Right ventricular involvement in acute myocardial infarction

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The presence of right ventricular dysfunction in patients with acute myocardial infarction has important implications. It is a marker for in-hospital mortality and failure to recognize it may lead to inappropriate treatment with serious consequences for the patient. Patients surviving the acute event do, however, have a relatively good long-term prognosis.

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Involvement of the right ventricular myocardium is not uncommon in patients sustaining myocardial infarction (MI) and represents a distinct clinical syndrome. This article explains how to detect right ventricular involvement in acute MI and discusses the implications for treatment and prognosis.

EPIDEMIOLOGY

Isolated infarction of the right ventricular myocardium is rare. Damage is usually associated with infarction involving the inferior wall of the left ventricle and occurs in approximately one third of these patients (Verani et al, 1985), although it is of haemodynamic significance in probably only a third to one half of this subset (Lopez-Sendon et al, 1983). The presence of right ventricular dysfunction in acute MI had received relatively little attention until the study by Cohn et al (1974).

TABLE 1.
Sequence of events in the pathogenesis of cardiogenic shock when right ventricular involvement complicates acute myocardial infarction

Fall in left ventricular preload	Right ventricular ischaemia
	Right ventricular diastolic dysfunction
	Increased right ventricular end-diastolic pressure
	Decreased right ventricular stroke volume
	Impaired left ventricular filling
	Fall in left ventricular stroke volume
Ventricular interdependence	Right ventricular ischaemia
	Right ventricular diastolic dysfunction
	Right ventricular volume overload
	Displacement of the interventricular septum towards the left ventricle
	Reduction in left ventricular diastolic volume
	Fall in left ventricular stroke volume

PATHOPHYSIOLOGY

The initial insult

The relative absence of involvement of the right ventricle in anterolateral MI can be explained by the coronary anatomy. The majority of the right ventricular myocardium is supplied by branches of the right coronary artery, which in most cases also supply the inferior wall of the left ventricle. Occlusion of the right coronary artery proximal to the marginal branches that perfuse the right ventricular anterior wall is the usual prerequisite for right ventricular involvement. Proximal occlusion of a dominant right coronary artery causes the greatest risk to right ventricular viability (Braat et al, 1984). Occasionally patients with dominance of the left coronary system have right ventricular involvement, with occlusion of the circumflex coronary artery (Isner and Roberts, 1978).

Mechanism of myocardial dysfunction

It is important to recognize that much of the contractile dysfunction of the right ventricle probably represents myocardial stunning rather than infarction, as this has implications for recovery of function, and there is evidence that the right ventricle is relatively resistant to infarction during ischaemic injury. A possible explanation for this is the lower afterload and myocardial mass compared to the left ventricle, with lower myocardial oxygen demand.

Patients with right ventricular hypertrophy are probably more likely to sustain right ventricular MI (Kopelman et al, 1985) and those with pre-infarction angina were shown to be at lower risk in a recent study of patients with inferior MI (Shiraki

et al, 1998), possibly because of more extensive collateralization of the right ventricle from the left coronary system. It has been suggested that diffusion of oxygen from intracavitary blood through the thin wall of the right ventricle may confer myocardial protection (Haupt et al, 1983).

CLINICAL FEATURES

Early experimental studies have suggested that relatively little cardiovascular decompensation resulted from exclusion of the right ventricle from the circulation (Jamison et al, 1954), but this was not confirmed by later work (Pugh and McGoon, 1973), and the importance of the right ventricle became increasingly clear. The earliest description of predominant right ventricular dysfunction in MI was by Cohn et al (1974) who noticed a characteristic haemodynamic profile with signs of a poor cardiac output in the absence of pulmonary congestion. These clinical features, in addition to enzymatic release greater than expected from the clinical impression of left ventricular dysfunction in a patient with inferior MI, should raise the question of right ventricular involvement. In extreme cases the appearances of a supine patient with a raised venous pressure but no breathlessness can be striking. The diagnosis should also be suspected in any patient with inferior MI in whom administration of a vasodilator results in an unexpected fall in systemic blood pressure.

The clinical sequelae vary widely with approximately 60% of patients manifesting no haemodynamic compromise. The sequence of events involved in the deterioration in haemodynamic parameters has not been fully clarified. An important role is thought to be played by a reduced right ventricular stroke volume leading to a fall in left ventricular preload but the contribution of ventricular interdependence (leftward motion of the septum compressing the left ventricle) may have been underestimated. The sequence of events relating to each of these scenarios are described in *Table 1*.

INVESTIGATIONS

Clinical recognition of the presence of right ventricular involvement in MI is inaccurate and clarification may require a more detailed assessment. Determination of the presence or absence of haemodynamically significant right ventricular involvement in MI has traditionally depended on invasive monitoring of right and derived-left heart pressures. This typically reveals a disproportionate elevation of right heart pressures, with a right atrial pressure of 10 mmHg or more and a ratio of right atrial to pulmonary capillary wedge pressure of greater than 0.8. Volume loading further increases the diagnostic sensitivity in these circumstances (Dell'italia et al, 1984). The purpose of non-invasive investigations should be to act as a screening tool for the identification of patients with this clinical syndrome in whom volume loading may be useful in management.

Electrocardiography

The electrocardiographic assessment of involvement of the right ventricle conventionally relies on the recording of right precordial leads. The presence of ST segment elevation in lead V4R during the acute phase of inferior MI suggests right ventricular involvement (*Figure 1*). The

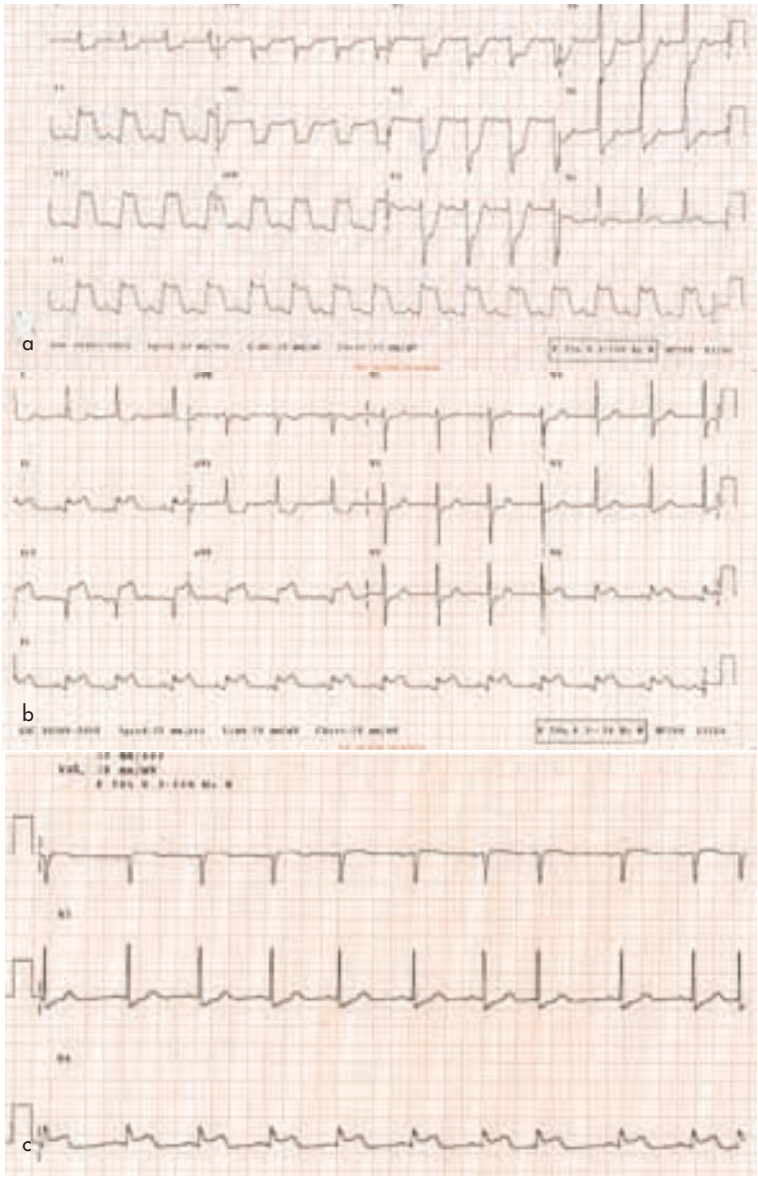

Figure 1. Electrocardiographic appearances of acute inferior myocardial infarction. a. Significant anterior ischaemia (note reciprocal anterior ST segment depression V2–V6). b and c. Right ventricular involvement (note ST segment elevation in lead V4R).

sensitivity of these changes is high but specificity may be lower than 70% because of the proportion of patients with anterior left ventricular MI who manifest these changes (Lopez-Sendon et al, 1985). In this study ST segment elevation in leads V1–V3 was consistently greater than that found in V4R in patients without right ventricular involvement. The criterion of electrocardiographic changes in the right precordial leads greater than in V1–V3 gives the best combination of sensitivity and specificity for clinical decision making. It is likely that the combined assessment of leads V4R–V6R is a better indicator of right ventricular involvement than lead V4R alone (Croft et al, 1982). ST segment elevation in the right precordial leads must be sought early in the clinical course of patients presenting with inferior MI as it may resolve.

Echocardiography

The echocardiographic assessment of right ventricular function poses certain specific problems. Because of the complex geometry of the right ventricular cavity, with inflow, body and infundibular outflow portions, the accurate assessment of volume is difficult. More advanced ultrasound techniques such as three-dimensional imaging allow accurate anatomical information to be derived but are unlikely to be practically applicable in the acute setting. Nevertheless, if significant right ventricular dilatation is present it can usually be demonstrated by simple M-mode and two-dimensional imaging (*Figure 2*).

Two-dimensional imaging allows the identification of right ventricular regional wall motion abnormalities and paradoxical septal movement, both of which are common with right ventricular systolic dysfunction (Lorell et al, 1979). These features are seen more frequently than the characteristic haemodynamic abnormalities measured by right heart catheterization and hence identify patients with subclinical right ventricular dysfunction.

Echocardiography is the investigation of choice in distinguishing between right ventricular dysfunction and pericardial tamponade — a distinction which may be difficult to make on clinical grounds. The presence of tricuspid regurgitation can readily be determined by colour flow mapping and allows the estimation of right ventricular systolic pressure. Doppler echocardiographic indices of right ventricular diastolic function, such as transtricuspid flow velocity patterns, may be useful in detecting the haemodynamic abnormalities in patients with right ventricular involvement in MI (Isobe et al, 1987), but this approach is technically demanding and has not become accepted into widespread clinical practice.

Other techniques

The combination on radionuclide ventriculography of a right ventricular ejection fraction of less than 40% and regional wall motion abnormality has been shown to be highly predictive for the presence of haemodynamically significant right ventricular involvement in acute MI (Starling et al, 1984). However, ejection fraction estimations by this technique are subject to inter-observer variability to some degree and do not distinguish between myocardial ischaemia and infarction.

Myocardial perfusion scintigraphy has been used to detect the presence of right ventricular infarction but the specificity is reported to be disappointingly low (Starling et al, 1984). The main weakness of any nuclear technique is that it is impractical for clinical application in the acutely ill patient in the coronary care environment where it would be most likely to impact significantly on management.

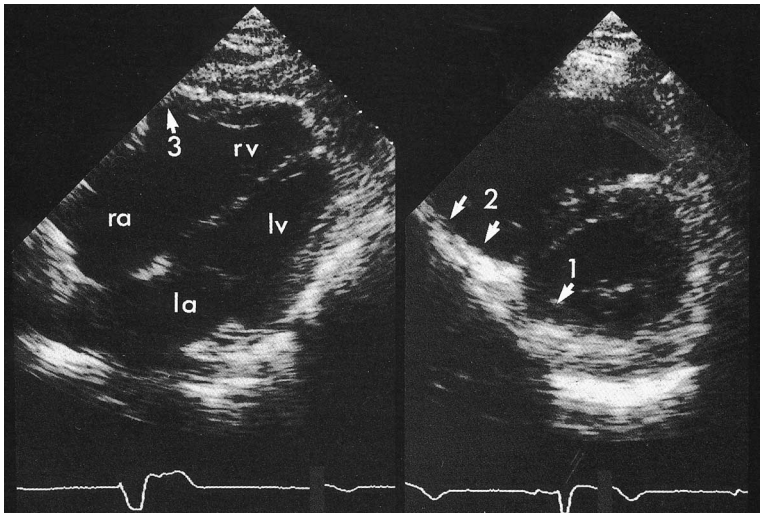

Figure 2. Two-dimensional echocardiogram demonstrating right ventricular dysfunction. There is an infarct of the inferior wall of the left ventricle (1) with thinning and akinesis of the adjacent part of the right ventricle (2) The base of the right ventricular free wall (3) is also affected.

COMPLICATIONS

In addition to causing potentially reversible cardiogenic shock, right ventricular involvement in acute MI is associated with characteristic complications (*Table 2*). Because of the relative thinness of the anterior free wall of the right ventricle it is disproportionately susceptible to rupture, resulting in cardiac tamponade which may be rapidly fatal. Venous stasis in a dilated right ventricle with poor systolic performance may put the patient at risk of pul-

monary thromboembolism. In the event of the development of a bradyarrhythmia necessitating transvenous cardiac pacing, difficulties may be encountered. Ventricular tachyarrhythmias can occur during catheter manipulation and a high pacing threshold frequently has to be accepted. Sensing failure is an additional problem in these patients. Tricuspid regurgitation is common and related to papillary muscle ischaemia or tricuspid ring dilatation as the right ventricle enlarges.

RIGHT VENTRICULAR INVOLVEMENT AND PROGNOSIS

A strong body of evidence has evolved to suggest that right ventricular dysfunction is an important prognostic factor in inferior MI. The risk of in-hospital mortality in the presence and absence of right ventricular involvement was reported to be 31% and 6% respectively in one study (Zehender et al, 1993). In the elderly, electrocardiographic evidence of right ventricular involvement in inferior MI is associated with at least a four-fold increase in in-hospital mortality.

The presence of right ventricular dilatation on echocardiography further risk stratifies those patients with electrocardiographic changes. Cardiogenic shock and the requirement for temporary transvenous cardiac pacing are more common in patients with right ventricular dilatation. The presence of impaired right ventricular systolic function confers an adverse prognosis independent of infarct location, because in patients with widespread myocardial damage the involvement of both ventricles suggests the presence of widespread coronary disease, which in itself is an adverse prognostic factor.

There is, however, a spontaneous improvement in global and regional right ventricular function over time in a large proportion of patients and this portends a more favourable long-term prognosis. The poor long-term outlook for those presenting with shock in association with left ventricular infarction is, therefore, not applicable to patients with predominant right ventricular dysfunction. The latter is less commonly predictive of irreversible myocardial damage as the initial depression of right ventricular function may be a manifestation of myocardial stunning rather than true infarction. Indeed, in the original study by Cohn et al (1974), recovery from shock was usual with near normal right heart pressures on assessment 3 months post-MI.

In another group of patients there is a discrepancy in the natural history of the condition, with persistent severe depression of right ventricular function. These individuals may represent a different population in terms of pathophysiology in that they have sustained true transmural right ventricular infarction with irreversible myocardial necrosis, and the long-term prognosis in these patients is less favourable.

TREATMENT

Thrombolysis

The timely reperfusion of threatened myocardium is particularly important in this group of patients. Successful reperfusion is associated with a significantly lower incidence of in-hospital mortality and death (Bowers et al, 1998), and there is evidence that angiographic evidence of reperfusion is a marker for haemodynamic improvement (Kinn et al, 1995).

The determination of the existence of right ventricular involvement in a patient with inferior MI is a useful means of risk stratification and can be applied in decision making with regard to thrombolysis, particularly in those patients in whom relative contraindications to treatment are present. In fact, Zehender et al (1994) showed that, in terms of in-hospital complications and mortality, no benefit from thrombolysis was conferred to patients with inferior infarction in the absence of right ventricular involvement. In patients with failure of reperfusion, recovery of right ventricular function ultimately does occur in most cases, providing the patient survives the acute stage of the illness.

Management of shock

In addition to thrombolysis it is important to consider the adjunctive management in the subgroup of patients who develop cardiogenic shock in the context of right ventricular infarction, because it can usually be reversed in the majority of patients. The recognition of right ventricular involvement is of clinical value because the excessive use of diuretics and/or vasodilators to reduce the raised venous pres-

TABLE 2.
Complications of right ventricular involvement in acute myocardial infarction

Cardiogenic shock as a result of low left ventricular filling pressure
Right ventricular free wall rupture
Posterior ventricular septal rupture
Tricuspid regurgitation
Pulmonary embolus
Difficulties during transvenous pacing (poor capture/sensing, increased propensity to ventricular arrhythmias during pacing catheter manipulation)

sure will cause a progressive fall in left ventricular filling pressure and worsening systemic hypotension. This treatment is at best unhelpful and may be extremely deleterious to some patients.

Identification of right ventricular involvement will enable the clinician to avoid such inappropriate therapy and prompt the consideration for invasive haemodynamic assessment. Conventional early treatment for haemodynamic compromise in this context is volume loading, and invasive monitoring is useful in assessing the response to fluid administration. Fluid loading helps to correct the low output state by improving left ventricular filling pressure. Inotropic agents are likely to be required if the systolic blood pressure is not consistently above 90 mmHg with an adequate urine output despite these initial measures.

CONCLUSIONS

The right ventricle is often involved in acute inferior MI. Right ventricular involvement is indicated by the presence of ST segment elevation in the right-sided precordial leads on electrocardiography and right ventricular wall motion abnormalities on transthoracic echocardiography. In the presence of systemic hypotension, echocardiography should be performed if available. The clinical features are distinct from left ventricular infarction and the implications for acute management and long-term prognosis are important. HM

Figure 2 *is reproduced by kind permission of Parthenon Publishing Group and J Chambers from Chambers (1996).*

KEY POINTS

- Involvement of the right ventricle occurs in approximately one third of patients with acute inferior myocardial infarction but is clinically apparent in less than a half of cases.
- It is associated with a characteristic clinical syndrome and an increased in-hospital mortality.
- Right ventricular infarction is a misnomer in the majority of cases since right ventricular dysfunction is usually associated with myocardial stunning without true tissue necrosis and the natural history is frequently a spontaneous recovery of function.
- The diagnosis should be suspected by recording ST segment elevation more prominent in the right sided than the left sided precordial leads and confirmed if possible by echocardiography.
- Recognition is important in order to avoid inappropriate treatment which may lead to progressive haemodynamic deterioration and to identify that if cardiogenic shock is present it is probably reversible.

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