)

Class of recommendation I, level of evidence A

- The survival advantage of CRT-D vs. CRT-P has not been adequately addressed. Due to the documented effectiveness of ICD therapy in the prevention of sudden cardiac death, the use of a CRT-D device is commonly preferred in clinical practice in patients satisfying CRT criteria including an expectation of survival with good functional status for >1 year.

Key evidence

- CRT is used in order to synchronize interventricular and intraventricular contraction in patients with HF in whom there is evidence of electrical dyssynchrony (QRS width ≥120 ms). Several single-centre observational studies have suggested that one or more measures of mechanical dyssynchrony may predict benefit with CRT in patient selection. Although CRT devices have been implanted in patients without ECG evidence of electrical dyssynchrony (QRS width <120 ms) based on echocardiographic evidence of dyssynchrony, there is no trial evidence supporting this practice. The recently published PROSPECT trial does not support the use of echocardiographic and tissue Doppler-based indices of mechanical synchrony in the selection of patients.
- The first clinical trials investigating the value of CRT in the management of patients with NYHA class III and IV HF, a reduced LVEF, and a wide QRS demonstrated that CRT improves functional class, exercise duration, and quality of life.
- Two major trials investigated the effect of CRT on all-cause mortality in HF patients with class III and IV HF and dyssynchrony. In COMPANION, CRT-P and CRT-D were both associated with a 20% reduction in the primary combined end-point of all-cause mortality and all-cause hospitalization (P < 0.01). CRT-D was associated with a significant decrease in total mortality (P = 0.003), whereas reduction in mortality associated with CRT-P was not statistically significant (P = 0.059). It is important to note that the study was not designed or powered to evaluate effects on total mortality nor to compare CRT-P and CRT-D, and conclusive data comparing the effect of CRT-P to CRT-D are not available.
- In the CARE-HF trial, CRT-P was associated with a significant reduction of 37% in the composite end-point of total death and hospitalization for major cardiovascular events (P < 0.001) and...
Natriuretic peptide levels are powerful markers of increased cardiovascular risk, and reduction in NT-proBNP is associated with a better outcome. Patients with marked elevation of NT-proBNP receive a smaller relative benefit from CRT but, due to their higher risk, the absolute benefit is similar.

**Implantable cardioverter defibrillator (ICD) (Table 23)**

- ICD therapy for secondary prevention is recommended for survivors of ventricular fibrillation (VF) and also for patients with documented haemodynamically unstable VT and/or VT with syncope, a LVEF \( \leq 40\% \), on optimal medical therapy, and with an expectation of survival with good functional status for \( > 1 \) year.

**Class of recommendation I, level of evidence A**

- ICD therapy for primary prevention is recommended to reduce mortality in patients with LV dysfunction due to prior MI who are at least 40 days post-MI, have an LVEF \( \leq 35\% \), in NYHA functional class II or III, receiving optimal medical therapy, and who have a reasonable expectation of survival with good functional status for \( > 1 \) year.

**Class of recommendation I, level of evidence A**

- ICD therapy for primary prevention is recommended to reduce mortality in patients with non-ischaemic dilated cardiomyopathy with an LVEF \( \leq 35\% \), in NYHA functional class II or III, receiving optimal medical therapy, and who have a reasonable expectation of survival with good functional status for \( > 1 \) year.

**Class of recommendation I, level of evidence B**

**Key evidence**

- Approximately half of the deaths observed in patients with HF are related to sudden cardiac death (SCD). Reduction of the proportion of patients dying for an arrhythmic event is therefore an important part of the effort to reduce total mortality in this population.

- Treatment of the arrhythmogenic substrate in HF

Pharmacological intervention in patients with HF has been confirmed to reduce morbidity and mortality substantially. A reduction of sudden cardiac death should be considered an important indication in planning a treatment strategy in patients with HF.

- Secondary prevention of cardiac arrest

Clinical trials in post-MI patients who have survived a cardiac arrest have demonstrated that the use of an ICD is more effective than antiarrhythmic drugs in the prevention of SCD. Meta-analyses of primary prevention trials have shown that the benefit on survival with ICDs is highest in the post-MI patients with depressed systolic function (LVEF \( \leq 35\% \)). No studies have addressed the population with a non-ischaemic aetiology who survived a cardiac arrest.

- Primary prevention of cardiac arrest

The results of drug trials performed in the 1980s and 1990s with class I and III antiarrhythmic drugs did not demonstrate efficacy. The SCD-HeFT trial demonstrated a lack of survival benefit in patients in NYHA functional class II and III and with an LVEF \( \leq 35\% \) treated with amiodarone, irrespective of the aetiology of HF.

Most of the ICD trials for primary prevention of SCD have focused on patients with HF of ischaemic aetiology, and have included patients with a reduced EF. Unfortunately the different trials have used variable cut-offs of EF (\( \leq 30\% \), \( \leq 35\% \), or \( \leq 40\% \)). This heterogeneity accounts for the slightly different recommendations produced by various guideline task forces. Importantly, there is discrepancy between the protocol inclusion EF criteria for the randomized trials and the actual average EF of the study cohorts. The strongest evidence exists for patients in NYHA classes II and III. The data for patients in NYHA class I are less robust.

Data on the role of the ICD in patients with non-ischaemic dilated cardiomyopathy (DCM) are more limited. The SCD-HeFT trial enrolled patients with both DCM and ischaemic LV dysfunction, and showed a 23% reduction in mortality. A meta-analysis of trials enrolling only non-ischaemic DCM patients showed a 25% reduction in mortality in the group of patients receiving an ICD (\( P = 0.003 \)). These data suggest that the aetiology of HF may not justify a different approach for the primary prevention of SCD. A useful algorithm for selecting patients for device therapy (CRT, ICD) is presented in Figure 2.

**Heart transplantation, ventricular assist devices, and artificial hearts**

**Heart transplantation**

Heart transplantation is an accepted treatment for end-stage HF. Although controlled trials have never been conducted, there is consensus that transplantation, provided proper selection criteria are applied, significantly increases survival, exercise capacity, return to work, and quality of life compared with conventional treatment.

**Class of recommendation I, level of evidence C**

**Key points**

Patients with severe HF symptoms, a poor prognosis, and with no alternative form of treatment should be considered for heart transplantation. The introduction of new techniques and more sophisticated pharmacological treatment has modified the prognostic significance of the variables traditionally used to identify heart transplant candidates (peak VO\(_2\)). The patient must be well informed, motivated, emotionally stable, and capable of complying with intensive medical treatment.

Apart from the shortage of donor hearts, the main challenge of heart transplantation is prevention of rejection of the allograft,
which is responsible for a considerable percentage of deaths in the first post-operative year. The long-term outcome is limited predominantly by the consequences of long-term immunosuppression therapy (infection, hypertension, renal failure, malignancy, and CAD). Heart transplantation should be considered in motivated patients with end-stage HF, severe symptoms, no serious co-morbidity, and no alternative treatment options. The contraindications include: current alcohol and/or drug abuse, lack of proper cooperation, serious mental disease not properly controlled, treated cancer with remission and <5 years follow-up, systemic disease with multiorgan involvement, active infection, significant renal failure (creatinine clearance <50 mL/min), irreversible high pulmonary vascular resistance (6–8 Wood units and mean transpulmonary gradient >15 mmHg), recent thromboembolic complications, unhealed peptic ulcer, evidence of significant liver impairment, or other serious co-morbidity with a poor prognosis.

**Left ventricular assist devices (LVAD) and artificial hearts**

There has been rapid progress in the development of LVAD technology and artificial hearts. Due to the nature of the target population, there is limited documentation from randomized clinical trials. The current recommendations reflect this limited evidence. There is therefore no consensus concerning LVAD indications or the most appropriate patient population. LVAD technology is likely to undergo substantial improvement in the near future, and the recommendations will need revision accordingly.168,169

- Current indications for LVADs and artificial hearts include bridging to transplantation and managing patients with acute, severe myocarditis.

**Class of recommendation IIa, level of evidence C**

- Although experience is limited, these devices may be considered for long-term use when no definitive procedure is planned.

**Class of recommendation IIb, level of evidence C**

**Key evidence**

Haemodynamic support with an LVAD may prevent or reduce clinical deterioration and may improve the patient’s clinical condition prior to transplant, or reduce mortality in patients with severe acute myocarditis. During longer term support, the risk of complications, including infection and embolization, increases.

**Ultrafiltration**

Ultrafiltration should be considered to reduce fluid overload (pulmonary and/or peripheral oedema) in selected patients and correct hyponatraemia in symptomatic patients refractory to diuretics.

**Class of recommendation IIa, level of evidence B**

**Key evidence**

Although earlier studies suggested only temporary benefit, more recent trials have demonstrated sustained effects.170 The most appropriate selection criteria have not been established. However, technological advances facilitate ultrafiltration and will probably increase experience in this population.

**Remote monitoring**

Remote monitoring can be summarized as the continuous collection of patient information and the capability to review this information without the patient present. The collection of this information may require patient participation for measures such as weight, BP, ECG, or symptoms. Newer implanted devices provide access to information such as heart rate, arrhythmia episodes, activity, intracardiac pressure, or thoracic impedance without the need to actively involve the patient.

Continuous analysis of these trends can activate notification mechanisms when clinically relevant changes are detected, and therefore facilitate patient management. Although unproven, remote monitoring may decrease healthcare utilization through fewer hospital admissions for chronic HF, fewer heart failure-related re-admissions, and more efficient device management. Ongoing trials will assess the clinical utility of such an approach.

**Class of recommendation IIb, level of evidence C**

**Arrhythmias in heart failure**

The ACC/AHA/ESC Guidelines for management of patients with arrhythmias124 are applicable to patients with HF. This section emphasizes aspects of management that are particularly relevant in HF.

**Atrial fibrillation (Table 24)**

AF is the most common arrhythmia in HF. Its onset may lead to worsening of symptoms, an increased risk of thromboembolic complications, and poorer long-term outcomes. AF

**Table 24 Management of patients with heart failure and atrial fibrillation**

**General recommendations**

- Precipitating factors and co-morbidities should be identified
- HF treatment should be optimized

**Rhythm control**

- Immediate electrical cardioversion is recommended for patients with new-onset AF and myocardial ischaemia, symptomatic hypotension or symptoms of pulmonary congestion or rapid ventricular response not controlled by appropriate pharmacological measures

**Rate control**

- Digoxin alone or in combination with β-blocker is recommended

**Prevention of thromboembolism**

- Antithrombotic therapy is recommended, unless contraindicated
- Optimal approach should be based on risk stratification: in patients at highest risk of stroke [prior stroke, transient ischaemic attack (TIA), or systemic embolism] oral anticoagulant therapy with a vitamin K antagonist is recommended
may be classified as: first episode, paroxysmal, persistent, or permanent.

- Potential precipitating factors and co-morbidity should be identified and, if possible, corrected (e.g. electrolyte abnormalities, hyperthyroidism, alcohol consumption, mitral valve disease, acute ischaemia, cardiac surgery, acute pulmonary disease, infection, uncontrolled hypertension).
- Background HF treatment should be carefully re-evaluated and optimized.
- Management of HF patient with AF, involves three objectives: rate control; correction of the rhythm disturbance; and prevention of thromboembolism. 171
- Most patients with symptomatic HF are treated with a β-blocker, and caution is advised when adding an anti-arrhythmic agent.

The following recommendations are particularly applicable for HF patients:

**Pharmacological rate control during atrial fibrillation (see section Pharmacological therapy)**
- A β-blocker or digoxin is recommended to control the heart rate at rest in patients with HF and LV dysfunction.

**Class of recommendation I, level of evidence B**
- A combination of digoxin and a β-blocker may be considered to control the heart rate at rest and during exercise.
- In LV systolic dysfunction, digoxin is the recommended initial treatment in haemodynamically unstable patients.
- Intravenous administration of digoxin or amiodarone is recommended to control the heart rate in patients with AF and HF, who do not have an accessory pathway.

**Class of recommendation I, level of evidence B**
- In patients with HF and preserved LVEF, a non-dihydropyridine calcium channel antagonist (alone or in combination with digoxin) should be considered to control the heart rate at rest and during exercise.

**Class of recommendation Ia, level of evidence C**
- Atrioventricular node ablation and pacing should be considered to control the heart rate when other measures are unsuccessful or contraindicated.

**Class of recommendation Ia, level of evidence B**
- Antithrombotic therapy to prevent thromboembolism is recommended for all patients with AF, unless contraindicated.

**Class of recommendation I, level of evidence A**
- In patients with AF at highest risk of stroke such as prior thromboembolism, stroke, transient ischaemic attack, or systemic embolism, chronic oral anticoagulant therapy with a vitamin K antagonist to achieve the target international normalized ratio (INR) of 2.0–3.0 is recommended, unless contraindicated.

**Class of recommendation I, level of evidence A**
- Anticoagulation is recommended for patients with >1 moderate risk factor. Such factors include: age ≥ 75 years, hypertension, HF, impaired LV function (LVEF ≤ 35%), and diabetes mellitus.

**Class of recommendation I, level of evidence A**
- In patients with HF and AF who do not have any additional risk factors (see above), therapy with either aspirin (81–325 mg daily) or a vitamin K antagonist is reasonable for primary prevention of thromboembolism.

**Class of recommendation IIa, level of evidence A**
- Rhythm control

There is no clear evidence that restoring and maintaining sinus rhythm is superior to rate control in reducing morbidity and mortality in patients with persistent AF and HF. 172

- Electrical cardioversion is recommended when the rapid ventricular rate does not respond promptly to appropriate pharmacological measures and especially in patients with AF causing myocardial ischaemia, symptomatic hypotension, or symptoms of pulmonary congestion. Precipitating factors should be detected and treated. TOE may be required to rule out atrial thrombus.

**Class of recommendation I, level of evidence C**
- In patients who require immediate cardioversion because of haemodynamic instability, the following approach to prevent thromboembolism is recommended: If AF is of ≥48 h duration or of unknown duration, heparin by i.v. bolus should be administered followed by a continuous infusion. Subcutaneous, low molecular weight heparin is an acceptable alternative. TOE may be required.

**Class of recommendation I, level of evidence C**
- In patients with AF and HF and/or depressed LV function, the use of antiarrhythmic therapy to maintain sinus rhythm should be restricted to amiodarone.

**Class of recommendation I, level of evidence C**
- In patients with symptomatic HF and persistent (non-self-terminating) AF, electrical cardioversion should be considered, although its success rate may depend on the duration of arrhythmia and left atrial size.

**Class of recommendation IIa, level of evidence C**
- Administration of i.v. amiodarone is a reasonable option for pharmacological cardioversion of AF, particularly when rapid restoration of sinus rhythm is not required. Patients should be anticoagulated.

**Class of recommendation IIa, level of evidence A**
- Invasive, catheter-based ablation procedures (pulmonary vein isolation) should be considered in refractory patients but have not been evaluated in clinical trials.
Class of recommendation IIa, level of evidence C

Ventricular arrhythmias

Ventricular arrhythmias (VAs) are frequent in HF patients, particularly in those with a dilated LV and reduced LVEF. Ambulatory ECG recordings detect premature ventricular complexes in virtually all HF patients, and episodes of asymptomatic, non-sustained VT are common. Complex VA is associated with a poor outcome.

On the basis of existing evidence including recent ACC/AHA/ESC Guidelines for management of VAs and sudden death, 163 the following recommendations are particularly applicable for HF patients with VA:

- It is essential to detect and, if possible, correct all potential factors precipitating VA. Neurohumoral blockade with optimal doses of β-blockers, ACEIs, ARBs, and/or aldosterone blockers is recommended.

Class of recommendation I, level of evidence A

- VA may be caused by myocardial ischaemia in HF, and aggressive therapy is essential. Evaluation for CAD and the potential for revascularization is recommended in high-risk patients.

Class of recommendation I, level of evidence C

- Routine, prophylactic use of antiarrhythmic agents in patients with asymptomatic, non-sustained VA is not recommended. In HF patients, class Ic agents should not be used.

Class of recommendation III, level of evidence B

Patients with heart failure and symptomatic VA

(see section Devices and Surgery)

- In patients who survived VF or had a history of haemodynamically unstable VT or VF with syncope, with reduced LVEF (<40%), receiving optimal pharmacological treatment and with a life expectancy of >1 year, ICD implantation is recommended.

Class of recommendation I, level of evidence A

- Amiodarone is recommended in patients with an implanted ICD, otherwise optimally treated, who continue to have symptomatic VA.

Class of recommendation I, level of evidence C

- Catheter ablation is recommended as a adjunct therapy in patients with an ICD implanted who have recurrent symptomatic VT with frequent shocks that is not curable by device reprogramming and drug therapy. 173

Class of recommendation I, level of evidence C

- Amiodarone may be considered as an alternative to ICD to suppress symptomatic VT in already optimally treated HF patients in whom ICD is not an alternative.

Class of recommendation IIb, level of evidence C

- Amiodarone may be considered in HF patients with ICD implanted who have recurrent symptomatic VT with frequent ICD shocks despite optimal therapy to prevent discharge.

Class of recommendation IIb, level of evidence C

- Electrophysiological evaluation and catheter ablation techniques may be considered in patients with HF and serious VA refractory to management.

Bradyarrhythmia

The indications for pacing in patients with HF are similar to those of other patients. These recommendations are detailed in the ESC Guidelines on pacing 138 and further discussed in the Devices and surgery section of these guidelines. Several points specifically related to patients with HF deserve mention.

- Physiological pacing to maintain an adequate chronotropic response and maintain atrial–ventricular coordination with a DDD system is preferable to VVI pacing in patients with HF.
- The indications for an ICD, CRT-P, or CRT-D device should be detected and evaluated in patients with HF prior to implantation of a pacemaker for an AV conduction defect.
- Right ventricular pacing may induce dyssynchrony and worsen symptoms.
- Pacing in order to permit initiation or titration of β-blocker therapy in the absence of conventional indications is not recommended.

Co-morbidities and special populations

Hypertension, CAD, and valvular dysfunction are frequently causal risk factors for HF or may co-exist with another primary aetiology. It is useful to highlight aspects of these conditions that may influence diagnosis, treatment, and prognosis in patients with HF (See section Devices and surgery).

Arterial hypertension (Table 25)

- Treatment of hypertension substantially reduces the risk of developing HF. Optimal values have not been established, but according to the current ESH/ESC Guidelines 175 target BP: (i) 140/90 and (ii) should be reduced to at least below 140/90 mmHg (systolic/diastolic), and to lower values if tolerated, in all hypertensive

| Table 25 Management of arterial hypertension in patients with heart failure |
|-----------------------------|-----------------------------|
| **In hypertensive patients with evidence of LV dysfunction** |
| - Systolic and diastolic blood pressure should be carefully controlled with a therapeutic target of ≤140/90 and ≤130/80 mmHg in diabetics and high risk patients |
| - Anti-hypertensive regimes based on renin–angiotensin system antagonists (ACEIs or ARBs) are preferable |
| **In hypertensive patients with HFPEF:** |
| - Aggressive treatment (often with several drugs with complementary mechanisms of action) is recommended |
| - ACEIs and/or ARBs should be considered the first-line agents |
patients; and (ii) should be <130/80 mmHg in diabetics and other high risk patients, such as those with evidence of target organ damage (stroke, MI, renal dysfunction, proteinuria).

Class of recommendation I, level of evidence A

Diabetes mellitus (DM)

Key points
- DM is a major risk factor for the development of cardiovascular disease and HF.\(^{176,177}\)
- ACEIs and ARBs can be useful in patients with DM to decrease the risk of end-organ damage and cardiovascular complications and subsequently risk of HF.

Class of recommendation IIa, level of evidence A for ACEI and C for ARB

- DM is a frequent co-morbidity in HF, affecting 20–30% of patients.\(^{178}\) DM may have a deleterious impact on the natural course of HF particularly in those with ischaemic cardiomyopathy. DM and ischaemic heart disease may interact to accelerate the deterioration of myocardial dysfunction, HF progression, and unfavourably influence prognosis.\(^{179,180}\)
- Although the relationship between elevated glucose level and a higher risk for HF is established in patients with DM, a direct beneficial effect of glucose lowering in reducing the risk of HF has not been convincingly demonstrated.\(^{181}\)

Management of DM in patients with HF

The recommendations in the ESC/EASD Guidelines for the management of DM apply to most patients with HF.\(^{181}\) In HF the following specific issues are of special interest:

Class of recommendation I, level of evidence A
- Elevated blood glucose should be treated with tight glycaemic control.

Class of recommendation IIa, level of evidence A
- Oral antidiabetic therapy should be individualized.

Class of recommendation I, level of evidence B
- Metformin should be considered as a first-line agent in overweight patients with type II DM without significant renal dysfunction (GFR > 30 mL/min).

Class of recommendation IIa, level of evidence B
- Thiazolidinediones have been associated with increased peripheral oedema and symptomatic HF. The risk of developing oedema with thiazolidinediones is dose related and higher in diabetic patients who are taking concomitant insulin therapy. They are therefore contraindicated in HF patients with NYHA functional class III–IV, but may be considered in patients with NYHA functional class I–II with careful monitoring for fluid retention.

Class of recommendation IIb, level of evidence B
- Early initiation of insulin may be considered if glucose target cannot be achieved.

Class of recommendation IIb, level of evidence C
- Agents with documented effects on morbidity and mortality such as ACEIs, β-blockers, ARBs, and diuretics confer benefit at least comparable with that demonstrated in non-diabetic HF patients.

Class of recommendation I, level of evidence A
- Evaluation of the potential for revascularization may be particularly important in patients with ischaemic cardiomyopathy and DM.

Class of recommendation IIa, level of evidence C

Renal dysfunction

Key points
- Renal dysfunction is common in HF, and the prevalence increases with HF severity, age, a history of hypertension, or DM.
- In HF, renal dysfunction is strongly linked to increased morbidity and mortality.\(^{182}\)
- The cause of renal dysfunction should always be sought in order to detect potentially reversible causes such as hypotension, dehydration, deterioration in renal function due to ACEIs, ARBs, or other concomitant medications (e.g. NSAIDs), and renal artery stenosis.\(^{7}\)

Management of heart failure patients with renal dysfunction

Therapy in HF patients with concomitant renal dysfunction is not evidence-based, as these patients are not adequately represented in RCTs in HF (see section Pharmacological therapy). The following specific issues are of interest:

- Therapy with an ACEI or ARB is usually associated with a mild deterioration in renal function as evidenced by some increase in blood urea nitrogen and creatinine levels and a decrease in estimated GFR. These changes are frequently transient and reversible. Patients with pre-existing renal insufficiency or renal artery stenosis are at a higher risk. If renal deterioration continues, other secondary causes such as excessive diuresis, persistent hypotension, other nephrotoxic therapies, or concurrent renovascular disease should be excluded.
- There is no absolute level of creatinine which precludes the use of ACEIs/ARBs. However, if the serum creatinine level is >250 μmol/L (~2.5 mg/dL), specialist supervision is recommended. In patients with a serum creatinine >500 μmol/L (~5 mg/dL), haemofiltration or dialysis may be needed to control fluid retention and treat uraemia.
- Aldosterone antagonists should be used with caution in patients with renal dysfunction as they may cause significant hyperkalaemia.
- HF patients with renal dysfunction often have excessive salt and water retention, which require more intensive diuretic
treatment. In patients with a creatinine clearance <30 mL/min, thiazide diuretics are ineffective and loop diuretics are preferred.

- Renal dysfunction is associated with impaired clearance of many drugs (e.g. digoxin). To avoid toxicity, the maintenance dose of such drugs should be reduced and plasma levels monitored.

### Chronic obstructive pulmonary disease (COPD)

**Key points**

- COPD is a frequent co-morbidity in HF, and the prevalence ranges between 20 and 30%. Restrictive and obstructive pulmonary abnormalities are common.
- COPD patients have a markedly elevated risk of HF, and COPD is a strong and independent risk factor for cardiovascular morbidity and mortality. Co-existing COPD further worsens prognosis in HF patients.
- Diagnostic assessment of HF in the presence of COPD is challenging in clinical practice. There is a significant overlap in the signs and symptoms, with a relatively lower sensitivity of diagnostic tests such as chest X-ray, ECG, echocardiography, and spirometry.
- Evaluation of natriuretic peptide (BNP or NT-proBNP) levels may be helpful in this population, but the results are often intermediate. The negative predictive value may be most useful.
- Accurate quantification of the relative contribution of cardiac and ventilatory components to the disability of the patient is difficult but may be the key to optimal management. It is essential to detect and treat pulmonary congestion.
- Agents with documented effects on morbidity and mortality such as ACEIs, β-blockers, and ARBs are recommended in patients with co-existing pulmonary disease.
- The majority of patients with HF and COPD can safely tolerate β-blocker therapy. Initiation at a low dose and gradual up-titration is recommended. Mild deterioration in pulmonary function and symptoms should not lead to prompt discontinuation. If symptoms worsen, a reduction of the dosage or withdrawal may be necessary. Selective β-blockade may be the preferable option.
- A history of asthma should be considered a contraindication to the use of any β-blocker. Inhaled β-agonists should be administered as required in patients with COPD.
- Co-existence of COPD and HF may dramatically reduce exercise tolerance. Supervised rehabilitation programmes may be appropriate to improve skeletal muscle function and fatigue.

### Anaemia

- The reported prevalence of anaemia in HF ranges widely from 4 to 70% due to a lack of an established, consistent definition of anaemia in HF. The prevalence of anaemia increases with HF severity, advanced age, female gender, renal disease, and other co-morbidities.
- Anaemia in patients with HF is frequently associated with a substantially decreased aerobic capacity, a subjective experience of fatigue and reduced functional status, and poor quality of life. Anaemia has been consistently shown to be an independent risk factor for hospital admission and mortality. The most important underlying causes include haemodilution, renal dysfunction, malnutrition, chronic inflammation, impaired bone marrow function, iron deficiency, and drug therapy.
- Anaemia may aggravate the pathophysiology of HF by adversely affecting myocardial function, activating neurohormonal systems, compromising renal function, and contributing to circulatory failure.
- Correction of anaemia has not been established as routine therapy in HF. Simple blood transfusion is not recommended to treat the anaemia of chronic disease in HF. Among potential therapies, the use of erythropoietin-stimulating agents, usually together with iron, to increase red blood cell production represents an unproven option.

### Cachexia

- Body wasting is a serious complication of HF, which may affect 10–15% of CHF patients during the natural course of the disease. This is a generalized process that encompasses loss in all body compartments, i.e. lean tissue (skeletal muscle), fat tissue (energy reserves), and bone tissue (osteoporosis). Cachexia can be defined as involuntary non-oedematous weight loss of ≥6% of total body weight within the last 6–12 months.
- Pathophysiology of cachexia in the HF syndrome still remains unclear, and poor nutrition, malabsorption, impaired calorie and protein balance, hormone resistance, proinflammatory immune activation, neurohormonal derangements, and depletion in anabolic drive may be operative.
- Cachexia usually coincides with severe symptoms of dyspnoea and weakness with a poor quality of life. Wasting is also related to very poor outcome. The mortality of cachectic HF patients is higher than in most malignant diseases.
- It has not yet been established whether prevention and treatment of cachexia complicating HF should be a treatment goal. Options include hypercaloric feeding, appetite stimulants, exercise training, and anabolic agents (insulin, anabolic steroids).

### Gout

- Patients with HF are prone to develop hyperuricaemia as a result of loop diuretic therapy use and renal dysfunction. Hyperuricaemia confers a poor prognosis in HF. In acute gout a short course of colchicine to suppress pain and inflammation may be considered. NSAIDs should be avoided, if possible, in symptomatic patients. Prophylactic therapy with a xanthine oxidase inhibitor (allopurinol) is recommended to prevent recurrence.

### Adults with congenital heart disease

- In children, heart failure is most often related to high-output situations due to intracardiac shunting. This is less frequently observed in adults. Complex lesions associated with cyanosis secondary to impaired pulmonary perfusion may make the diagnosis of HF difficult. Therefore, natriuretic peptide measurements should be included regularly in these patients. Eisenmenger patients represent special problems with
For elderly HF patients suffering from cognitive impairment, polypharmacy increases the risk of adverse interactions and non-cardiovascular morbidities may precipitate AHF. Common symptoms of exercise intolerance are often attributed to ageing, co-existing co-morbidities, and poor health status. Common co-morbidities which may have an impact on management, include renal failure, diabetes, stroke, cognitive impairment, and COPD.

- For elderly HF patients suffering from cognitive impairment, individually structured multidisciplinary HF programmes may be particularly useful and may improve adherence to therapy and prevent hospitalization.
- Relative contraindications to diagnostic procedures and interventions should be carefully evaluated and weighed against the indications.

### Acute heart failure

#### Definition

Acute heart failure (AHF) is defined as a rapid onset or change in the signs and symptoms of HF, resulting in the need for urgent therapy. AHF may be either new HF or worsening of pre-existing chronic HF. Patients may present as a medical emergency such as acute pulmonary oedema.

The cardiac dysfunction may be related to ischaemia, abnormalities in cardiac rhythm, valvular dysfunction, pericardial disease, increased filling pressures or elevated systemic resistance. These diverse cardiovascular aetiologies and conditions often interact. Table 26 presents the common causes and precipitating factors of AHF. It is essential that these factors be identified and incorporated into the treatment strategy.

AHF is usually characterized by pulmonary congestion, although in some patients reduced cardiac output and tissue hypoperfusion may dominate the clinical presentation. Multiple cardiovascular and non-cardiovascular morbidities may precipitate AHF. Common examples include (i) increased afterload due to systemic or pulmonary hypertension; (ii) increased preload due to volume overload or fluid retention; or (iii) circulatory failure as in high output states, i.e. infection, anaemia, or thyrotoxicosis. Other conditions that may precipitate AHF include non-adoherence with HF medications or medical advice, drugs such as NSAIDs, cyclo-oxygenase (COX) inhibitors, and thiazolidinediones. Severe AHF may also result in multiorgan failure (see Table 26).

The symptoms of HF may be aggravated by non-cardiovascular co-morbidities such as obstructive lung disease or co-existing end-organ disease, especially renal dysfunction. Appropriate initial and long-term therapy is required. If possible, anatomical correction of the underlying pathology, e.g. valve replacement or revascularization, may prevent further episodes of acute decompensation and improve long-term prognosis.

#### Clinical classification

The clinical presentation of AHF reflects a spectrum of conditions, and any classification will have its limitations. The patient with AHF will usually present in one of six clinical categories. Pulmonary oedema may or may not complicate the clinical presentation. Figure 3 demonstrates the potential overlap between these conditions.

- **Worsening or decompensated chronic HF** (peripheral oedema/congestion): there is usually a history of progressive worsening of known chronic HF on treatment, and evidence of systemic and pulmonary congestion. Low BP on admission is associated with a poor prognosis.
- **Pulmonary oedema**: patients present with severe respiratory distress, tachypnoea, and orthopnoea with rales over the lung fields. Arterial O₂ saturation is usually <90% on room air prior to treatment with oxygen.
- **Hypertensive HF**: signs and symptoms of HF accompanied by high BP and usually relatively preserved LV systolic function. There is evidence of increased sympathetic tone with tachycardia and vasoconstriction. The patients may be euvoalaemic or only mildly hypervolaemic, and present frequently with signs of pulmonary congestion without signs of systemic congestion.

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**Table 26 Causes and precipitating factors of acute heart failure**

<table>
<thead>
<tr>
<th>Ischaemic heart disease</th>
<th>Circulatory failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute coronary syndromes</td>
<td>Septicaemia</td>
</tr>
<tr>
<td>Mechanical complications of acute MI</td>
<td>Thyrotoxicosis</td>
</tr>
<tr>
<td>Right ventricular infarction</td>
<td>Anaemia</td>
</tr>
<tr>
<td>Valvular</td>
<td>Shunts</td>
</tr>
<tr>
<td>Valve stenosis</td>
<td>Tamponade</td>
</tr>
<tr>
<td>Valvular regurgitation</td>
<td>Pulmonary embolism</td>
</tr>
<tr>
<td>Endocarditis</td>
<td></td>
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<tr>
<td>Aortic dissection</td>
<td></td>
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<tr>
<td>Myopathies</td>
<td></td>
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<tr>
<td>Postpartum cardiomyopathy</td>
<td></td>
</tr>
<tr>
<td>Acute myocardiitis</td>
<td></td>
</tr>
<tr>
<td>Hypertension/arrhythmia</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
</tr>
<tr>
<td>Acute arrhythmia</td>
<td></td>
</tr>
</tbody>
</table>

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The elderly

- Most clinical trials have included younger patients with a mean age of ~61 years, and commonly 70% of patients have been male. Half of the patients with HF in the population are >75 years in age, and only in younger age groups do males predominate. HF with a preserved EF is more common in the elderly and in females.
- HF in the elderly is frequently underdiagnosed, as cardinal symptoms of exercise intolerance are often attributed to ageing, co-existing co-morbidities, and poor health status. Common co-morbidities which may have an impact on management, include renal failure, diabetes, stroke, cognitive impairment, and COPD.
- Polypharmacy increases the risk of adverse interactions and side-effects which may reduce compliance. Altered pharmacokinetic and pharmacodynamic properties of drugs must always be considered. Impairment of renal function is a natural consequence of ageing. Therefore, dosages of ACEIs, ARBs, spironolactone, and digoxin may need adjustment.
- For elderly HF patients suffering from cognitive impairment, individually structured multidisciplinary HF programmes may be particularly useful and may improve adherence to therapy and prevent hospitalization.
- Relative contraindications to diagnostic procedures and interventions should be carefully evaluated and weighed against the indications.

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The cardiac dysfunction may be related to ischaemia, abnormalities in cardiac rhythm, valvular dysfunction, pericardial disease, increased filling pressures or elevated systemic resistance. These diverse cardiovascular aetiologies and conditions often interact. Table 26 presents the common causes and precipitating factors of AHF. It is essential that these factors be identified and incorporated into the treatment strategy.

AHF is usually characterized by pulmonary congestion, although in some patients reduced cardiac output and tissue hypoperfusion may dominate the clinical presentation. Multiple cardiovascular and non-cardiovascular morbidities may precipitate AHF. Common examples include (i) increased afterload due to systemic or pulmonary hypertension; (ii) increased preload due to volume overload or fluid retention; or (iii) circulatory failure as in high output states, i.e. infection, anaemia, or thyrotoxicosis. Other conditions that may precipitate AHF include non-adoherence with HF medications or medical advice, drugs such as NSAIDs, cyclo-oxygenase (COX) inhibitors, and thiazolidinediones. Severe AHF may also result in multiorgan failure (see Table 26).

The symptoms of HF may be aggravated by non-cardiovascular co-morbidities such as obstructive lung disease or co-existing end-organ disease, especially renal dysfunction. Appropriate initial and long-term therapy is required. If possible, anatomical correction of the underlying pathology, e.g. valve replacement or revascularization, may prevent further episodes of acute decompensation and improve long-term prognosis.
The response to appropriate therapy is rapid, and hospital mortality is low. 

- **Cardiogenic shock**: is defined as evidence of tissue hypoperfusion induced by HF after adequate correction of preload and major arrhythmia. There are no diagnostic haemodynamic parameters. However, typically, cardiogenic shock is characterized by reduced systolic blood pressure (SBP; < 90 mmHg or a drop of mean arterial pressure > 30 mmHg) and absent or low urine output (< 0.5 mL/kg/h). Rhythm disturbance are common. Evidence of organ hypoperfusion and pulmonary congestion develop rapidly.

- **Isolated right HF**: is characterized by a low output syndrome in the absence of pulmonary congestion with increased jugular venous pressure, with or without hepatomegaly, and low LV filling pressures. 

- **ACS and HF**: many patients with AHF present with a clinical picture and laboratory evidence of an ACS. Approximately 15% of patients with an ACS have signs and symptoms of HF. Episodes of acute HF are frequently associated with or precipitated by an arrhythmia (bradycardia, AF, VT).

Various classifications of acute HF are utilized in intensive cardiac care units. The Killip classification is based on clinical signs following acute MI (see section Preamble and introduction). The Forrester classification is also based on clinical signs and haemodynamic characteristics after acute MI. Figure 4 presents a clinical classification modified from the Forrester classification.

**Prognosis**

The data from several recent AHF registries and surveys such as the EuroHeart Failure Survey II, the ADHERE registry in the USA, and the national surveys from Italy, France, and Finland have been published. Many of the patients included in these registries were elderly with considerable cardiovascular and non-cardiovascular co-morbidity and a poor short- and long-term prognosis. ACS is the most frequent cause of acute new-onset HF. In-hospital mortality is especially high in patients with evidence of cardiogenic shock (from 40 to 60%). In contrast, patients with acute hypertensive HF have low in-hospital mortality, with patients usually discharged alive and frequently asymptomatic.

Median length of stay in hospital following admission due to AHF in the EuroHeart Survey II was 9 days. Registries indicate that almost half of the patients hospitalized with AHF are rehospitalized at least once within 12 months. Estimates of the combined outcome of death or rehospitalizations within 60 days of admission vary from 30 to 50%. Adverse prognostic indicators are similar to those in chronic HF (Table 17).

**Diagnosis of acute heart failure**

The diagnosis of AHF is based on the presenting symptoms and clinical findings (see section Definition and diagnosis). Confirmation and refinement of the diagnosis is provided by appropriate investigations such as the history, physical examination, ECG, chest X-ray, echocardiography, and laboratory investigation, with blood gases and specific biomarkers. The diagnostic algorithm is similar for AHF developing de novo or as an episode of decompensation in chronic HF (see section Diagnostic techniques and Figure 5).

**Initial evaluation**

Systematic assessment of the clinical presentation is essential, with a focused history and appropriate physical examination. Assessment of peripheral perfusion, skin temperature, and venous filling pressures are important. Cardiac auscultation for systolic and diastolic murmurs as well as a third and fourth heart sounds should be performed. Mitral insufficiency is extremely common in the acute phase. Significant aortic stenosis or insufficiency should be detected. Pulmonary congestion is detected by chest auscultation, with the presence of bibasal rales often with bronchial constriction over the lung fields usually indicating raised left heart filling pressure. Right heart filling pressures are assessed by evaluating jugular venous filling. Pleural effusions are common in acutely decompensated chronic HF.

The following investigations are considered appropriate in patients with AHF. However, the recommendations largely represent expert consensus opinion without adequate documented evidence. Class of recommendation I, level of evidence C applies unless otherwise stated.
Electrocardiogram (ECG)

The ECG provides essential information regarding heart rate, rhythm, conduction, and frequently aetiology. The ECG may indicate ischaemic ST segment changes suggestive of ST-segment elevation myocardial infarction (STEMI) or non-STEMI. Q waves indicate previous transmural infarction. Evidence of hypertrophy, bundle branch block, electrical dyssynchrony, prolonged QT interval, dysrhythmia, or perimyocarditis should be sought.

Chest X-ray

Chest X-ray should be performed as soon as possible at admission for all patients with AHF to assess the degree of pulmonary congestion and to evaluate other pulmonary or cardiac conditions (cardiomegaly, effusion, or infiltrates). The limitations of a supine film in an acutely ill patient should be noted.

Arterial blood gas analysis

Arterial blood gas analysis enables assessment of oxygenation (pO2), respiratory function (pCO2), and acid–base balance (pH), and should be assessed in all patients with severe respiratory distress. Acidity due to poor tissue perfusion or CO2 retention is associated with a poor prognosis. Non-invasive measurement with pulse oximetry can often replace arterial blood gas analysis but does not provide information on pCO2 or acid–base status, and is unreliable in very low output syndromes or vasoconstricted, shock states.

Laboratory tests

Initial diagnostic evaluation of patients with AHF includes full blood count, sodium, potassium, urea, creatinine, glucose, albumin, hepatic enzymes, and INR. Low sodium and high urea and creatinine serum levels are adverse prognostic factors in AHF. A small elevation in cardiac troponin may be seen in patients with AHF without ACS. Elevated troponin compatible with ACS is associated with an adverse prognosis.213

Natriuretic peptides

B-type natriuretic peptides (BNP and NT-proBNP) taken in the acute phase have a reasonable negative predictive value for excluding HF, although the evidence for this practice is not as extensive as with chronic HF (see section Definition and diagnosis). There is no consensus regarding BNP or NT-proBNP reference values in AHF. During ‘flash’ pulmonary oedema or acute MR, natriuretic peptide levels may remain normal at the time of admission. Increased BNP and NT-pro BNP levels on admission and before discharge carry important prognostic information.59,214

Echocardiography

Echocardiography with Doppler is an essential tool for the evaluation of the functional and structural changes underlying or associated with AHF. All patients with AHF should be evaluated as soon as possible. The findings will frequently direct treatment strategy. Echo/Doppler imaging should be used to evaluate and monitor regional and global left and right ventricular systolic function, diastolic function, valvular structure and function, pericardial pathology, mechanical complications of acute MI, and evidence of dyssynchrony. Non-invasive, semi-quantitative assessment of right and left ventricular filling pressures, stroke volume, and pulmonary artery pressures may influence treatment strategy. An echo/Doppler study, repeated as required during the hospital stay, may often obviate the need for invasive evaluation/monitoring.

Instrumentation and monitoring of patients in acute heart failure

Monitoring of the patient with AHF should be started as soon as possible after the arrival at the emergency unit, concurrent with ongoing diagnostic measures focused on determining the primary aetiology as well as the response to the initial treatment strategy.

Non-invasive monitoring

In all critically ill patients, monitoring the routine basic observations of temperature, respiratory rate, heart rate, BP, oxygenation, urine output, and the electrocardiogram is mandatory. A pulse oximeter should be used continuously in any unstable patient who is being treated with a fraction of inspired oxygen (FiO2) that is greater than air, and the values recorded at regular intervals in patients receiving oxygen therapy for AHF.

Invasive monitoring

Arterial line

The indications for the insertion of an arterial catheter are the need for either continuous analysis of arterial BP due to haemodynamic instability, or the requirement for frequent arterial blood samples.

Class of recommendation IIa, level of evidence C

Central venous lines

Central venous lines provide access to the central circulation and are therefore useful for the delivery of fluids and drugs, and monitoring of the central venous pressure (CVP) and venous oxygen saturation (SVO2), which provides an estimate of the body oxygen consumption/delivery ratio.
Class of recommendation IIa, level of evidence C

Pulmonary artery catheter
The insertion of a pulmonary artery catheter (PAC) for the diagnosis of AHF is usually unnecessary. A PAC can be useful to distinguish between a cardiogenic and non-cardiogenic mechanism in complex patients with concurrent cardiac and pulmonary disease, especially when echo/Doppler measurements are difficult to obtain. A PAC may be useful in haemodynamically unstable patients who are not responding as expected to traditional treatments.

The complication rate following insertion of a PAC increases with the duration of its utilization. It is critical to have clear objectives prior to insertion of the catheter. Pulmonary capillary wedge pressure is not an accurate reflection of LV end-diastolic pressure in patients with mitral stenosis, aortic regurgitation, pulmonary venous occlusive disease, ventricular interdependence, high airway pressure, respirator treatment, or a poorly compliant LV. Severe tricuspid regurgitation, frequently found in patients with AHF, can make the estimate of cardiac output measured by thermodilution unreliable.

Class of recommendation IIb, level of evidence B

Coronary angiography
In cases of AHF and evidence of ischaemia such as unstable angina or ACS, coronary angiography is indicated in patients without strong contraindications. Revascularization options (PCI/CABG) should be considered if technically possible in appropriate patients with an acceptable risk profile. Successful reperfusion treatment has been shown to improve prognosis.215

Class of recommendation I, level of evidence B

Since the majority of patients presenting with AHF have CAD, diagnosing CAD is important for decisions concerning medical therapy such as IIb/IIa glycoprotein antagonists, oral antiplatelet agents, statins, and potential revascularization.

Organization of acute heart failure treatment

The immediate goals are to improve symptoms and to stabilize the haemodynamic condition (see Table 27 and Figure 6). Treatment of hospitalized patients with AHF requires a well-developed treatment strategy with realistic objectives and a plan for follow-up that should be initiated prior to discharge. Many patients will require long-term treatment if the acute episode leads to chronic HF. The treatment of AHF should be followed-up by a HF management programme when available, as recommended in these guidelines.

Class of recommendation I, level of evidence B

Management

Multiple agents are used to manage AHF, but there is a paucity of clinical trials data and their use is largely empiric. Adequate long-term outcome data are not available. In the published AHF trials, most agents improve haemodynamics but no agent has been shown to reduce mortality. Potential limitations in these trials include the heterogeneous populations studied and the delay between hospital presentation and therapeutic intervention.

The following management options are considered appropriate in patients with AHF. However, the recommendations largely represent expert consensus opinion without adequate documentation from randomized clinical trials. Therefore, level of evidence C applies unless otherwise stated.

Oxygen
It is recommended to administer oxygen as early as possible in hypoxaemic patients to achieve an arterial oxygen saturation ≥95% (>90% in COPD patients). Care should be taken in patients with serious obstructive airways disease to avoid hypercapnia.
Class of recommendation I, level of evidence C

Non-invasive ventilation

Indications
Non-invasive ventilation (NIV) refers to all modalities that assist ventilation without the use of an endotracheal tube but rather with a sealed face-mask. NIV with positive end-expiratory pressure (PEEP) should be considered as early as possible in every patient with acute cardiogenic pulmonary oedema and hypertensive AHF as it improves clinical parameters including respiratory distress. NIV with PEEP improves LV function by reducing LV afterload. NIV should be used with caution in cardiogenic shock and right ventricular failure.

Class of recommendation IIa, level of evidence B

Key points
• Three recent meta-analyses reported that early application of NIV in patients with acute cardiogenic pulmonary oedema reduces both the need for intubation and short-term mortality. However, in 3CPO, a large RCT, NIV improved clinical parameters but not mortality.216–219
• Intubation and mechanical ventilation should be restricted to patients in whom oxygen delivery is not adequate by oxygen mask or NIV, and in patients with increasing respiratory failure or exhaustion as assessed by hypercapnia.

Contraindications
• Patients who cannot cooperate (unconscious patients, severe cognitive impairment, or anxiety)
• Immediate need of endotracheal intubation due to progressive life-threatening hypoxia
• Caution in patients with severe obstructive airways disease

How to use non-invasive ventilation

Initiation
• A PEEP of 5–7.5 cmH2O should be applied first and titrated to clinical response up to 10 cmH2O; FiO2 delivery should be ≥0.40.

Duration
• Usually 30 min/h until patient’s dyspnoea and oxygen saturation remain improved without continuous positive airway pressure (CPAP)

Potential adverse effects
• Worsening of severe right ventricular failure
• Drying of the mucous membranes with prolonged, continuous use
• Hypercapnia
• Anxiety or claustrophobia
• Pneumothorax
• Aspiration

Morphine and its analogues in acute heart failure
Morphine should be considered in the early stage of the treatment of patients admitted with severe AHF especially if they present with restlessness, dyspnea, anxiety, or chest pain.220–222 Morphine relieves dyspnoea and other symptoms in patients with AHF and may improve cooperation for the application of NIV. The evidence in favour of morphine use for AHF is limited.
• Intavenous boluses of morphine 2.5–5 mg may be administered as soon as the i.v. line is inserted in AHF patients. This dosing can be repeated as required.
• Respiration should be monitored.
• Nausea is common, and antiemetic therapy may be required.
• Caution in patients with hypotension, bradycardia, advanced AV block, or CO2 retention.

Loop diuretics

Indications
• Administration of i.v. diuretics is recommended in AHF patients in the presence of symptoms secondary to congestion and volume overload (see Table 28).

Class of recommendation I, level of evidence B

Key points
• The symptomatic benefits and universal clinical acceptance of acute diuretic treatment has precluded formal evaluation in large-scale randomized clinical trials.223–226
• Patients with hypotension (SBP <90 mmHg), severe hypotension, or acidosis are unlikely to respond to diuretic treatment.
• High doses of diuretics may lead to hypovolaemia and hypotension, and increase the likelihood of hypotension on initiation of ACEIs or ARBs.
• Alternative treatment options such as IV vasodilators may reduce the need for high-dose diuretic therapy.

How to use a loop diuretic in acute heart failure

• The recommended initial dose is a bolus of furosemide 20–40 mg i.v. (0.5–1 mg of bumetanide; 10–20 mg of torasemide) at admission. Patients should be assessed frequently in the initial phase to follow urine output. The placement of a bladder catheter is usually desirable in order to monitor urinary output and rapidly assess treatment response.
• In patients with evidence of volume overload, the dose of i.v. furosemide may be increased according to renal function and a history of chronic oral diuretic use. In such patients, continuous infusion may also be considered after the initial starting dose. The total furosemide dose should remain <100 mg in the first 6 h and 240 mg during the first 24 h.

Combination with other diuretics
Thiazides in combination with loop diuretics may be useful in cases of diuretic resistance. In case of volume-overloaded AHF, thiazides (hydrochlorothiazide 25 mg p.o.) and aldosterone antagonists (spironolactone, eplerenone 25–50 mg p.o.) can be used in association with loop diuretics. Combinations in low doses are often more effective with fewer side-effects than with the use of higher doses of a single drug.
Potential adverse effects of loop diuretics

- Hypokalaemia, hyponatraemia, hyperuricaemia
- Hypovolaemia and dehydration; urine output should be assessed frequently
- Neurohormonal activation
- May increase hypotension following initiation of ACEI/ARB therapy

Vasopressin antagonists

Several types of vasopressin receptors have been identified: V1a receptors mediate vasoconstriction, whereas stimulation of V2 receptors located in the kidneys promotes water re-absorption. The two most extensively investigated vasopressin antagonists are conivaptan (a dual V1a/V2 receptor antagonist) in hyponatraemia, and tolvaptan (an oral, selective antagonist of the V2 receptor) in AHF. In EVEREST, tolvaptan relieved symptoms associated with AHF and promoted weight loss in the acute phase, but did not reduce mortality or morbidity at 1 year.227

Vasodilators

Vasodilators are recommended at an early stage for AHF patients without symptomatic hypotension, SBP <90 mmHg or serious obstructive valvular disease. The recommended dosage of vasodilators is presented in Table 29.

Class of recommendation I, level of evidence B

Indications

Intravenous nitrates and sodium nitroprusside are recommended in AHF patients with SBP >110 mmHg and may be used with caution in patients with SBP between 90 and 110 mmHg. These agents decrease SBP, decrease left and right heart filling pressures and systemic vascular resistance, and improve dyspnoea. Coronary blood flow is usually maintained unless diastolic pressure is compromised.228,229

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Table 28 Indications and dosing of diuretics in acute heart failure

<table>
<thead>
<tr>
<th>Fluid retention</th>
<th>Diuretic</th>
<th>Daily dose (mg)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>Furosemide or bumetanide or torasemide</td>
<td>20–40</td>
<td>Oral or i.v. according to clinical symptoms</td>
</tr>
<tr>
<td>Severe</td>
<td>Furosemide Furosemide infusion Bumetanide Torasemide</td>
<td>40–100 (5–40 mg/h) 1–4 20–100</td>
<td>i.v. Increase dose Better than very high bolus doses Oral or i.v.</td>
</tr>
<tr>
<td>Refractory to loop diuretic</td>
<td>Add hydrochlorothiazide or metolazone or spironolactone</td>
<td>50–100 2.5–10 25–30</td>
<td>Combination better than very high dose of loop diuretics More potent if creatinine cl &lt; 30 ml/min Spironolactone best choice if no renal failure and normal or low K</td>
</tr>
<tr>
<td>With alkalosis</td>
<td>Acetazolamide</td>
<td>500</td>
<td>i.v.</td>
</tr>
<tr>
<td>Refractory to loop diuretics and thiazides</td>
<td>Add dopamine (renal vasodilation) or dobutamine</td>
<td></td>
<td>Consider ultrafiltration or haemodialysis if co-existing renal failure Hyponatraemia</td>
</tr>
</tbody>
</table>

Table 29 Indications and dosing of i.v.vasodilators in acute heart failure

<table>
<thead>
<tr>
<th>Vasodilator</th>
<th>Indication</th>
<th>Dosing</th>
<th>Main side-effects</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitroglycerine</td>
<td>Pulmonary congestion/oedema BP &gt; 90 mmHg</td>
<td>Start 10–20 µg/min, increase up to 200 µg/min</td>
<td>Hypotension, headache</td>
<td>Tolerance on continuous use</td>
</tr>
<tr>
<td>Isosorbide dinitrate</td>
<td>Pulmonary congestion/oedema BP &gt; 90 mmHg</td>
<td>Start with 1 mg/h, increase up to 10 mg/h</td>
<td>Hypotension, headache</td>
<td>Tolerance on continuous use</td>
</tr>
<tr>
<td>Nitroprusside</td>
<td>Hypertensive HF congestion/oedema BP &gt; 90 mmHg</td>
<td>Start with 0.3 µg/kg/min and increase up to 5 µg/kg/min</td>
<td>Hypotension, isocyanate toxicity</td>
<td>Light sensitive</td>
</tr>
<tr>
<td>Nesiritide*</td>
<td>Pulmonary congestion/oedema BP &gt; 90 mmHg</td>
<td>Bolus 2 µg/kg + infusion 0.015–0.03 µg/kg/min</td>
<td>Hypotension</td>
<td></td>
</tr>
</tbody>
</table>

*Not available in many ESC countries.
Intravenous nesiritide may be initiated with or without a bolus. Slow titration of i.v. nitrates and frequent BP measurement is recommended to avoid large drops in SBP. Any vasodilator should be avoided in AHF patient with SBP < 90 mmHg as it may reduce central organ perfusion. Hypotension should be avoided, especially in patients with renal dysfunction. Patients with aortic stenosis may demonstrate marked hypotension following the initiation of i.v. vasodilator treatment.

How to use vasodilators in AHF
Nitrates (nitroglycerine isosorbide mononitrate, and isosorbide dinitrate), sodium nitroprusside, and nesiritide are used as continuous infusion. Intravenous nitroglycerine is the agent most widely used in AHF, with a predominantly venodilator effect. Intravenous nitroprusside is a potent balanced vasodilator with combined preload and afterload reduction. Intravenous nesiritide, a recombinant form of human B-type natriuretic peptide, is a venous and arterial vasodilator with a combined modest diuretic and natriuretic effect.

- It is recommended to administer nitroglycerine in the early phase of AHF frequently followed by a continuous infusion of nitroglycerine, nitroprusside spray of 400 µg (2 puffs) every 5–10 min, buccal nitrate (isosorbide dinitrate 1 or 3 mg), or 0.25–0.5 mg sublingual nitroglycerine.
- The initial recommended dose of i.v. nitroglycerin is 10–20 µg/min, increased in increments of 5–10 µg/min every 3–5 min as needed.
- Slow titration of i.v. nitrates and frequent BP measurement is recommended to avoid large drops in SBP. An arterial line is not routinely required but will facilitate titration in patients with borderline pressures.
- Intravenous nitroprusside should be administered with caution. The initial infusion rate should be 0.3 µg/kg/min with titration up to 5 µg/kg/min. An arterial line is recommended.
- Intravenous nesiritide may be initiated with or without a bolus infusion with infusion rates from 0.015 to 0.03 µg/kg/min. Non-invasive BP measurements are usually adequate. Combination with other i.v. vasodilators is not recommended. Nesiritide is not available in most European countries.

Potential adverse effects
Headache is frequently reported with nitrates. Tachyphylaxis is common after 24–48 h, necessitating incremental dosing with nitrates. Intravenous nitroprusside should be used cautiously in patients with ACS, as abrupt hypotension is not infrequent. Hypotension may also occur with i.v. nitroglycerine or nesiritide infusion.

Inotropic agents (Table 30)
Inotropic agents should be considered in patients with low output states, in the presence of signs of hypoperfusion or congestion despite the use of vasodilators and/or diuretics to improve symptoms. Figure 7 describes a treatment algorithm based on the level of SBP, and Figure 8 describes the treatment algorithm based on a clinical assessment of patients filling pressures and perfusion.

Class of recommendation IIa, level of evidence B

Indications for inotropic therapy
Inotropic agents should only be administered in patients with low SBP or a low measured cardiac index in the presence of signs of hypoperfusion or congestion. Signs of hypoperfusion include cold, clammy skin, in patients who are vasoconstricted with acidosis, renal impairment, liver dysfunction, or impaired mentation. Therapy should be reserved for patients with dilated, hypokinetic ventricles.

When needed, inotropic agents should be administered as early as possible and withdrawn as soon as adequate organ perfusion is restored and/or congestion reduced. Although inotropes may acutely improve the haemodynamic and clinical status of patients with AHF, they may promote and accelerate some pathophysiological mechanisms, causing further myocardial injury and leading to increased short- and long-term mortality.

In some cases of cardiogenic shock, inotropic agents may stabilize patients at risk of progressive haemodynamic collapse or serve as a life-sustaining bridge to more definitive therapy such as mechanical circulatory support, ventricular assist devices, or cardiac transplantation. Infusion of most inotropes is accompanied by an increased incidence of both atrial and ventricular arrhythmias. In patients with AF, dobutamine/dopamine may facilitate conduction through the AV node and lead to tachycardia. Continuous clinical monitoring and ECG telemetry is required.

Dobutamine
Dobutamine, a positive inotropic agent acting through stimulation of β1-receptors to produce dose-dependent positive inotropic and chronotropic effects, is usually initiated with a 2–3 µg/kg/min infusion rate without a loading dose. The infusion rate may then be progressively modified according to symptoms, diuretic response, or clinical status. Its haemodynamic actions are dose-related, which can be increased to 15 µg/kg/min. BP should be monitored, invasively or non-invasively. In patients receiving β-blocker therapy, dobutamine doses may have to be increased to as high as 20 µg/kg/min to restore its inotropic effect. The elimination of the drug is rapid after cessation of infusion. Care should be exercised in weaning patients from dobutamine infusion. Gradual tapering (i.e. decrease in dosage by steps of 2 µg/kg/min) and simultaneous optimization of oral therapy are essential.

Class of recommendation IIa, level of evidence B

Dopamine
Dopamine, which also stimulates β-adrenergic receptors both directly and indirectly with a consequent increase in myocardial contractility and cardiac output, is an additional inotropic agent. Infusion of low doses of dopamine (≤2–3 mg/kg/min) stimulates dopaminergic receptors but has been shown to have limited effects on diuresis. Higher doses of dopamine may be used to
maintain SBP, but with an increasing risk of tachycardia, arrhythmia, and α-adrenergic stimulation with vasoconstriction. Dopamine and dobutamine should be used with caution in patients with a heart rate >100 b.p.m. The alpha stimulation at higher doses may lead to vasoconstriction and elevated systemic vascular resistance. Low-dose dopamine is frequently combined with higher doses of dobutamine.

**Class of recommendation IIb, level of evidence C**

**Milrinone and enoximone**

Milrinone and enoximone are the two type III phosphodiesterase inhibitors (PDEIs) used in clinical practice. The agents inhibit the breakdown of cyclic AMP and have inotropic and peripheral vasodilating effects, with an increase in cardiac output and stroke volume, and a concomitant decline in pulmonary artery pressure, pulmonary wedge pressure, and systemic and pulmonary vascular resistance. As their cellular site of action is distal to the β-adrenergic receptors, the effects of PDEIs are maintained during concomitant β-blocker therapy. Milrinone and enoximone are administered by a continuous infusion possibly preceded by a bolus dose in patients with well-preserved BP. Caution should be used with the administration of PDEIs in patients with CAD, as it may increase medium-term mortality.

**Class of recommendation IIb, level of evidence B**

**Levosimendan**

Levosimendan is a calcium sensitizer that improves cardiac contractility by binding to troponin-C in cardiomyocytes. It exerts significant vasodilatation mediated through ATP-sensitive potassium channels and has mild PDE inhibitory action. Levosimendan infusion in patients with acutely decompensated HF increases cardiac output and stroke volume and reduces pulmonary wedge pressure, systemic vascular resistance, and pulmonary vascular resistance. The haemodynamic response to levosimendan is

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**Table 30 Dosing of positive inotropic agents in acute heart failure**

<table>
<thead>
<tr>
<th>Agent</th>
<th>Bolus</th>
<th>Infusion rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dobutamine</td>
<td>No</td>
<td>2–20 μg/kg/min (β+)</td>
</tr>
<tr>
<td>Dopamine</td>
<td>No</td>
<td>&lt;3 μg/kg/min: renal effect (β+)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3–5 μg/kg/min: inotropic (β+)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;5 μg/kg/min: (β+), vasopressor (α+)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.375–0.75 μg/kg/min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.25–7.5 μg/kg/min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1 μg/kg/min which can be decreased to 0.05 or increased to 0.2 μg/kg/min</td>
</tr>
<tr>
<td>Milrinone</td>
<td>25–75 μg/kg over 10-20 min</td>
<td></td>
</tr>
<tr>
<td>Enoximone</td>
<td>0.25–0.75 mg/kg</td>
<td></td>
</tr>
<tr>
<td>Levosimendan*</td>
<td>12 μg/kg over 10 min (optional)**</td>
<td></td>
</tr>
<tr>
<td>Norepinephrine</td>
<td>No</td>
<td>0.2–1.0 μg/kg/min</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>No</td>
<td>0.05–0.5 μg/kg/min</td>
</tr>
</tbody>
</table>

*Bolus: 1 mg can be given i.v. during resuscitation, repeated every 3–5 min.*

*This agent also has vasodilator properties.

**In hypotensive patients (SBP <100 mmHg) initiation of therapy without a bolus is recommended.

---

*Figure 7* AHF treatment strategy according to systolic blood pressure.

*Figure 8* AHF treatment strategy according to LV filling pressure.
maintained over several days. Levosimendan may be effective in patients with decompensated chronic HF. In that the inotropic effect is independent of β-adrenergic stimulation, it represents an alternative for patients on β-blocker therapy. Levosimendan treatment is associated with a slight increase in heart rate and a decrease in the BP, especially if a loading dose is administered.235,237

Levosimendan may be administered as a bolus dose (3–12 μg/kg) during 10 min followed by a continuous infusion (0.05–0.2 μg/kg/min for 24 h). The infusion rate may be increased once stability is confirmed. In patients with SBP <100 mmHg, the infusion should be started without a bolus dose to avoid hypotension.

Class of recommendation IIa, level of evidence B

Vaspressors

Vaspressors (norepinephrine) are not recommended as first-line agents and are only indicated in cardiogenic shock when the combination of an inotropic agent and fluid challenge fails to restore SBP >90 mmHg, with inadequate organ perfusion, despite an improvement in cardiac output. Patients with sepsis complicating AHF may require a vasopressor. Since cardiogenic shock is usually associated with a high systemic vascular resistance, all vasopressors should be used with caution and discontinued as soon as possible. Noradrenaline might be used with any of above-mentioned inotropic agents in cardiogenic shock, ideally perfused through a central line. Caution is advised with dopamine that already exerts a vasopressor effect. Epinephrine is not recommended as an inotrope or vasopressor in cardiogenic shock and should be restricted to use as rescue therapy in cardiac arrest.

Class of recommendation IIb, level of evidence C

Cardiac glycosides

In AHF, cardiac glycosides produce a small increase in cardiac output and a reduction of filling pressures. It may be useful to slow ventricular rate in rapid AF.

Class of recommendation IIb, level of evidence C

Algorithm for acute heart failure management

After the initial assessment, all patients should be considered for oxygen therapy and NIV. The goal of treatment in the pre-hospital setting or at the emergency room is to improve tissue oxygenation and optimize haemodynamics in order to improve symptoms and permit interventions (see Figure 6). A specific treatment strategy should be based on distinguishing the clinical conditions as described below:

- **Decompensated chronic HF**: vasodilators along with loop diuretics are recommended. Consider higher dose of diuretics in renal dysfunction or with chronic diuretic use. Inotropic agents are required with hypotension and signs of organ hypoperfusion.

- **Pulmonary oedema**: morphine is usually indicated, especially when dyspnoea is accompanied by pain and anxiety. Vasodilators are recommended when BP is normal or high, and diuretics in patients with volume overload or fluid retention. Inotropic agents are required with hypotension and signs of organ hypoperfusion. Intubation and mechanical ventilation may be required to achieve adequate oxygenation.

- **Hypertensive HF**: vasodilators are recommended with close monitoring and low-dose diuretic treatment in patients with volume overload or pulmonary oedema.

- **Cardiogenic shock**: a fluid challenge if clinically indicated (250 mL/10 min) followed by an inotrope if SBP remains <90 mmHg is recommended. If the inotropic agent fails to restore SBP and signs of organ hypoperfusion persist, norepinephrine may be added with extreme caution. An intra-aortic balloon pump (IABP) and intubation should be considered. LVADs may be considered for potentially reversible causes of acute HF as a bridge to treatment response (i.e. surgery or recovery).

- **Right HF**: a fluid challenge is usually ineffective. Mechanical ventilation should be avoided. Inotropic agents are required when there are signs of organ hypoperfusion. Pulmonary embolism and right ventricular MI should be suspected.

- **AHF and ACS**: all patients with ACS and signs and symptoms of HF should undergo an echocardiographic study to assess systolic and diastolic ventricular function, valvular function, and rule out other cardiac abnormalities or mechanical complications of MI.

Class of recommendation I, level of evidence C

In ACS complicated by AHF, early reperfusion may improve prognosis (Management of acute myocardial infarction in patients presenting with persistent ST-segment elevation. Eur Heart J 2008, doi:10.1093/eurheartj/ehn416, in press). If neither PCI nor surgery is readily available or can only be provided after a delay, early fibrinolytic therapy is recommended in patients with STEMI. Urgent surgery is indicated in patients with mechanical complications after AMI. In cardiogenic shock caused by ACS, insertion of an IABP, coronary angiography, and revascularization (primary PCI) should be considered as soon as possible.

Class of recommendation I, level of evidence C

Management of patients with acutely decompensated chronic heart failure treated with β-blockers and ACEIs/ARBs

ACEIs are not indicated in the early stabilization of patients with AHF. However, as these patients are at high risk for development of chronic HF, ACEIs/ARBs have an important role in early management of AHF patients and acute MI, particularly in the presence of HF and/or evidence of LV systolic dysfunction. These agents attenuate remodelling, and reduce morbidity and mortality. There is no consensus on the ideal timing for initiation of ACEI/ARB therapy in AHF. In general, it is recommended that treatment with these agents should be initiated before discharge from hospital. Patients on ACEIs/ARBs admitted with worsening HF should be continued on this treatment whenever possible.

Class of recommendation I, level of evidence A

In patients with acutely decompensated HF, the dose of β-blocker may need to be reduced temporarily or omitted, although generally treatment should not be stopped, unless the patient is clinically
unstable with signs of low output. Treatment may be interrupted or reduced in the presence of complications (bradycardia, advanced AV block, bronchospasm, or cardiogenic shock) or in cases of severe AHF and an inadequate response to initial therapy. In patients following an AMI, with symptoms of HF or evidence of LV dysfunction, β-blockers should also be initiated early and preferably prior to discharge. In patients admitted with AHF, β-blockers should be considered when the patient has been stabilized on an ACEI or ARB and preferably initiated before hospital discharge.

**Class of recommendation IIa, level of evidence B**

**Implementation and delivery of care**

In many European countries, >2% of the total healthcare budget is related to HF management, and up to 70% of this cost is related to hospitalizations.\(^238\) Optimization of therapy is often not achieved either in primary or in secondary care, even during hospitalization. In addition, discharge planning and follow-up after hospitalization are frequently insufficient, leading to poor self-care behaviour, inadequate support for the patients, and suboptimal treatment. Poor or non-adherence to medication, diet, or symptom recognition is common\(^70,71\) and may be responsible for over one-third of the hospital readmissions. Management programmes are designed to improve outcomes through structured follow-up with patient education, optimization of medical treatment, psychosocial support, and access to care.

Management of patients with HF exemplifies the relevance of a shift of the emphasis of management away from acute and subacute episodes of illness toward chronic conditions where the nature of professional and patient transactions is distinctly different. Table 31 summarises the goals and measures involved during potential phases of this transition.

### Heart failure management programmes

- Heart failure management programmes are recommended for patients with HF recently hospitalized and for other high-risk patients.

**Class of recommendation I, level of evidence A**

HF management programmes are structured as a multidisciplinary care approach that coordinate care along the continuum of HF and throughout the chain of care delivered by various services within the healthcare systems. Multidisciplinary teams in HF may include nurses, cardiologists, primary care physicians, physical therapists, dieticians, social workers, psychologists, pharmacists, geriatricians, and other healthcare professionals and services. The content and structure of HF management programmes vary widely in different countries and healthcare settings, and are tailored to meet local needs.\(^239\)

Many programmes focus on symptomatic, hospitalized patients with HF since they have a poorer prognosis and are at a higher risk for readmissions. An outpatient visit, early after discharge, is recommended to assess clinical status, identify objectives, and design an effective treatment strategy. Although it seems reasonable to assume that more intensive programmes should be more effective than less intensive programmes, the available studies do not unequivocally show a reduction in admission rates with more intensified interventions,\(^240,241\) and low intensity interventions compared with no structured follow-up has been shown to improve event-free survival.\(^242,243\)

If possible, patients should learn to recognize symptoms and practice self-care measures (see section Non-pharmacological management). Nurses are often involved in drug titration, and titration protocols and treatment algorithms should be employed.\(^244\) Programmes may also be involved in the management of patients with an implanted device (CRT/ICD). Increased access to care through

### Table 31 Treatment goals and strategies during the course of the patient’s journey

<table>
<thead>
<tr>
<th>Phase</th>
<th>Diagnostic strategy</th>
<th>Action</th>
<th>Goals</th>
<th>Players</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute</td>
<td>Assess clinical status</td>
<td>Treat and stabilize</td>
<td>Stabilize, admit, and triage to appropriate department</td>
<td>Paramedics Primary care/ER physicians</td>
</tr>
<tr>
<td></td>
<td>Identify cause of symptoms</td>
<td>Initiate monitoring</td>
<td></td>
<td>Intensivists Nurses Cardiologists</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plan required interventions</td>
<td></td>
<td>Hospital physicians Cardiologists CV nurses HF Management team</td>
</tr>
<tr>
<td>Subacute</td>
<td>Assess cardiac function</td>
<td>Initiate chronic medical treatment</td>
<td>Shorten hospitalization</td>
<td>Primary care physicians HF Management team</td>
</tr>
<tr>
<td></td>
<td>Identify aetiology and co-morbidities</td>
<td>Perform additional diagnostics</td>
<td>Plan post-discharge follow-up</td>
<td>Cardiologists</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Perform indicated procedures</td>
<td></td>
<td>Palliative care team</td>
</tr>
<tr>
<td>Chronic</td>
<td>Target symptoms, adherence, and prognosis</td>
<td>Optimize pharmacological and device treatment</td>
<td>Reduce morbidity and mortality</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Identify decompensation early</td>
<td>Support self-care behaviour</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remote monitoring</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>End of life</td>
<td>Identify patient concerns and symptoms</td>
<td>Symptomatic treatment</td>
<td>Palliation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plan for long-term care</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
daily telephone calls to a HF nurse provides reassurance and allows patients the opportunity to discuss symptoms, treatment, side-effects, and self-care behaviour. Contact with the programme can be initiated during hospitalization, at discharge, during the first weeks after discharge, or as a request for consultation from primary care.

It is recommended that HF management programmes include the components shown in Table 32. Adequate education is essential. Remote management is an emerging field within the broader context of HF management programmes, and extends the reach of individualized care to the large group of individuals unable to access traditional programmes of care.

Telephone support is a form of remote management that can be provided through scheduled calls from a HF nurse or physician, or through a telephone service, which the patients can contact if questions arise or symptoms of deterioration occur. Telemonitoring is another form of management that allows daily monitoring of symptoms and signs measured by patients, family, or caregivers at home while allowing patients to remain under close supervision. Telemonitoring equipment may include recording BP, heart rate, ECG, oxygen saturation, weight, symptom response systems, medication adherence, device control and video consultation equipment—all of which can be installed in the patient’s home. There is no consensus regarding which variables are most helpful to monitor, and new equipment with additional monitoring parameters and more sophisticated technology is under development. There are also internal monitoring devices capable of delivering remote physiological monitoring (see section Devices and surgery).

Cardiac rehabilitation, as multifaceted and multidisciplinary interventions, has been proven to improve functional capacity, recovery, and emotional well-being, and to reduce hospital readmissions.

Key evidence
- Several meta-analyses based on >8000 patients have evaluated the effect of multidisciplinary, often nurse-led, interventions with follow-up and patient education combined with optimization of medical treatment. The meta-analyses demonstrate that home-based follow-up or follow-up in a clinic setting significantly reduced hospitalization. The risk reduction ranged between 16 and 21%. Mortality was also significantly reduced.
- A large multicentre study evaluating the effect of education and an intense support programme by HF nurses on top of frequent visits with cardiologist did not show a reduction in the combined primary end-point of HF hospitalizations and mortality.
- HF management programmes are likely to be cost-effective in that they reduce hospital readmissions and can be established on a relatively modest budget.
- It has not been established which of the various models of care is optimal. Both clinic- and home-based models seem to be equally effective. Face-to-face visits with a HF nurse have been shown to have large effects on outcomes. Accurate assessment of local conditions and needs is essential. Advantages and disadvantages with each model are summarized in Table 33.
- A recent meta-analysis comparing predominantly telephone-based vs. face-to-face programmes of care suggested that the latter were more efficacious in reducing the risk of all-cause readmission and mortality. The most contemporary meta-analysis of 14 randomized trials involving 4264 patients incorporating sophisticated models of remote HF management demonstrated 21 and 20% significant reductions in the risk of a HF-related admission and all-cause mortality, respectively.
- The organization of a HF management programme should be based on patient needs, financial resources, available personnel, and administrative policies. As delivery of care varies in Europe, structured care needs to be adapted to local priorities and infrastructure.

Palliative care for patients with heart failure
- Patients with clinical features of advanced HF who continue to experience symptoms refractory to optimal evidence-based therapy have a poor short-term prognosis and should be considered appropriate for a structured palliative care approach. Psychological symptoms such as anxiety need to be addressed.

Class of recommendation I, level of evidence C

Features that should trigger such consideration and the proposed steps in the process of providing palliative care are presented in Table 34.

Advanced HF has a very poor 1-year survival rate, and the prognosis is worse than for most common forms of cancer. However, in most European countries, patients with end-stage HF are frequently referred to specialist palliative care. HF has an unpredictable disease trajectory and it is often difficult to identify a specific time point to introduce palliative care to HF management. Interventions should focus on improvement in quality of life, control of symptoms, early detection and treatment of episodes of deterioration, and on pursuing a holistic approach to patient care.
Table 33 Advantages and disadvantages of different models of heart failure programmes

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinic visits</td>
<td>• Convenient with medical expertise, facilities and equipment available. • Facilitates diagnostic investigation and adjustments of treatment strategy</td>
<td>• Frail, non-ambulatory patients not suitable for out-patient follow-up</td>
</tr>
<tr>
<td>Home care</td>
<td>• Access to immobile patients • More reliable assessment of the patient’s needs, capabilities and adherence to treatment in their own home environment</td>
<td>• Time consuming travel for the HF team • Transportation and mobile equipment required</td>
</tr>
<tr>
<td>Telephone support</td>
<td>• Low cost, time saving and convenient both for the team and the patient</td>
<td>• Difficult to assess symptoms and signs of heart failure and no tests can be performed</td>
</tr>
<tr>
<td>Remote monitoring</td>
<td>• Facilitates informed clinical decisions • Need is increasing as care shifts into patients’ homes • New equipment and technology becoming rapidly available</td>
<td>• Requires education on the use of the equipment • Time-consuming for HF team • Difficult for patients with cognitive disability • Most helpful measurements not known</td>
</tr>
</tbody>
</table>

Table 34 Goals and steps in the process of providing palliative care in patients with heart failure

<table>
<thead>
<tr>
<th>Patient features</th>
<th>&gt;1 episode of decompensation/6 months despite optimal tolerated therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confirm diagnosis</td>
<td>Need for frequent or continual IV support</td>
</tr>
<tr>
<td>Patient education</td>
<td>Chronic poor quality of life with NYHA IV symptoms</td>
</tr>
<tr>
<td>Establish an Advanced Care Plan</td>
<td>Signs of cardiac cachexia</td>
</tr>
<tr>
<td>Services should be organised</td>
<td>Clinically judged to be close to the end of life</td>
</tr>
<tr>
<td>Symptom Management</td>
<td>Essential to ensure optimal treatment.</td>
</tr>
<tr>
<td>Identifying end-stage heart failure</td>
<td>Principles of self-care maintenance and management of HF</td>
</tr>
<tr>
<td>Breaking bad news to the patient and family</td>
<td>Designed with the patient and a family member. Reviewed regularly and includes the patients’ preferences for future treatment options</td>
</tr>
<tr>
<td>Establishing new goals of care</td>
<td>The patients’ care within the multidisciplinary team, to ensure optimal pharmacological treatment, self-care management and to facilitate access to supportive services.</td>
</tr>
<tr>
<td></td>
<td>Requires frequent assessment of patients’ physical, psychological, social and spiritual needs.</td>
</tr>
<tr>
<td></td>
<td>Patients frequently have multiple co-morbidities that need to be identified.</td>
</tr>
<tr>
<td></td>
<td>Confirmation of end-stage HF is advisable to ensure that all appropriate treatment options have been explored a plan for the terminal stage of illness should be agreed upon.</td>
</tr>
<tr>
<td></td>
<td>Explaining disease progression and a change in treatment emphasis is a sensitive issue and must be approached with care.</td>
</tr>
<tr>
<td></td>
<td>End-of-life care should include avoidance of circumstances which may detract from a peaceful death. All current pharmacological treatment and device programmes should be considered. Resuscitation orders should be clear.</td>
</tr>
</tbody>
</table>

Gaps in evidence

Clinicians responsible for managing patients with HF must frequently make treatment decisions without adequate evidence or consensus expert opinion. The following is a shortlist of selected, common issues that deserve to be addressed in future clinical research.

- Females and the elderly have not been adequately represented in clinical trials and there is a need for further evaluation of treatments in these two populations.
Diagnosis and co-morbidity
- Is there a diagnostic role for natriuretic peptide assay in patients with HFPEF?
- Does any specific treatment of the following co-morbidities in patients with HF reduce morbidity and mortality?
  - renal dysfunction
  - anaemia
  - diabetes
  - depression
  - disordered breathing during sleep

Non-pharmacological, non-interventional therapy
- How can adherence in HF be improved?
- Is salt restriction beneficial in HF?
- Does exercise training improve survival in HF?
- Can cardiac cachexia be prevented or treated?

Pharmacological therapy
- Which pharmacological agents reduce morbidity and mortality in patients with an EF between 40 and 50% or HFPEF?
- Is aspirin use associated with a higher risk of HF hospitalization?

In patients with heart failure and systolic dysfunction
- Should ACEIs always be prescribed before β-blockers?
- Should an aldosterone antagonist or an ARB be added next in symptomatic patients on an ACEI and a β-blocker?
- Does tailoring HF therapy according to plasma natriuretic peptide concentrations reduce morbidity and mortality?
- Does an aldosterone antagonist reduce morbidity and mortality in patients with mild symptoms (NYHA class II)?
- Is quadruple therapy (ACEI, ARB, aldosterone antagonist, and β-blocker) better at reducing morbidity and mortality than use of three of these agents?

Intervention
- Does revascularization reduce morbidity and mortality in patients with HF, systolic dysfunction, and CAD?
- Does revascularization in patients with hibernating myocardium improve clinical outcomes?
- What criteria should be used in evaluating patients with HF and aortic stenosis/regurgitation or mitral regurgitation for valvular surgery?

Devices
- In patients with HF and a wide QRS complex, which patient characteristics should lead to a CRT-D being preferred over a CRT-P?
- Is there any role for echocardiographic assessment of dysynchrony in the selection of patients for CRT?
- Does CRT improve clinical outcomes in patients with a low LVEF, a wide QRS, but mild symptoms (NYHA class II)?
- Does CRT improve clinical outcomes in patients with a low LVEF, severe symptoms (NYHA class III/IV), and a QRS width <120 ms?
- Does an ICD improve clinical outcomes in HF with an EF >35%?
- How should patients be selected for bridge to recovery with an LVAD?
- Do LVADs provide an alternative treatment to transplantation in advanced heart failure?

Arrhythmias
- Does restoring sinus rhythm reduce morbidity and mortality in patients with HF, AF, and either systolic dysfunction or HFPEF?

Acute heart failure
- What is the role of NIV in AHF?
- Which is the most efficacious vasodilator in AHF in terms of reducing morbidity and mortality?
- Which is the most efficacious inotrope in AHF in terms of reducing morbidity and mortality?
- How should β-blocker treatment be managed in patients with acute decompensation?
- Does ultrafiltration expedite recovery and discharge in patients with AHF and volume overload?

Implementation
- Which components of HF management programmes are most important for reducing morbidity and mortality?
- Do HF management programmes reduce morbidity and mortality in patients with HFPEF?
- What aspects of remote monitoring might best detect early decompensation?

Detailed evidenced tables for treatment with ACEIs, ARBs, β-blockers, and devices are available on the Guidelines Section of the ESC website http://www.escardio.org/guidelines.
<table>
<thead>
<tr>
<th>Glossary</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACC</td>
<td>American College of Cardiology</td>
</tr>
<tr>
<td>ACE</td>
<td>angiotensin-converting enzyme</td>
</tr>
<tr>
<td>ACEI</td>
<td>angiotensin-converting enzyme inhibitor</td>
</tr>
<tr>
<td>ACS</td>
<td>acute coronary syndrome</td>
</tr>
<tr>
<td>AF</td>
<td>atrial fibrillation</td>
</tr>
<tr>
<td>AHA</td>
<td>American Heart Association</td>
</tr>
<tr>
<td>AHF</td>
<td>acute heart failure</td>
</tr>
<tr>
<td>ANA</td>
<td>antinuclear antibody</td>
</tr>
<tr>
<td>AR</td>
<td>aortic regurgitation</td>
</tr>
<tr>
<td>ARB</td>
<td>angiotensin receptor blocker</td>
</tr>
<tr>
<td>ARR</td>
<td>absolute risk reduction</td>
</tr>
<tr>
<td>AS</td>
<td>aortic stenosis</td>
</tr>
<tr>
<td>ATP</td>
<td>adenosine triphosphate</td>
</tr>
<tr>
<td>AV</td>
<td>atrioventricular</td>
</tr>
<tr>
<td>AVP</td>
<td>arginine vasopressin</td>
</tr>
<tr>
<td>b.i.d.</td>
<td>twice a day</td>
</tr>
<tr>
<td>BNP</td>
<td>B-type natriuretic peptide</td>
</tr>
<tr>
<td>BP</td>
<td>blood pressure</td>
</tr>
<tr>
<td>b.p.m.</td>
<td>beats per minute</td>
</tr>
<tr>
<td>BUN</td>
<td>blood urea nitrogen</td>
</tr>
<tr>
<td>CABG</td>
<td>coronary artery bypass grafting</td>
</tr>
<tr>
<td>CAD</td>
<td>coronary artery disease</td>
</tr>
<tr>
<td>CCU</td>
<td>coronary care unit</td>
</tr>
<tr>
<td>CHF</td>
<td>chronic heart failure</td>
</tr>
<tr>
<td>Class 1c</td>
<td>Vaughan Williams antiarrhythmic classification</td>
</tr>
<tr>
<td>CMR</td>
<td>cardiac magnetic resonance</td>
</tr>
<tr>
<td>COPD</td>
<td>chronic obstructive pulmonary disease</td>
</tr>
<tr>
<td>CPAP</td>
<td>continuous positive airway pressure</td>
</tr>
<tr>
<td>CR</td>
<td>sustained release</td>
</tr>
<tr>
<td>CRP</td>
<td>C-reactive protein</td>
</tr>
<tr>
<td>CRT</td>
<td>cardiac resynchronization therapy</td>
</tr>
<tr>
<td>CRT-D</td>
<td>cardiac resynchronization therapy - defibrillator</td>
</tr>
<tr>
<td>CRT-P</td>
<td>cardiac resynchronization therapy - pacemaker</td>
</tr>
<tr>
<td>CT</td>
<td>computer tomography</td>
</tr>
<tr>
<td>DDD</td>
<td>dual chamber pacing</td>
</tr>
<tr>
<td>DCM</td>
<td>dilated cardiomyopathy</td>
</tr>
<tr>
<td>dL</td>
<td>deciliter</td>
</tr>
<tr>
<td>DM</td>
<td>diabetes mellitus</td>
</tr>
<tr>
<td>EASD</td>
<td>European Association for the Study of Diabetes</td>
</tr>
<tr>
<td>ECG</td>
<td>electrocardiogram</td>
</tr>
<tr>
<td>ED</td>
<td>emergency department</td>
</tr>
<tr>
<td>EF</td>
<td>ejection fraction</td>
</tr>
<tr>
<td>EMB</td>
<td>endomyocardial biopsy</td>
</tr>
<tr>
<td>FiO₂</td>
<td>fraction of inspired oxygen</td>
</tr>
<tr>
<td>GFR</td>
<td>glomerular filtration rate</td>
</tr>
<tr>
<td>h</td>
<td>hour</td>
</tr>
<tr>
<td>HF</td>
<td>heart failure</td>
</tr>
<tr>
<td>HFPEF</td>
<td>heart failure with preserved ejection fraction</td>
</tr>
<tr>
<td>H-ISDN</td>
<td>hydralazine and isosorbide dinitrate</td>
</tr>
<tr>
<td>HIV</td>
<td>human immunodeficiency virus</td>
</tr>
<tr>
<td>IABP</td>
<td>intra-aortic balloon pump</td>
</tr>
<tr>
<td>ICD</td>
<td>implantable cardioverter defibrillator</td>
</tr>
<tr>
<td>ICU</td>
<td>intensive care unit</td>
</tr>
<tr>
<td>INR</td>
<td>international normalized ratio</td>
</tr>
<tr>
<td>ISDN</td>
<td>isosorbide dinitrate</td>
</tr>
<tr>
<td>i.v.</td>
<td>intravenous</td>
</tr>
<tr>
<td>JVP</td>
<td>jugular venous pressure</td>
</tr>
<tr>
<td>LBBB</td>
<td>left bundle branch block</td>
</tr>
<tr>
<td>LV</td>
<td>left ventricular</td>
</tr>
<tr>
<td>LVAD</td>
<td>left ventricular assist device</td>
</tr>
<tr>
<td>LVEF</td>
<td>left ventricular ejection fraction</td>
</tr>
<tr>
<td>MI</td>
<td>myocardial infarction</td>
</tr>
<tr>
<td>mg</td>
<td>milligrams</td>
</tr>
<tr>
<td>mmHg</td>
<td>millimetres of mercury</td>
</tr>
<tr>
<td>mmol</td>
<td>millimol</td>
</tr>
<tr>
<td>MR</td>
<td>mitral regurgitation</td>
</tr>
<tr>
<td>ms</td>
<td>millisecond</td>
</tr>
<tr>
<td>ng/mL</td>
<td>nanograms per millilitre</td>
</tr>
<tr>
<td>NIPPV</td>
<td>non-invasive positive pressure ventilation</td>
</tr>
<tr>
<td>NIV</td>
<td>non-invasive ventilation</td>
</tr>
<tr>
<td>NNT</td>
<td>number needed to treat</td>
</tr>
<tr>
<td>NSAID</td>
<td>non-steroidal anti-inflammatory drug</td>
</tr>
<tr>
<td>NTG</td>
<td>nitroglycerine</td>
</tr>
<tr>
<td>NT-proBNP</td>
<td>N-terminal pro B-type natriuretic peptide</td>
</tr>
<tr>
<td>NYHA</td>
<td>New York Heart Association</td>
</tr>
<tr>
<td>o.d.</td>
<td>once a day</td>
</tr>
<tr>
<td>PAC</td>
<td>pulmonary artery catheter</td>
</tr>
<tr>
<td>PCI</td>
<td>percutaneous coronary intervention</td>
</tr>
<tr>
<td>PDEI</td>
<td>phosphodiesterase inhibitor</td>
</tr>
<tr>
<td>PEEP</td>
<td>positive end-expiratory pressure</td>
</tr>
<tr>
<td>PET</td>
<td>positron emission tomography</td>
</tr>
<tr>
<td>pCO₂</td>
<td>partial pressure of carbon dioxide</td>
</tr>
<tr>
<td>PCWP</td>
<td>pulmonary capillary wedge pressure</td>
</tr>
<tr>
<td>pH</td>
<td>acid-base balance</td>
</tr>
<tr>
<td>pg</td>
<td>picograms</td>
</tr>
<tr>
<td>p.o.</td>
<td>oral</td>
</tr>
<tr>
<td>RCM</td>
<td>restrictive cardiomyopathy</td>
</tr>
<tr>
<td>RCTs</td>
<td>randomized clinical trials</td>
</tr>
<tr>
<td>RRR</td>
<td>relative risk reduction</td>
</tr>
<tr>
<td>RV</td>
<td>right ventricular</td>
</tr>
<tr>
<td>S3</td>
<td>gallop heart sound</td>
</tr>
<tr>
<td>SBP</td>
<td>systolic blood pressure</td>
</tr>
<tr>
<td>SPECT</td>
<td>single photon emission tomography</td>
</tr>
<tr>
<td>STEMI</td>
<td>ST-segment elevation myocardial infarction</td>
</tr>
<tr>
<td>SvO₂</td>
<td>mixed venous oxygen saturation</td>
</tr>
<tr>
<td>t.i.d.</td>
<td>three times a day</td>
</tr>
<tr>
<td>TDI</td>
<td>tissue Doppler imaging</td>
</tr>
<tr>
<td>TOE</td>
<td>transoesophageal echocardiography</td>
</tr>
<tr>
<td>TR</td>
<td>tricuspid regurgitation</td>
</tr>
<tr>
<td>μmol</td>
<td>micromole</td>
</tr>
<tr>
<td>V</td>
<td>vasopressin receptor</td>
</tr>
<tr>
<td>VA</td>
<td>ventricular arrhythmia</td>
</tr>
<tr>
<td>VE/VCO₂</td>
<td>minute ventilation/carbon dioxide production</td>
</tr>
<tr>
<td>VHD</td>
<td>valvular heart disease</td>
</tr>
<tr>
<td>VO₂</td>
<td>oxygen consumption</td>
</tr>
<tr>
<td>VT</td>
<td>ventricular tachycardia</td>
</tr>
<tr>
<td>VVI</td>
<td>right ventricular pacing</td>
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</table>


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