Age and the cardiovascular system

HU Rehman

Congestive heart failure is a common cause of morbidity and mortality in the elderly population. Important changes occur in the structure and function of the cardiovascular system with advancing age. An understanding of these changes is vital for optimum management of these patients.

Cardiovascular disease contributes to a great deal of morbidity and is the most common cause of death among older people (Wei and Gersh, 1987). The prevalence of congestive cardiac failure (CCF) increases from 1% in the 50–59-year-old age group to 10% in those aged 80–89 years (Kannel and Belanger, 1991). The incidence also increases with age. Understanding the physiological changes that occur to the cardiovascular system with advancing age is important for the optimum management of these patients.

When examining the physiology of ageing, it is often extremely difficult to separate the effects of disease and lifestyle from those of ageing. This review will concentrate on the physiological changes associated with ageing and the management of chronic heart failure (CHF) in elderly people, paying particular attention to diastolic heart failure.

MORPHOLOGICAL CHANGES

Even in the absence of hypertension or coronary artery disease, degenerative changes in cardiac structure and function occur with age. In the absence of concomitant cardiovascular disease, these changes do not produce CHF. However, such changes may predispose elderly patients to CHF in the presence of hypertension or coronary heart disease.

The size of the myocytes increases with age, causing degenerative processes such as lipid deposition, tubular dilatation and lipofuscin deposition. Alongside this there is a progressive age-related loss of myocytes (Olivetti et al, 1991). The hypertrophy of the myocytes seems to be a compensatory process to the loss of cardiomyocytes. The number of pacemaker cells in the sinus node markedly decreases, which may be the reason for the high prevalence of sick sinus syndrome in the elderly population (Wei and Gersh, 1987). Fibrous tissue in the internodal tracts increases to a lesser extent.

Left atrial dimension increases with age, and the left ventricular wall may show a slight increase in thickness (Olivetti et al, 1991). Amyloid deposits are scattered throughout the myocardium (Lie and Hammond, 1988), and the valves (especially the mitral annulus and the aortic valve) show fibrosis and calcification, although this is usually not sufficient to cause functional impairment (Lie and Hammond, 1988). Nearly 50% of patients over 70 years of age have detectable amyloid in the cardiovascular system, and the incidence rises sharply thereafter. Cardiac amyloidosis is, however, a rare cause of heart disease, and whether cardiac amyloidosis is part of normal ageing is debatable. There are two immunologically distinct forms of senile amyloidosis: one is limited to the atria and the other to the ventricles.

The aorta becomes dilated and elongated. The endothelial cells in the intima of coronary arteries become more heterogeneous in size, shape and axial orientation. The thickness of the subendothelial layer increases, as does its calcium, connective tissue and lipid content. There are changes in the amount and nature of elastin and collagen. Glycoprotein gradually disappears from the elastin fibrils, which become frayed (Lakatta, 1995). The smooth muscle in the media thickens and calcification increases. These changes result in increased stiffness of the vessel wall and occur in the left coronary artery long before the right coronary and the posterior descending arteries (Yin, 1980) (*Table 1*).

Dr HU Rehman is Specialist Registrar in the Department of Medicine, Hull Royal Infirmary, Hull HU3 2JZ

TABLE 1.
Morphological changes in the cardiovascular system associated with ageing

Loss of myocytes
Myocyte hypertrophy
Loss of pacemaker cells in the sinus node
Amyloid deposits
Fibrosis of valves and conduction system
Intimal endothelial cell changes
Changes in the amount and nature of vascular collagen
Thickening of the smooth muscle in the media

FUNCTIONAL CHANGES

In normotensive subjects with no indication of coronary heart disease, there is no age-related decline of the ejection fraction and cardiac output at rest and during exercise (Lakatta, 1993b). The moderate increase in afterload is adequately compensated by left ventricular hypertrophy and an increase in left ventricular end-diastolic volume (Van Tosh et al, 1986). During strenuous aerobic exercise, the stroke volume is preserved as the dilated left ventricle contracts more vigorously, according to the Frank–Starling mechanism.

Endurance exercise training enhances early diastolic filling at rest and during exercise in both the old and the young. This may be an important adaptation to allow an increase in stroke volume, cardiac output and maximal oxygen consumption during exercise (Levy et al, 1993). There is a decrease in maximum achievable heart rate during physical exercise (Shannon et al, 1986), suggesting compensation for an age-related reduction in sensitivity to catecholamines (Tzankoff et al, 1980). Reduced early diastolic ventricular filling (Manning et al, 1991), increased afterload and prolonged myocardial relaxation (Wei et al, 1984), are age-related changes. There is more ventricular filling in the later part of the diastole, to compensate for the reduced early filling. This is accomplished by a more vigorous atrial contraction and is manifested on auscultation as a fourth heart sound (Lakatta, 1995).

Basal contractile function is well maintained. The combination of prolonged myocardial relaxation time and increased stiffness of the myocardium, caused by increased interstitial fibrosis, result in reduced ventricular filling. This contributes to higher left ventricular diastolic pressures at rest and during exercise (Wei, 1990). Hypertrophy of cardiac myocytes is associated with a prolongation of calcium transient (movement of calcium ions across the cell membrane), which results from a decreased concentration of the enzyme responsible for reuptake of calcium in the sarcoplasmic reticulum, thus causing a prolongation of the excitation–contraction coupling cycle (Lakatta, 1993a).

In one study, diastolic filling was dramatically altered with ageing (Pearson et al, 1991). The elderly subjects in this study also demonstrated a doubling of percent atrial contribution to the stroke volume, thus emphasizing the importance of maintaining sinus rhythm in older people. This is important clinically, as it may cause signs and symptoms of heart failure despite a normal systolic function (Luchi et al, 1982). Diastolic abnormalities usually precede the development of systolic abnormalities (*Table 2*).

Elderly people are more susceptible to small changes in plasma volume because of the increased stiffness of the vessel wall (Shannon et al, 1986). There is an attenuated inotropic response to sympathetic stimulation (Lakatta et al, 1975) and cardiac glycosides. Baroreceptor reflex function is attenuated, as suggested by diminished heart rate and blood pressure response to head-up tilt, the Valsalva manoeuvre, the cold pressor test (Romero-Vecchione et al, 1993) and static exercise (Gribbin et al, 1971; Smith et al, 1981).

A combination of reduced beta-adrenoceptor responsiveness and reduced baroreflex function makes older people more sensitive to the therapeutic and postural hypotensive effects of diuretics and vasodilators. There is a gradual decline in β_1-adrenergic receptor density with age (White et al, 1994), but no change in β_2-adrenergic receptor density. Beta-adrenoceptor desensitization is thought to be the mechanism behind the decreased β-adrenoceptor response.

This age-related decrease in β-adrenoceptor responsiveness is related to changes in G-protein function (Ferrara et al, 1997). It has been shown in rats that the diminution of the cardiac response to sympathetic and vagal stimulation during ageing may be partly explained by a decrease in corresponding receptor density: these changes are reversible and the density of these two groups of receptors can return to adult control values following chronic administration of the appropriate antagonist (Chevalier et al, 1991). This may explain why beta-blocker therapy is effective in CHF as shown in recent trials (Lechat et al, 1998). Spontaneous variations in heart rate are less pronounced, including sinus arrhythmia.

There is diminished heart rate variability in older age groups (Jensen-Urstad et al, 1997). Plasma noradrenaline concentration increases and plasma renin, angiotensin II and aldosterone concentrations decrease with advancing age (Tsunoda et al, 1986). Plasma atrial natriuretic peptide concentrations increase with age (Clark et al, 1991), and may in part be responsible for the suppressed renin and aldosterone levels found in older people.

Elderly people are prone to syncope caused by postural change because of inadequate or delayed cardiovascular reflexes. For example, postprandial hypotension can be substantial in the elderly, while no change in blood pressure occurs in the young (Lipsitz et al, 1983). This is because the left ventricular ejection fraction increases to a lesser extent, as the reduction in left ventricular end-systolic volume during exercise is blunted (Lakatta, 1994). Endurance exercise training induces an enhancement of left ventricular systolic function in response to an afterload stress in older healthy men (Spina et al, 1997).

CLINICAL IMPLICATIONS

CCF is a common problem in the elderly population. The pathophysiology of CCF is different in elderly patients than in middle-aged subjects. In CCF resulting from systolic dysfunction, peripheral mechanisms are less able to compensate for the decline in left ventricular performance caused by deconditioning of the skeletal muscles, decreased vasodilatory response to exercise, and reduced capacity to excrete sodium (Bijou et al, 1993). Diastolic dysfunction is the primary cause of heart failure in the older patient. Over 50% of elderly patients with heart failure have normal systolic function (Rich, 1997). Since myocardial relaxation requires more oxygen than myocardial contraction, and arterial oxygen tension declines with age, relaxation is more vulnerable to hypoxia, even in the absence of coronary artery disease. It is important to be aware of this as treatment of diastolic dysfunction differs from that of systolic dysfunction.

Other factors contributing to diastolic dysfunction are myocardial ischaemia (Barry et al, 1974; Carroll et al, 1983), myocardial fibrosis (Gaasch et al, 1976; Grossman, 1991), left ventricular hypertrophy (Lorell and Grossman, 1987) and left ventricular pressure overload (Gaasch et al, 1980). Since arterial stiffness increases with age, the prevalence of hypertension and ischaemic heart disease increases in elderly people, making them more susceptible to developing diastolic heart failure.

Abnormal diastolic function causes symptoms of dyspnoea and fatigue secondary to an inadequate increase in cardiac output, because with decreased ventricular compliance, the ability to increase stroke volume via increased preload may be limited. During exercise left ventricular diastolic pressure rises rapidly, reflecting back to the left atrium and producing pulmonary venous congestion. Patients with abnormal relaxation are also more sensitive to shortening of the diastolic filling that occurs with increasing heart rate.

In severe CHF, the activity of the sympathetic nervous system increases in response to the

TABLE 2.
Functional changes associated with ageing of the cardiovascular system

Normal ejection fraction
Normal cardiac output
Decreased maximal achievable heart rate
Increased left ventricular end-diastolic volume
Reduced early diastolic ventricular filling
Increased afterload
Prolonged myocardial relaxation
Attenuated inotropic response to sympathetic stimulation
Attenuated baroreflex function
Decline in maximal oxygen uptake
Decline in β_1-adrenergic receptor density
Increased plasma noradrenaline concentrations
Reduced plasma renin, angiotensin II and aldosterone concentrations
Increased plasma atrial natriuretic peptide concentrations

reduced cardiac output as an adaptive mechanism to maintain pressure. Although this increased sympathetic activity may be initially helpful for the chronically failing heart, it can lead to a desensitization of β-adrenergic receptors. The number of cardiac β-adrenoceptors is decreased in the failing human heart (Brodde et al, 1989), which may be a result of the high levels of plasma norepinephrine. In the failing human heart there is also a selective decline in β-adrenergic receptors, which is what occurs in the ageing heart. This results in a reduction in the effectiveness of β-adrenergic modulation of heart rate and myocardial contractility in healthy older humans as well as in those with CHF.

DIAGNOSIS AND MANAGEMENT

Hypertension and coronary heart disease are the commonest causes of CCF in the aged, as in other age groups. Valvular heart disease is a relatively uncommon cause. Calcific aortic stenosis is the commonest valvular disease causing heart failure in older people, followed by mitral regurgitation.

Clinical diagnosis of heart failure in older patients may be difficult because of the absence of typical symptoms and physical findings. At rest, patients may complain of symptoms of low cardiac output, e.g. weakness, fatigue and tiredness. The resulting lack of exercise will prevent dyspnoea being an early symptom. Reduced cerebral perfusion caused by a low cardiac output may produce confusion, falls, blackouts and fits. Cardiac cachexia is common and is caused by a combination of factors, including decreased dietary intake, malabsorption, increased metabolism and iatrogenic factors. Among the clinical signs elevation of the jugular venous pulse and the presence of a third heart sound are more specific. The presence of the fourth heart sound is not a reliable sign of heart failure in the elderly for the reasons stated above.

Clinical assessment and investigation should aim to confirm the diagnosis, define the type of ventricular dysfunction, determine the type of underlying cardiovascular disease and recognize the presence of comorbid conditions.

Left ventricular ejection fraction should be measured in all elderly people with CHF. Underlying causes of CHF should be treated when possible. Elderly people with an abnormal left ventricular ejection fraction should be put on a low sodium diet, diuretics and treated with an angiotensin-converting enzyme inhibitor (ACEI). Renal dysfunction unrelated to renal artery stenosis is not a contraindication to ACEI therapy. Digoxin can be added for its inotropic effects. If CHF still persists, isosorbide dinitrate and hydralazine should be added. This regimen has proved effective on the basis of the Vasodilator Heart Failure Trial (V-HeFT; Loeb et al, 1993). Calcium-channel blockers should not be used.

Angiotensin II type 1 (ATI) receptor antagonists have shown promising results in the treatment of CHF (Anonymous, 1997). They inhibit the renin–angiotensin system more completely than ACEIs, and do not increase bradykinin levels as ACEIs do. The use of β-blockers in the treatment of CHF with abnormal left ventricular ejection fraction is experimental. However, recent trials have shown that addition of β-blockers to a regimen of diuretics and ACEIs can substantially decrease mortality and morbidity for these patients (CIBIS-II Investigators and Committees, 1999).

Diastolic heart failure can be diagnosed only after other factors that may impair ventricular filling, such as constrictive pericarditis or cardiac tamponade, have been excluded. The diagnosis can be made by showing elevated filling pressures in a patient with normal left ventricular volume and preserved systolic function. Doppler flow echocardiography and radionuclide angiography will provide valuable information, but cardiac catheterization remains the best method to evaluate ventricular diastolic properties. Recently the European working group on diastolic heart failure published their recommendations on the diagnosis of diastolic heart failure (Working Group Report, 1998). Three conditions need to be simultaneously satisfied:

1. Presence of signs or symptoms of CCF
2. Presence of normal or mildly abnormal left ventricular systolic function
3. Evidence of abnormal left ventricular diastolic function.

Evidence of abnormal left ventricular diastolic function can consist of:

1. Slow isovolumic left ventricular relaxation and/or
2. Slow early left ventricular filling and/or
3. Reduced left ventricular diastolic distensibility and/or
4. Increased left ventricular chamber stiffness or increased myocardial muscle stiffness.

Commonly used indices of slow isovolumic left ventricular relaxation include:

1. Peak negative left ventricular dP/dt (rate of fall of left ventricular pressure; a value of less than 1100 mmHg/s is considered abnormal)

2. Isovolumic relaxation time — the time interval between aortic valve closures and mitral valve opening — which is age dependent
3. The time constant of left ventricular pressure decay (τ=tau). This is independent of age.

Evidence of slow early left ventricular filling includes peak left ventricular filling rate, which can be measured by a contrast left ventricular angiogram, radionuclide left ventricular angiogram, mitral Doppler flow velocity signal or pulmonary vein Doppler flow velocity signal.

Left ventricular end-diastolic distensibility is reduced when left ventricular end-diastolic pressure or mean pulmonary venous pressure are elevated in the presence of normal left ventricular end-diastolic volume index or normal left ventricular end-diastolic internal dimension index. Increased left ventricular chamber stiffness or myocardial muscle stiffness is the inverse of a change in diastolic left ventricular pressure relative to diastolic left ventricular volume (dV/dP), and can be measured by measuring Doppler mitral inflow deceleration time.

Management of diastolic heart failure includes attention to the potentially reversible processes that contribute to impaired diastolic function. This may involve reduction of arterial blood pressure, reduction of myocardial ischaemia and regression of left ventricular hypertrophy. Diuretics are effective in reducing pulmonary congestion but they should be used cautiously because of the volume sensitivity of these patients. The use of inotropic agents, except ACEIs, is not indicated, as they will cause a fall in blood pressure without a concomitant increase in cardiac output, resulting in tachycardia and salt and water retention. Treatment with digitalis may increase left ventricular stiffness and therefore is not indicated.

Beta-blockers may be efficacious in prolonging the diastolic filling period by indirectly slowing heart rate, reducing myocardial oxygen demand, controlling blood pressure and causing regression of left ventricular hypertrophy. Calcium-channel blocking agents have been shown to improve some parameters of diastolic function in hypertrophic cardiomyopathy, and may be useful in patients with diastolic heart failure. They are the only agents shown to improve symptoms and exercise tolerance in clinical trials (Setaro et al, 1990).

The use of ACEIs in diastolic heart failure has not been extensively studied, but they may be beneficial because of their blood pressure-lowering effects and regression of left ventricular hypertrophy (Schunkert et al, 1990). Local production of angiotensin II in the heart may play an important role in stimulating myocardial fibrosis, which ACEIs may prevent. In patients with atrial fibrillation, electrical or pharmacological cardioversion should be attempted, as these patients, because of decline in early diastolic filling, are particularly dependent on atrial contraction to achieve adequate ventricular filling. The use of antiarrhythmics and anticoagulation agents must be considered on an individual basis.

CONCLUSIONS

More than 10% of very elderly patients have CHF. Age-related changes in the cardiovascular system modify the clinical presentation of the disease and affect its clinical course and prognosis. Among the most notable age-related changes are impaired myocardial relaxation and a diminished responsiveness to β-adrenergic modulation. As many as 50% of elderly patients with heart failure may have normal systolic function and isolated diastolic heart failure, which may be difficult to diagnose. An awareness of this is important for the optimum management of these patients. Continued clinical and basic research is needed for better therapeutic approaches to elderly patients with CHF. HM

Anonymous (1997) New therapeutic principle in the management of cardiac insufficiency. A II antagonists. Results of the ELITE study (Evaluation of losartan in the elderly). *Dtsch Med Wochenschr* **122**(39 Suppl): 1–4

Barry WH, Brooker JZ, Alderman EL, Harrison DC (1974) Changes in diastolic stiffness and tone of the left ventricle during angina pectoris. *Circulation* **49:** 255–63

Bijou R, LeJemtel TH, Sonnenblik EH (1993) From left ventricular dysfunction to heart failure in the elderly patient. *Am J Geriatric Cardiol* **2(1):** 14–27

Brodde OE, Zerkowski HR, Doetsch N et al (1989) Myocardial beta-adrenoceptor changes in heart failure: Concomitant reduction in beta-1 and beta-2 adrenoceptor function related to the degree of heart failure in patients with mitral valve disease. *J Am Coll Cardiol* **14:** 323–31

Carroll JD, Hess OM, Hirzel HO, Krayenbuehl HP (1983) Exercise-induced ischaemia: the influence of altered relaxation on early diastolic pressures. *Circulation* **67:** 521–8

Chevalier B, Mansier P, Teiger E, Callens-El Amrani F, Swynghedauw B (1991) Alterations in beta adrenergic and muscarinic receptors in aged rat heart. Effects of chronic administration of propranolol and atropine. *Mech Ageing Dev* **60(2):** 215–24

CIBIS-II Investigators and Committees (1999) The cardiac insufficiency bisoprolol study II: a randomised trial. *Lancet* **353**: 9–13

Clark BA, Elahi D, Shanon RP, Wei JY, Epstein FH (1991) Influence of age and dose on the end-organ responses to atrial natriuretic peptide in humans. *Am J Hypertens* **4:** 500–7

Ferrara N, Davia K, Abete P, Rengo F, Harding SE (1997) Alterations in beta-adrenoceptor mechanisms in the aging heart. Relationship with heart failure. *Aging* **9(6):** 391–403

Gaasch WH, Levine HJ, Quinones MA, Alexander JK (1976) Left ventricular compliance: Mechanisms and clinical implications. *Am J Cardiol* **38:** 645–53

Gaasch WH, Blaustein AS, Andrias CW, Donahue RP, Avitall B (1980) Myocardial relaxation. II. Hemodynamic determinants of rate of left ventricular pressure decline. *Am J*

Physiol **239:** H1–6
Gribbin B, Pickering TC, Sleight P, Peto R (1971) Effect of age and high blood pressure on baroreflex sensitivity in man. *Circ Res* **29:** 424–31
Grossman W (1991) Diastolic dysfunction in congestive heart failure. *N Engl J Med* **325:** 1557–64
Jensen-Urstad K, Storck N, Bouvier F, Ericson M, Lindblad LE, Jensen-Urstad M (1997) Heart rate variability in healthy subjects is related to age and gender. *Acta Physiolog Scand* **160(3):** 235–41
Kannel WB, Belanger AJ (1991) Epidemiology of heart failure. *Am Heart J* **121:** 951–7
Lakatta EG (1993a) Myocardial adaptations in advanced age. *Basic Res Cardiol* **88**(Suppl 2): 125–33
Lakatta EG (1993b) Cardiovascular regulatory mechanisms in advanced age. *Physiol Rev* **73:** 413–67
Lakatta EG (1994) Cardiovascular reserve capacity in healthy older humans. *Aging* **6(4):** 213–23
Lakatta EG (1995) Normal changes of aging. In: Abrams WB, Beers MH, Berkow R, eds. *Merck Manual of Geriatrics.* Merck, Whitehouse Station, NJ: 425–40
Lakatta EG, Gerstenblith G, Angell CS, Shock NW, Weisfeldt ML (1975) Diminished inotropic response of aged myocardium to catecholamines. *Circ Res* **36:** 262–9
Lechat P, Packer M, Chalon S, Cucherat M, Arab T, Biossel JP (1998) Clinical effects of beta-adrenergic blockade in chronic heart failure: a meta-analysis of double-blind, placebo-controlled, randomized trials. *Circulation* **98(12):** 1184–91
Levy WC, Cerqueira MD, Abrass IB, Schwartz RS, Stratton JR (1993) Endurance exercise training augments diastolic filling at rest and during exercise in healthy young and older men. *Circulation* **88:** 116–26
Lie JT, Hammond PI (1988) Pathology of the senescent heart: anatomic observations on 237 autopsy studies of patients 90 to 105 years. *Mayo Clin Proc* **63:** 552–64
Lipsitz LA, Nyquist RP Jr, Wei JY, Rowe JW (1983) Postprandial reduction in blood pressure in the elderly. *N Engl J Med* **309:** 81–3
Loeb HS, Johnson G, Henrick A et al (1993) Effect of enalapril, hydralazine plus isosorbide mononitrate, and prazosin on hospitalization in patients with chronic congestive heart failure. The V-HeFT VA Cooperative Studies Group. *Circulation* **87**(6 Suppl): V178–87
Lorell BH, Grossman W (1987) Cardiac hypertrophy: the consequences for diastole. *J Am Coll Cardiol* **9:** 1189–93
Luchi RJ, Snow E, Luchi JM, Nelson CL, Pircher FJ (1982) Left ventricular function in hospitalized geriatric patients. *J Am Geriatr Soc* **30:** 700–5
Manning WJ, Shannon RP, Santinga JA et al (1991) Reversal of changes in left ventricular diastolic filling associated with normal aging using diltiazem. *Am J Cardiol* **67:** 894–6
Olivetti G, Melissari M, Capasso JM, Anversa P (1991) Cardiomyopathy of the aging human heart: myocyte loss and reactive cellular hypertrophy. *Circ Res* **68:** 1560–8
Pearson AC, Gudipati CV, Labovitz AJ (1991) Effects of aging on left ventricular structure and function. *Am Heart J* **121**(3 Pt 1): 871–5
Romero-Vecchione E, Wessolosky M, Lupi J, Vasquez J, Velasco M, Gomez J (1993) Changes produced by age in cardiovascular reflex responses. *Investigacion Clinica* **34:** 193–208
Schunkert H, Dzau VJ, Tang SS, Hirsch AT, Apstein CS, Lorell BH (1990) Increased rat cardiac angiotensin converting enzyme activity and mRNA expression in pressure overload hypertrophy: effects on coronary resistance, contractility, and relaxation. *J Clin Invest* **86:** 1913–20
Setaro J, Zaret BL, Schulman DS et al (1990) Usefulness of verapamil for congestive heart failure associated with abnormal left ventricular diastolic performance. *Am J Cardiol* **66(12):** 981–6
Shannon RP, Wei JY, Rosa RM, Epstein FH, Rowe JW (1986) The effect of age and sodium depletion on cardiovascular response to orthostasis. *Hypertension* **8:** 438–43
Smith JJ, Ebert TJ, Tristani FE, Porth CJ, Stekiel WJ, Barney JA (1981) Effect of age and coronary artery disease on autonomic responses to circulatory stress. *Adv Physiol Sci* **9**(Cardiovasc physiol): 357–65
Spina RJ, Turner MJ, Ehsani AA (1997) Exercise training enhances cardiac function in response to an afterload stress in older men. *Am J Physiol* **272**(2 Pt 2): H995–1000
Tsunoda K, Abe K, Goto T et al (1986) Effect of age on the renin-angiotensin-aldosterone system in normal subjects: simultaneous measurement of active and inactive renin, renin substrate, and aldosterone in plasma. *J Clin Endocrinol Metab* **62:** 384–9
Tzankoff SP, Fleg JL, Norris AH, Lakatta EG (1980) Age-related increase of plasma catecholamines in response to dynamic exercise in healthy adult men. *Physiologist* **23:** 50
Wei JY (1990) Congestive heart failure. In: Abrams WB, Berkow R, eds. *Merck Manual of Geriatrics.* Merck, West Point, NY: 380–6
Wei JY, Gersh BJ (1987) Heart disease in the elderly. *Curr Probl Cardiol* **12:** 1–65
Wei JY, Spurgeon HA, Lakatta EG (1984) Excitation-contraction in rat myocardium: alterations with adult aging *Am J Physiol* **246:** H784–H791
White M, Roden R, Minobe W et al (1994) Age-related changes in β-adrenergic neuroeffector systems in the human heart. *Circulation* **90(3):** 1225–38
Working Group Report (1998) How to diagnose diastolic heart failure. European Study Group on diastolic heart failure. *Eur Heart J* **19:** 990–1003
Yin FCP (1980) The aging vasculature and its effects on the heart. In: Weisfeldt ML, ed. *The Aging Heart: its Function and Response to Stress.* Aging. Vol. 12. Raven Press, New York: 137–214
Van Tosh A, Lakatta EG, Fleg JL et al (1986) Ventricular changes during submaximal exercise: effect of aging in normal man. *Circulation* **62**(4;Pt II): 111–29

KEY POINTS

- Cardiovascular disease is the most common cause of death among older people.
- Over 50% of elderly patients with chronic heart failure have normal systolic function.
- Prolonged myocardial relaxation time and increased stiffness of the myocardium result in reduced ventricular filling.
- Elderly people are more susceptible to small changes in plasma volume.
- A combination of reduced beta-adrenoceptor responsiveness and reduced baroreflex function makes older people more sensitive to the therapeutic and postural hypotensive effects of diuretics and vasodilators.
- Treatment of diastolic heart failure has important differences from treatment of systolic heart failure.