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Complications of Myocardial Infarction and Postinfarction Care

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RISK STRATIFICATION

Knowledge of the probable outcome after myocardial infarction (MI) is important in formulating an appropriate plan of management, as with ST elevation MI versus non-ST elevation MI (non-Q-wave MI). The following information on risk stratification is relevant to decision making.

Acute MI in-hospital mortality is about 12–14% (Table 2.1.). Several characteristics alter the in-hospital and postdischarge mortality:

- Age over 70.
- Prior MI, angina, or heart failure (HF) is associated with a twofold or greater increase in mortality.
- Non-ST elevation MI, in contrast to ST elevation MI, has a lower in-hospital mortality (about 2%) but a threefold higher incidence of reinfarction within the following 3 months, and angina occurs in 33–66% of patients during the first year postdischarge;
- On admission to the hospital, 40–50% of patients with ST elevation MI have mild-to-moderate HF, and the presence of this complication carries a twofold early mortality. Table 2.2. gives comparison outcomes in acute ST elevation MI and non-ST elevation MI (non-Q wave infarction). Overall, increasing age beyond 70 and the degree of HF or reduction in ejection fraction (EF) that relates to the size of infarction are the most telling predictors. Thus, frank pulmonary edema or an EF less than 35% before discharge is most unfavorable.
- Recurrence of ischemic symptoms after day 1 represents an unstable state and carries a high mortality rate if not appropriately managed.

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Table 2.1.
Acute Myocardial Infarction: Mortality Risk Stratification

| <i>Parameters</i> | <i>In hospital</i> | <i>Approximate %</i> | | |
|----------------------------------|--------------------|----------------------|---------------|-----------------|
| | | <i>1 year</i> | <i>3 year</i> | <i>5 year</i> |
| Overall mortality | 12–14 | 10–15 | | 33 ^a |
| Uncomplicated | | | | |
| Anterior infarction | 12 | 15 | 33 | |
| Inferior infarction | 3 | 5 | 12 | |
| Complicated | | | | |
| Anterior infarction | | | | |
| Moderate HF | 30 | 50 | 60 | |
| Cardiogenic shock | 80 | | | |
| Ejection fraction | | | | |
| <30% | 30 | 50 | 60 | |
| 30–40% | 15 | 25 | | |
| 40–50% | 5 | 15 | | |
| >50% | 3 | | | |
| Previous infarct | 25 | 30 | 50 | |
| Postinfarction angina (day 2–10) | 20 | 20 | | |
| Anterior infarct (year) | | | | |
| Age >70 | 25 | | | |
| Age <50 | 7 | | | |

^aunchanged 1960–1969, 1970–1979 (1980–2000 not available).

Table 2.2.
Comparison of Outcomes in Acute ST Elevation MI and Non-ST Elevation MI
(Non-Q-Wave Infarction)

| <i>Parameters</i> | <i>Approximate %</i> | |
|--|----------------------|---------------------|
| | <i>Q-wave</i> | <i>Non-Q-wave</i> |
| Incidence prehospital fatal infarcts | >50 | <10 |
| Incidence in hospital | 80 | 20 ^{a,b} |
| In-hospital mortality | | |
| All patients | 12 (18) | 6 (9) |
| First infarction | 10 (15) | 3 (5) |
| Incidence of moderate/severe heart failure | >20 | <1 |
| Incidence of arrhythmias | High | Low |
| Incidence of postinfarction angina (12 months) | <40 | >60 |
| Reinfarction < 3 months | 6 | 10; 16 ^c |

^a10% in GISSI-2.

^bExcept if previous ST elevation MI.

^cPooled data before the use of aspirin and β -blockers, and diltiazem.

() pooled data, 1962–1988, before thrombolytic therapy and general use of aspirin and β -blockers.

The complications of MI determine prognosis. The outcome can be improved, however, by appropriate pharmacological therapy and by percutaneous coronary intervention (PCI) or coronary artery bypass graft surgery in properly selected patients. The complications of acute MI are listed in Table 2.3.

Table 2.3.
Complications of Myocardial Infarction

| |
|---|
| Heart failure |
| Cardiogenic shock |
| Recurrent/ischemia |
| Angina |
| Reinfarction |
| Early mechanical complications |
| Free-wall rupture |
| Interventricular septal rupture |
| Mitral regurgitation |
| Late mechanical complications |
| Aneurysm |
| Electrical |
| Ventricular fibrillation |
| Ventricular tachycardia, other tachyarrhythmias |
| Bradyarrhythmias, complete heart block |
| Left ventricular thrombus/embolism |
| Psychological |

HEART FAILURE POSTINFARCTION

The degree of HF is related to the size of the infarction. More than 50% of patients with anterior or anterolateral ST elevation MI shows evidence of mild or moderate HF. Less than 10% of inferior infarcts manifests HF that usually dissipates quickly over 1–2 days. Approximately 25% of patients with extensive inferior infarction is complicated by right ventricular involvement, and these patients often show signs of right-sided pump failure.

Mild-to-moderate left ventricular (LV) failure is observed in approximately 40% of patients admitted with acute infarction and is associated with a twofold increase in mortality. Frank pulmonary edema carries a fivefold mortality increase (Table 2.1). Patients over age 70 with large anterior or anterolateral infarcts complicated by moderate-to-severe HF have a particularly poor prognosis.

Patients with severe HF caused by acute MI have three possible outcomes:

- Relief of pulmonary edema achieved over 1–3 days with the use of morphine, diuretics, nitroglycerin intravenous (IV), and angiotensin-converting enzyme (ACE) inhibitors, plus or minus digoxin when mechanical complications are not present.
- HF refractory to drug therapy as outlined above persists, especially in patients with severe global hypokinesia, LV aneurysm, or mechanical complications.
- Death owing to malignant arrhythmias or mechanical complications.

Pathophysiology

Hemodynamic derangements occur as a result of six major determinants:

- Severe LV systolic dysfunction is usually associated with very large areas of myocardial necrosis, especially when superimposed on an old infarction.
- Significant ventricular diastolic dysfunction plays an important role, especially in patients with large infarcts, right ventricular infarction, old infarcts, or aneurysm.

- Mechanical complications include mitral regurgitation, septal, papillary, or, rarely, free wall rupture. In these situations, global LV function is generally well-preserved; otherwise, the patient would have succumbed at the onset of the complication.
- A variable area of mild myocardial ischemia and “stunned” myocardium usually surround the necrotic myocardium and can influence ventricular contractility and relaxation.
- The exact incidence of painless ischemia among patients with HF in the presence of large infarction is unknown, but appears to play a role within the first 48 hours of infarction. Painless ischemia is amenable to pharmacological intervention with IV nitroglycerin and β -blockade.
- Arrhythmias: atrial fibrillation (AF), atrial flutter, or other STs commonly precipitate or aggravate HF. The fast ventricular response reduces the time for ventricular filling and for coronary perfusion. In addition, the loss of atrial transport function reduces preload, especially important in patients with diastolic dysfunction.

Mild interstitial edema is common during the first 12 hours of infarction and responds to bedrest, oxygen administration, morphine, and the judicious use of furosemide. In contrast to the more severe forms of failure discussed earlier, this situation is not associated with a poor outcome.

In the presence of a normal serum albumin, a pulmonary capillary wedge pressure (PCWP) exceeding 25 mmHg results in pulmonary edema. Reduction of venous tone by nitrates, morphine, or the rapid loss of several hundred milliliters of urine with the aid of diuretics can reduce left atrial pressure by 10–15 mmHg, and thus prevent the formation of further pulmonary edema, provided that ventricular function is not too severely impaired by poor contractility or mechanical pump failure and cardiogenic shock does not supervene.

Factors that may precipitate HF and increase mortality risk in the patient with acute MI include:

- Concomitant therapy with a calcium antagonist: negative inotropic effect, lack of cardioprotection, a fall in blood pressure (BP) and, thus, decreased coronary perfusion.
- Antiarrhythmics, disopyramide, procainamide, and those that have a negative inotropic effect.
- Nonsteroidal anti-inflammatory drugs (NSAIDs).

Therapy

Mild HF: Mild interstitial edema occurs in over 40% of patients with acute MI and responds to bedrest, oxygen, morphine, and judicious use of furosemide.

Furosemide

A dosage of 20 mg IV is used; repetition with care to avoid potassium depletion suffices in the majority of cases.

Diuretic therapy improves symptoms, but excessive volume depletion stimulates the renin angiotensin system and may paradoxically increase myocardial wall stress. It is advisable, therefore, to use a small dose of diuretic along with an ACE inhibitor.

Morphine

A dosage of 4–8 mg IV at a rate of 1 mg/minute is used; repeat, if necessary, at a dose of 2–4 mg/minute. It is important to allay anxiety. Patients at this stage may not complain bitterly of chest pain, but mild discomfort increases apprehension, which must be avoided.

Morphine produces venous dilatation and thus reduces preload; in addition, the drug has a modest but important effect on elevating ventricular fibrillation (VF) threshold. Morphine should be avoided in patients with right ventricular infarction because all drugs that reduce preload are contraindicated in this setting.

Patients with mild HF, as discussed, represent about 25% of patients admitted and have about a 10% mortality rate. They do not require hemodynamic monitoring if they respond over a few hours to appropriate doses of furosemide and morphine. Some of these patients may require low-dose IV dobutamine via a peripheral vein, according to clinical status, before resorting to Swan-Ganz catheterization. In this subset of patients, if there is evidence of hypoperfusion with oliguria and/or a fall in systolic blood pressure (SBP) to less than 100 mmHg or a fall greater than 30 mm from baseline, hemodynamic monitoring is necessary to guide pharmacological intervention.

Severe HF: Patients with severe HF or early shock require the prompt insertion of a balloon flotation catheter. The choice of a pharmacological agent based on hemodynamic parameters is indicated in Table 2.4.

Severe HF and pulmonary edema, with PWCP exceeding 22 mmHg and a low cardiac index of less than 2.2 L/minute/m², carry an in-hospital mortality rate of about 30% (Table 2.1).

Intensive hemodynamic monitoring is essential in patients with severe HF. Large doses of pharmacological agents and combination therapy are usually required:

- 80 mg or more of furosemide in repeated doses if pulmonary edema is present with the wedge pressure greater than 24 mmHg. The subsequent development of hypotension after an IV bolus of furosemide should alert the physician to the possibility of hypovolemia secondary to the diuretic or the presence of right ventricular infarction. Care is required in some patients with severe HF and concomitant cardiogenic shock to maintain a wedge pressure as high as 24 mmHg, provided that fulminant pulmonary edema is absent (*see* Chapter 3).
- IV nitroglycerin is commenced if the SBP is greater than 100 mmHg, PCWP is greater than 20, and right atrial pressure is increased in the absence of right ventricular infarction. Titrate the dose to attain an optimal wedge pressure of 14–18 mmHg without causing a fall in SBP below 95 mmHg or 10% from baseline (Table 4.9).
- A fall in blood pressure is best managed with the use of dobutamine in combination with nitroglycerin. Other inotropes carry no advantages over dobutamine; if severe hypotension is present, dopamine is added.

ACE Inhibitors

- ACE inhibitors are given on the day of admission to all patients with anterior MI, extensive prior infarction, or pulmonary congestion and manifestation of HF in the absence of hypotension (BP < 100 mmHg). If an ACE inhibitor was not administered on day 1, then on day 2 if HF is present and the BP is stable (>100 mmHg), an ACE inhibitor is commenced.
- Ramipril 2.5 mg or captopril may be chosen because of its short half life. A dosage of captopril 3-6 or 6.25-mg test dose is given; observe for 2 hours. If tolerated without a fall in BP, give 6.25 to 12.5 mg twice daily. The dose is titrated slowly up to 25 mg, three times daily to a maximum 50 mg three times daily over the next 5 days, provided that the SBP is greater than 100 mmHg and the serum potassium and serum creatinine remains within normal range

Table 2.4.
Choice of Pharmacological Agents in Patients With Acute Myocardial Infarction Based on Hemodynamic Parameters

| <i>Drug effect</i> | <i>Furosemide</i> | <i>IV nitrates</i> | <i>Dobutamine</i> | <i>Dopamine</i> | <i>Nitroprusside</i> | <i>ACE inhibitors</i> |
|---|-------------------|--------------------|--------------------------------------|---|---|--|
| Preload | ↓ | ↓ | — | ↑ | ↓ | ↓ |
| Afterload | — | Minimal ↓ | Minimal ↓ | ↑ | ↓ | ↓ |
| Sinus tachycardia parameters | No | Yes | Minimal | Yes | Yes | No, minimal |
| Moderate HF | Yes | Yes | Yes, if SBP > 70 ^a | Yes, if SBP < 70 and oliguria (on dobutamine) | SBP > 110 and > 6 hours ^b postinfarction | Oral maintenance weaning nitroprusside |
| PCWP ≥ 20 > 24 | | | | | | |
| Severe HF | | | | | | |
| PCWP > 24 cardiac index > 2.5 L/minute/m ² | Yes | Yes if SBP > 95 | Yes if SBP > 70 | Yes if SBP > 70 ^c | CI < 6 hour | Yes |
| Cardiogenic shock if SBP < 95 | Yes | | | | | |
| PCWP > 18 cardiac index < 2.5 L/minute/m ² | CI | CI | Yes IABP | Yes | CI | RCl ^d |
| Right ventricular infarction JVP ↑ | CI | CI | Useful with titrated volume infusion | Relative CI ↑ PA pressure | CI | CI |

^asee Fig. 3.2.

^bcoronary steal during ischemic phase of infarction.

^cdopamine, dobutamine combination (see Chapter 3).

^dsee text.

Yes, useful; ↓, decrease; —, no change; ↑, increase; CI, contraindication; PCWP, pulmonary capillary wedge pressure; RCl, relative contraindication; SPB, systolic blood pressure mmHg.

- Captopril is later switched to enalapril twice daily or to a once-daily ACE inhibitor, such as ramipril, 5–10 mg daily. In the Acute Infarction Ramipril Efficacy (AIRE) trial, 2006 patients with clinical heart failure from 3–10 days after MI were randomized and treated with ramipril: death occurred in 23% of control versus ramipril 17%: a 27% significant reduction in mortality. If an ACE inhibitor causes undesirable adverse effects, an angiotensin receptor blocker (ARB), such as candesartan, 8–32 mg daily should be substituted. The CHARM study has shown the efficacy of this agent.

The CHARM-Alternative trial ($n = 2028$) examined the effects of the ARB candesartan in patients with a reduced left ventricular EF less than 40% who were ACE-inhibitor-intolerant. Treated patients received 4–8 mg of candesartan titrated to 32 mg once daily, plus the treatment given to placebo patients: standard ant-failure therapy that included diuretics, β -blocker, digoxin, and spironolactone (85%, 54%, 45%, and 24% respectively).

Results of this study showed that after 33.7 months, patients given candesartan were 23% less likely to experience cardiovascular death or HF hospitalization compared with those who received placebo (40% versus 33%, $p = 0.0004$).

There is no unfavorable interaction when candesartan and a β -blocker are used in combination, as opposed to that shown for the valsartan– β -blocker combination. It appears that ARBs, like β -blockers, have subtle and important clinical differences.

ACE inhibitors have proven effective in the management of acute MI for the modification of remodeling, preservation of LV function, and prevention of HF. These agents produce symptomatic improvement, decrease mortality, and prevent the recurrence of HF in postinfarction patients with HF or an EF below 40%. They cause a modest decrease in mortality in patients with HF with chronic ischemic heart disease when used in conjunction with digoxin and diuretics (*see* Chapter 5).

The renin angiotensin system is activated during the early hours of MI and appears to be an important compensatory mechanism that serves to maintain BP. The arterial vasoconstrictor effects of angiotensin II cause an unnecessarily great increase in afterload and ventricular wall stress, which initiate and perpetuate ventricular enlargement and an associated change in geometry with consequent further LV dysfunction. ACE inhibitors have been shown to attenuate these processes.

Studies that support the salutary effect of ACE inhibitors administered within a few days postinfarction include the following:

- The survival and ventricular enlargement (SAVE) trial randomized 2231 patients postinfarction several weeks with EF less than 40% and no evidence of HF. Captopril-treated patients followed-up for an average of 42 months experienced a significant decrease in mortality ($p = 0.019$) and recurrence of nonfatal infarction.
- The AIRE study randomized 2006 patients 3–10 days postinfarction with clinical evidence of heart failure new york heart association class II and III. At a minimum follow-up of 6 months and an average of 15 months, there were 170 deaths in the ramipril group and 222 deaths in the placebo group ($p = 0.002$), an observed risk reduction of 27%.
- In the survival of MI long-term evaluation (SMILE) study, zofenopril was commenced approximately 15 hours postinfarction and continued for 6 weeks in patients with acute anterior infarction. This therapy resulted in a significant decrease in the risk of severe HF. This beneficial effect occurred mainly in patients with previous infarction. Mortality at 1 year in the group treated for only 6 weeks was 10% versus 14% in the placebo group ($p = 0.011$). Thetrandolapril study confirms the beneficial effects of ACE inhibitors when begun 3–7 days in postinfarction patients with EF less than 35%.

ACE inhibitors are indicated maintenance therapy in the following categories of postinfarction patients:

- From the first day, postinfarction if HF was manifest.
- From the second day, postinfarction in patients with large anterior infarction, or in all patients with acute anterior infarction with previous infarction. If the EF at 6 weeks is more than 40%, ACE inhibitors can be discontinued but continued indefinitely in virtually all patients with EF less than 40%.
- From the second or third hospital day in virtually all postinfarction patients not in HF but with EF less than 40%.

ACE inhibitors must be used with caution, however, in patients who develop postinfarction angina or other manifestations of worsening ischemia, because coronary artery perfusion beyond a critical stenosis may be reduced by these and other vasodilators. These agents, as with other preload reducing agents, are contraindicated in patients with right ventricular infarction. ACE inhibitors reduce both preload and afterload.

Contraindications include the following:

- Severe anemia.
- Unilateral renal artery stenosis in a solitary kidney or severe bilateral renal artery stenosis.
- Hypotension.
- Aortic stenosis.

Interactions between ACE inhibitors and other therapies include the following:

- Except when the patient requires additional significant doses of loop diuretics, potassium supplements and potassium-sparing diuretics should not be given con-comitantly with ACE inhibitors or ARBs because severe hyperkalemia may ensue. Potassium supplementation may be hazardous, and close monitoring of serum potassium and serum creatinine is required because a sharp decline in renal function is sometimes seen. Spironolactone or eplerenone are usual additive agents and have been shown to decrease mortality and recurrent HF but should be avoided in patients with a creatinine clearance <60 mL/min or serum creatinine equal to or greater than 1.3 mg/dL (115 μ mol/L) because life-threatening hyperkalemia may occur
- Both nitrates and ACE inhibitors decrease preload and may precipitate presyncope or syncope.

Digoxin

Digoxin may increase oxygen demand, but in this situation with high mortality, there's little reason to withhold digoxin if HF is severe and unresponsive to standard therapy. The area of infarction is a necrotic zone, and there is little evidence to support the notion that digoxin increases infarct size. Improvement in cardiac function and hemodynamics may have salutary effects on the peripheral ischemic zone. The concern of increasing infarct size is irrelevant if severe HF persists on the second day postinfarction in the absence of recurrent chest pain or echocardiogram (ECG) signs of worsening ischemia or if mechanical complications are absent. Digoxin is usually not advisable within the first 12 hours of infarction, when the risk of the ischemia and arrhythmia is at its highest.

If the ECG shows no mechanical defect, digoxin is advisable for the management of severe HF, pulmonary edema, or for controlling the ventricular rate if AF develops. Also, when the patient is weaned off dobutamine or other inotropes, the action of digoxin is manifest. Although the effect of digoxin on long-term survival post-MI remains con-

roversial, the risk of precipitating an arrhythmia with digoxin is remote, as long as the dose is kept low enough to maintain a digoxin level less than 1 nmol/L. It is now appreciated that low-dose digoxin with low serum levels produces hemodynamic effects that are beneficial and provide safety compared with larger doses that were used over the past 50 years or more. In patients who have been previously treated with diuretics, magnesium and potassium depletion must be corrected to avoid digoxin-induced arrhythmias.

Digoxin IV is not normally required, except where AF with a fast ventricular response requires control. With sinus rhythm and severe HF, give orally 0.5 mg immediately and then 0.25 mg at bedtime in patients under age 70 with normal renal function and in the absence of conditions in which there is an increased sensitivity to digoxin (Table 5.4); follow with 0.25 mg daily. In patients over age 70 and those with slight elevation of serum creatinine, 1.3–2 mg/dL (115–160 $\mu\text{mol/L}$), the maintenance dose should be reduced to 0.125 mg daily after the second day (*see* Chapter 5). Digoxin is not advisable in patients with severe renal failure (serum creatinine >2 mg/dL [$160 \mu\text{mol/L}$]).

Digoxin is particularly useful in postinfarction patients with HF who have SBP less than 105 mmHg. In these patients, nitrates or ACE inhibitors combined with diuretics and β -blockers may further reduce SBP and preload, causing decreased coronary and cerebral perfusion that may induce ischemia or presyncope.

Intubation

Patients who manifest florid pulmonary edema and respond poorly to furosemide and IV nitroglycerin, with an arterial O_2 (paO_2) less than 50 or arterial CO_2 (paCO_2) greater than 50 mmHg, require mechanical ventilation and positive-end expiratory pressure (PEEP) in addition to the other measures described. Caution: PEEP may decrease cardiac output and precipitate hypotension.

Pump Failure and Shock

There are two hemodynamic subsets of pump failure, and patients may move from one subset to another. This chapter deals briefly with subset I. Chapter 3 presents a more detailed discussion of cardiogenic shock. The clinical spectrum of pump failure and shock embraces:

- Poor peripheral perfusion with cold cyanotic extremities.
- Obtundation.
- Oliguria.
- Weak pulse.
- Cuff SBP range: subset I, greater than 100 mmHg and subset II, less than 90 mmHg.
- Patients with systolic pressures between 90 and 100 mmHg may move toward subset I or subset II; close hemodynamic monitoring is necessary.
- Symptoms and signs of LV failure.

Salient therapeutic measures include the following:

- Define the filling pressure of the left ventricle to exclude volume depletion. Various causes of preload reduction must be defined.
- If the LV filling pressure is less than 15 mmHg, give a rapid IV fluid challenge over a very short period to increase the filling pressure to 18–23 mmHg. A prolonged infusion must be avoided, as it can worsen pulmonary congestion without increasing LV filling pressure appreciably.

If volume depletion and preload-reducing factors are absent, management must rapidly progress to:

- Relieving the load on the left ventricle with afterload-reducing agents but without decreasing BP and perfusion to vital areas.
- Improving myocardial oxygen supply: demand ratio with oxygen-sparing agents, reperfusion by thrombolysis, angioplasty, or finally resorting to coronary artery bypass surgery (CABS) if these alternatives are technically feasible, if a substantial amount of viable myocardium is believed to persist in the ischemic region, and if the patient's condition permits. Two hemodynamic subsets in the spectrum of pump failure and shock can be defined by hemodynamic monitoring.

Subset I

- LV filling pressure greater than 15 mmHg.
- SBP greater than 100 mmHg.
- Cardiac index less than 2.5 L/minute/m².
- Evidence of peripheral hypoperfusion and some evidence of pulmonary congestion.

This category of patients have LV failure, and the SBP range of 95–115 mmHg allows the use of afterload- and preload-reducing agents, thus relieving the load on the left ventricle and favorably altering myocardial oxygen supply:demand ratio. Salutory effects are obtained with the administration of nitroglycerin, dobutamine, dopamine, or nitroprusside, depending on hemodynamic parameters (Table 2.4).

Nitroglycerin

Nitroglycerin has advantages over nitroprusside during the early hours of infarction because, at this stage, ischemia is often present. The drug is reserved for selected cases in which continued ischemia is suspected of causing progression of infarction or LV dysfunction.

The drug reduces preload, which may be beneficial in some patients with severe pulmonary congestion but in whom blood pressure is reasonably well-maintained. However, patients with pump failure and severe shock may have deleterious effects from too great a reduction in preload. Higher doses also reduce afterload. Thus, careful hemodynamic monitoring is essential when using pharmacological agents that alter both preload and afterload.

Commence with 5 µg/minute via pump-controlled infusion (*see* nitroglycerin infusion pump chart, Table 4.9.). Increase by 5 (µg/min every 10 minutes. Do not allow a fall in SBP in excess of 10 mmHg. The SBP should not fall to less than 90 mmHg.

If nitroglycerin alone causes improvement in the pump failure or shock syndrome, achieving an acceptable increase in cardiac output, continue the infusion for 24–48 hours.

If hypotension persists or worsens and preload is high, decrease the nitroglycerin infusion and add 2–5 µg/kg/minute dobutamine (Table 3.5.). If the preload is low or BP decreases more precipitously, dopamine should replace dobutamine (*see* Chapter 3).

Dobutamine

Commence with 2 µg/kg/minute, increase slowly if needed to 5 µg to a maximum of 10 µg/kg/minute. If a 10-µg/kg/minute dose of dobutamine fails to maintain BP, a dopamine infusion should replace the dobutamine or a low-dose dobutamine/dopamine combination should be considered. Dopamine dose: 5–10 µg/kg/minute (*see* Table 3.6., Chapter 3).

Nitroprusside

This drug is a powerful afterload-reducing agent and has a role, especially when the SBP is in the range of 100–120 mmHg, in the presence of pump failure/shock syndrome. The drug can replace nitroglycerin in patients presenting with pump failure or shock syndrome after 6 hours of infarction if ischemia is not present and afterload reduction is considered necessary.

Commence with 0.4 µg/kg/minute with close monitoring of arterial pressure, increase the infusion given by infusion pump, and titrate the dosage in increments of 0.2 µg/kg/minute every 2–5 minutes (*see* Table 8.11.). A dose of up to 3 µg/kg/min should suffice to achieve salutary hemodynamic effects.

Caution: severe hypotension is a major risk. Also, the drug may produce a coronary steal, reflex tachycardia, and hypoxemia. These serious adverse effects may worsen ischemia and infarction and increase mortality. Thus, in each patient, the benefits and risks must be weighed before introduction of nitroprusside.

Contraindications include hepatic dysfunction, severe anemia, severe renal failure, and inadequate cerebral circulation.

There are adverse effects. Patients with liver disease may develop cyanide toxicity, and if kidney disease exists, thiocyanate levels must be monitored when treatment is given for more than 2 days. Severe hypotension causing increased shock, retrosternal chest pain, or palpitations may occur. Great care is necessary to avoid accidental acceleration of the infusion. If acute cyanide poisoning occurs, amyl nitrite inhalations and IV sodium thiosulfate should be given. For further information on nitroprusside, *see* Chapters 3 and 8.

Subset II

- SBP less than 90 mmHg.
- LV filling pressure greater than 15 mmHg.
- Cardiac index less than 2.5 L/minute/m².

These parameters define patients with severe cardiogenic shock. Failure to stabilize the patient with dopamine should prompt consideration of IABP and urgent coronary angiograms with a view to PCI or bypass surgery to enhance coronary perfusion or to correct underlying mechanical problems. Randomized trials that include few patients with true cardiogenic shock demonstrated the benefit of angioplasty over thrombolytic therapy for patients with large infarctions or right ventricular infarction.

The IABP is required in some cases when dobutamine, dopamine, and norepinephrine do not halt hemodynamic deterioration and an aggressive approach is considered appropriate. Table 2.5. shows indications and contraindications for IABP. The IABP improves coronary perfusion through diastolic augmentation and cardiac output through afterload reduction.

RIGHT VENTRICULAR INFARCTION

Right ventricular infarction is usually associated with inferoposterior infarction and, where present, frequently causes right-sided pump failure or shock. Approximately 25% of patients with inferior infarction show varying degrees of right ventricular infarction, but only those with a large affected area develop the characteristic signs. The diagnostic hallmarks of right ventricular infarction are given in Table 2.6. The right atrial and right

Table 2.5
Indications and Contraindications for Intra-Aortic Balloon Pump in Acute MI

| <i>Indications</i> |
|--|
| Cardiogenic shock (selected cases) Postinfarction angina (selected cases, stabilization for angiography) Right ventricular infarction with refractory hypotension (consider IABP) Early mechanical complications (Table 2.3) (if stabilization is necessary for interventional therapy) |
| <i>Contraindications</i> |
| Severe peripheral vascular disease Aortic aneurysm and aortic disease If contraindications to anticoagulants exist |

ventricular diastolic pressures are greater than 10 mmHg, the cardiac index is less than 2.5 L/minute/m², and the LV filling pressure is normal or elevated. Approximately 0.2% of acute inferior infarctions are accompanied by right ventricular infarction. Patients with inferior infarction and ST elevation in V₄R, indicating right ventricular infarction, were observed to have a 31% mortality rate and 64% in-hospital complications, versus 6% and 28%, respectively, for those with inferior infarction.

The mechanism of shock in right ventricular infarction combines the following:

- Acute right pump failure reduces the venous return to the left ventricle. Thus, decrease in LV preload is the principal mechanism for the decreased LV output.
- Interventricular septal shift toward the left ventricle reduces LV diastolic volume. Also, an increase in intrapericardial pressure occurs, which restricts LV filling and passively increases pulmonary artery pressure, thus increasing right ventricular afterload.

In the presence of severe right-sided HF, it is necessary to exclude cardiac tamponade, which may occasionally give hemodynamic findings resembling those seen with right ventricular infarction, with equalization of diastolic pressures resulting from intrapericardial pressure owing to a distended pericardium.

Therapy of Right Ventricular Infarction

Patients with extensive right ventricular infarction are very sensitive to volume depletion, and titrated volume infusion should be tried. The right ventricle is unable to deliver adequately the venous return to the left ventricle, however, and the reduced LV preload results in decreased systemic output. Thus, volume infusion is often partially or even completely ineffective but must be tried judiciously.

- Dobutamine infusion should be commenced at 2 µg/kg/minute and increased to a maximum of 10 µg/kg/minute if needed (Table 3.5.).
- Failure to respond to volume replacement and dobutamine is a strong indication for the use of IABP.
- Sublingual or IV nitroglycerin is contraindicated in patients with right ventricular infarction because reduction in preload must be avoided.
- Nitroprusside, as well as diuretics and ACE inhibitors, reduce preload and are not recommended.

Table 2.6
Right Ventricular Infarction

| |
|---|
| High jugular venous pressure with clear lung fields (exclude tamponade) |
| Kussmaul's sign present >90% |
| ECG evidence of inferoposterior infarct |
| ST segment depression V ₁ , V ₂ , elevation in V ₄ R |
| PCWP normal |
| Right atrial and right ventricular pressure > 10 mmHg |
| Ratio right atrial to PCWP >0.8 ^a |

^aPresent in <33% of patients

PCWP, pulmonary capillary wedge pressure.

- Dopamine increases pulmonary vascular resistance and may increase right ventricular pump failure. Dobutamine is thus superior to dopamine in patients with right ventricular infarction although the hypotensive effect may limit the dose that can be tolerated.
- Thrombolytic therapy is strongly indicated to ensure a patent infarct-related vessel.
- If hemodynamic deterioration occurs, angioplasty is advisable. Small clinical trials have documented the beneficial effects of angioplasty in patients with right ventricular infarction.

POSTINFARCTION ANGINA

Definite postinfarction angina, occurring after day 1 to discharge, associated with new ECG changes and correctly interpreted as owing to worsening ischemia, is an indication for coronary angiography with a view to PCI or CABS.

Consider and exclude pericarditis, esophagogastric origin of pain owing to stress ulceration, esophagitis, and the effects of aspirin in individuals with so-called sensitive stomachs. Some patients with a stuttering pattern of pain caused by to ischemia or reinfarction respond readily to β -adrenergic blockers and/or IV nitroglycerin therapy that stabilizes patients prior to PCI.

When the EF is below 35%, and perhaps as low as 25% or if the ischemic syndrome persists and lesions of the left main or triple vessel, with left anterior descending proximal occlusion are observed on angiography bypass surgery is preferred over PCI.

A study of 48-hour ECG ambulatory monitoring 5–7 days postinfarction revealed an incidence of myocardial ischemia of 23.4%. The mortality rate in patients with ischemia was 11.6% versus 3.9% among those without ischemia.

ARRHYTHMIAS

The mechanism of early infarction arrhythmias includes disturbances of impulse generation/enhanced automaticity, disturbances of impulse conduction/reentry, and focal conduction slowing; increased sympathetic and parasympathetic tone is a commonly prominent feature that influences the above underlying mechanisms.

Precipitating factors include the following:

- Ischemia with associated tissue acidosis and local increase in extracellular potassium concentration.

- Catecholamine release: may induce arrhythmia, as well as increase ischemia. Arrhythmias worsen ischemia and vice versa. Thus, a dynamic interplay perpetuates ventricular arrhythmias that may terminate in VF.
- Hypokalemia from prior use of diuretics or induced by verapamil.
- Hypomagnesemia resulting from diuretic use.
- Hypoxemia.
- Respiratory or metabolic acidosis or alkalosis.
- Severe HF related to extensive infarction.

Ventricular Premature Beats

During the late hospital phase, frequent ventricular premature beats (VPBS) (more than 10/hour multifocal beats or couplets) may increase risk, but there is only limited evidence that antiarrhythmic therapy, other than β -blocking agents, prolongs life in these patients. The cardiac arrhythmia suppression trial (CAST) indicated an increase in mortality among these patients with the use of flecanide and encainide. Patients with this category of arrhythmia should be given a β -adrenergic blocking agent, such as metoprolol or timolol, if there is no contraindication to the use of this class of drug. A study has shown improved survival among high-risk patients treated with amiodarone, but this finding requires confirmation (*see* Chapter 6).

Sustained Monomorphic Ventricular Tachycardia

- Monomorphic ventricular tachycardia (VT) asymptomatic with the pulse present and BP >100 mmHg occurring during the first 24 hours of MI (rare at this time); give lidocaine (lignocaine) IV 100-mg bolus. IV lidocaine infusion 2–3 mg/minute is given for a time after conversion without waiting for recurrence (*see* Fig. 6.1.). If the drug is ineffective and the patient is hemodynamically stable, give procainamide IV 100-mg bolus at the rate of 20 mg/minute and then 10 mg/minute; maximum 24 mg/minute not to exceed 1 g during the first hour. Procainamide has a negative inotropic effect and is not recommended for patients who manifest HF or with EF less than 40%. The drug is, therefore, reserved for patients who fail to respond to lidocaine or who have recurrent VT but who remain hemodynamically stable.
- The cardioverter should be prepared and connected to the patient while drug therapy is in progress; if conversion fails, apply 50 J of synchronized electrical cardioversion under brief anesthesia.
- Failure to control with lidocaine procainamide or IV amiodarone requires synchronized cardioversion.
- Any breakthrough should be treated by adding a β -blocker (if not already being administered) and, if needed, IV 300 mg of amiodarone in 20 minutes, preferably via a central vein followed by 50 mg/hour for 6–12 hours and then 30 mg/hour if stable (*see* Chapter 6). IV amiodarone may cause hypotension and caution is required. With the availability of IV amiodarone, which is effective and has good tolerability, the use of bretylium has appropriately dwindled and is currently not available. VT with no pulse present or hemodynamically unstable: chest pain, shortness of breath, clouding of consciousness, or obtundation, treat as VF (*see* Fig. 6.4.).
- IV amiodarone is recommended after sustained VT is converted to sinus rhythm.

It is advisable to obtain Holter recordings for all patients at 1–3 weeks post-MI to assist in assessing the risk profile, especially if the EF is less than 40%. A 24- or 48-hour Holter

study is indicated if the patient complains of palpitations, presyncope, syncope, or other symptoms. Holter monitoring is advisable in patients to document the presence of significant ischemia and arrhythmia requiring consideration of drug therapy.

Late-occurring sustained VT is very ominous. Sustained VT occurring after the first 48 hours or weeks after infarction greatly increases the risk of sudden death and indicates poor long-term survival.

Currently, it is not known what pharmacological agent is best for post-MI patients at highest risk. β -Adrenergic blockers are the only antiarrhythmic agents that have been proven to prevent cardiac death or sudden death. There is evidence from one study, however, that amiodarone may improve survival rates.

The basal antiarrhythmic study of infarct survival investigated the effects of prophylactic antiarrhythmic therapy in patients with asymptomatic complex ventricular arrhythmias postinfarction. Low-dose amiodarone, 200 mg daily, was given over 1 year. Cumulative mortality rates were 13% in the control group, 5% in the amiodarone-treated group ($p < 0.05$), and 10% in the individually treated patients who were administered mexiletine, quinidine, propafenone, sotalol, disopyramide, or flecainide. (Treatment failures were given amiodarone.) Arrhythmic events were also reduced in the amiodarone group.

In contrast with the beneficial effects of β -blocking agents and possibly for amiodarone, other antiarrhythmic agents have been shown to increase mortality. Flecainide, encainide, and moricizine caused an increase in cardiac mortality observed in CAST.

Late Ventricular Arrhythmias

The management of patients with late nonsustained VT, at least in short runs or complex ventricular arrhythmias, is presently unsatisfactory. Suggestive steps include the following:

- If a β -blocking drug is being administered as routine β -blocker post-MI prophylaxis, the dose should be increased (e.g., 100 mg metoprolol, 160 mg propranolol daily should be increased to 300 or 240, mg daily, respectively). If Holter monitoring shows persistence of multiform VPBs or rims of nonsustained VT, a change from one of the aforementioned β -blocking agents to sotalol, 160–320 mg daily, may be effective and should be given a trial but the serum potassium must be maintained > 4.5 mmol and with the avoidance of diuretics that cause potassium depletion.

Amiodarone and other antiarrhythmic agents are used only under close supervision by using repeated Holter monitoring, and the usual precautions are observed when prescribing amiodarone (*see* Chapter 6). The combination of amiodarone and a β -blocking agent (except sotalol) has a role in patients with lethal arrhythmias, as discussed in Chapter 6. The combination of amiodarone and sotalol is not advisable because the risk of torsades de pointes is increased.

Failure of this trial therapy should prompt consideration of selecting alternative treatments, such as a combination of antiarrhythmic agents guided by electrophysiologic testing (although the recommendation of antiarrhythmic therapy has several limitations); rare surgical excision of focus; catheter ablative techniques; an implantable implantation cardioverter-defibrillator (ICD), which has antibradycardia pacing and algorithms for pace termination of VT.

Table 2.7.
Incidence of Supraventricular Arrhythmias in Acute MI

| | <i>Approximate %</i> |
|---|----------------------|
| Atrial fibrillation | |
| Within 3 hours of infarction | 3 |
| New onset first week | 5 |
| Known prior (chronic) | 10 |
| Atrial flutter | 1–2 |
| Ectopic atrial tachycardia (benign) | 1–5(transient) |
| Non-paroxysmal AV junctional tachycardia (benign arrhythmia relates to size of infarction) | 5–15 |
| Atrioventricular nodal reentrant tachycardia | Rare |

Supraventricular Arrhythmias

The incidence of supraventricular arrhythmias in acute MI is shown in Table 2.7.

Atrial Fibrillation

AF occurs in more than 10% of patients with acute MI and precipitated by large infarction of the atrium, chronic atrial enlargement, HF with atrial dilatation, acute mitral regurgitation, increase catecholamines, acute pericarditis, hypoxemia, and inferior infarction more commonly than anterior infarction, with occlusion of the right coronary or circumflex artery.

AF is observed during the first few days of infarction in up to 15% of patients, and in approximately 10%, the onset is before infarction. Acute atrial fibrillation occurs within the first few hours of infarction in approximately 5% of patients and is often of short duration, lasting less than 2, 4, and 24 hours in 50, 75, and 95% of patients, respectively, and is associated with increased risk of death and embolic stroke.

Management of AF depends on the hemodynamic and proischemic effect of a rapid or uncontrolled ventricular response:

- Electrocardioversion: hemodynamic compromise requires immediate electrocardioversion (synchronized cardioversion is usually achieved at 100 J for AF and 50 J for atrial flutter).
- Digoxin: patients with symptomatic HF with a ventricular rate that requires control are usually managed by slow digitalization. However, digoxin may not reach peak effect for 6–12 hours, depending on the dosing schedule:
Dosage: For HF caused by AF intravenous digoxin 10–15 µg/kg lean body weight, with half dose administered initially and 25% of the dose given at 6-hour intervals for 2 doses or 0.75 to 1.0 mg IV infusion over 2 hours or more when rapid control is needed in patients with HF; *caution*, a lower dose is used in the elderly or if renal dysfunction is present indicated by a serum creatinine greater than 1.3 mg/dL (115 µmol/L). An oral dose of 0.125–0.25 mg is then administered depending on the ventricular response and serum creatinine levels.
- Esmolol: in patients with symptomatic HF in whom efforts to convert to sinus rhythm have failed, and rate control has not been achieved by the use of digoxin the short-acting, β-blocker esmolol has a role (half life 2–5 minutes).
- Dosage: loading dose, 0.5 mg/kg over 2–5 minutes followed by infusion of 0.05 mg/kg/minute titrated upward as needed to maximum dosage of 0.2 mg/kg/minute. It is recom-

mended that the loading dose be omitted in unstable patients with hypotension that could be increased. If the degree of heart failure increases, the infusion is discontinued immediately.

- Metoprolol: asymptomatic patients with a fast ventricular rate but no hemodynamic compromise or symptomatic HF are managed with IV metoprolol. Patients not in prominent HF with SBP greater than 110 mmHg and rates of 120–150/min can be managed with a β -blocking drug. A fast rate >120/minute not causing hemodynamic compromise should respond to metoprolol.

Dosage: 5 mg IV followed if needed every 5 minutes, up to 3 doses.

In patients with acute MI and persistent or chronic AF a β -blocking drug, particularly metoprolol, is recommended to control the ventricular rate; if HF is present, digoxin is the treatment of choice

- Diltiazem IV rapidly and effectively slows the ventricular response and is often used in patients with a fast ventricular rate presenting to emergency rooms in the absence of acute MI and HF. Diltiazem's negative inotropic effect is more prominent than that of titrated small doses of esmolol or metoprolol and is not advisable in acute infarction unless the use of a β -blocker is absolutely contraindicated by severe asthma. Dosage: IV 0.25 mg/kg; a second bolus of 0.35 mg/kg can be repeated after 15 minutes if the ventricular response remains >120/minute. Caution is required because diltiazem may precipitate LV failure in patients with known LV dysfunction; an increase in mortality rates with oral therapy in patients with LV dysfunction has been reported.
- Amiodarone administered IV may control the ventricular rate and cause conversion to sinus rhythm in more than 50% of cases.

Bradycarrhythmias

Early occurring sinus bradycardia, symptomatic or associated with hypotension usually with rates less than 45/minute, should be managed with atropine. Similarly, second- or third-degree atrioventricular (AV) block occurring during the first few hours after onset of MI often responds to this agent. Also, patients with asystole should be given atropine.

- Atropine dosage: 0.4–0.6 mg is given IV, repeated if needed every 5 or 10 minutes to a maximum of 2 mg.

Caution: rapid injection or too large a dose may cause unwanted sinus tachycardia and, rarely, VF. The dosage for asystole is 1 mg IV repeated in 2–5 minutes during which cardiopulmonary resuscitation (CPR) should continue. The total dose is 2.5 mg over 30 minutes. In the latter situation, a large dose given promptly is essential, without concern for tachycardia causing increased myocardial oxygen demand.

Indications:

- Sinus bradycardia associated with peripheral hypoperfusion, hemodynamic deterioration.
- Frequent VPBS associated with sinus bradycardia.
- All forms of AV blocks, second or third degree in patients with inferior MI, because they often respond if less than 8 hours postonset.
- Asystole, along with CPR and preparation for pacing.

Adverse effects include hallucination, sinus tachycardia, and, rarely, VT and VF. Severe bradycardia owing to mobitz type 2 or third-degree AV block not responding to atropine requires temporary pacing.

CARDIAC PACING

Temporary Cardiac Pacing

The use of a temporary cardiac pacemaker is an important procedure for establishing an adequate heart rate and, secondarily, cardiac output in patients with symptoms of bradyarrhythmia. It is usually an emergent procedure. Temporary pacing is indicated in a variety of clinical circumstances in which a symptomatic bradycardia is present or is likely to occur. These can include the following:

- Acute MI.
- Drug-induced bradyarrhythmias.
- During cardiac catheterization.
- Immediate treatment of tachyarrhythmia.

The use of temporary cardiac pacemakers in patients with acute MI requires knowledge of the vascular supply of the conduction system.

- The sinoatrial node, which is located near the junction of the right atrium and the superior vena cava, is supplied by the sinoatrial nodal artery. This is a branch of the right coronary artery in 55% of individuals and of the circumflex artery in the remainder.
- The AV node is supplied by the AV nodal branch of the right coronary artery in approximately 90% of individuals and by the left circumflex coronary artery in the remaining 10%. There is very little collateral blood supply for these structures.
- In contrast, the his bundle and proximal portions of both the left and right bundles have a dual blood supply from the AV nodal artery and the septal branch of the left anterior descending coronary artery. This anastomosis can allow retrograde flow into the his bundle and the AV node when the AV nodal artery is blocked.
- The right bundle branch, however, is a compact structure and receives blood supply from the left anterior descending artery. The left bundle branch is anatomically less discrete. The left anterior fascicle receives blood supply from the branches of the left anterior descending artery and the left posterior fascicle receives blood from the AV nodal and posterior descending arteries.

Conduction disturbances associated with right coronary artery occlusion depend on the site of occlusion. Occlusion proximal to the sinoatrial nodal artery can result in sinus node dysfunction, whereas occlusion more distally can result in AV block at the level of AV node. Therefore, AV block might result from occlusion of the AV nodal branch of the right coronary artery alone and is not necessarily associated with a sizable MI. Because the bundle branches are more diffuse, bundle branch block is usually associated with extensive anterior MI.

- The decision to insert a temporary pacemaker in patients with acute MI is dependent on the location of the block, the extent of MI, and the presence of preexisting conduction system presence.
- Inferior infarction is usually associated with conduction disturbances proximal to the his bundle. Escape rhythms usually have a narrow QRS complex, tend to be fast and stable, and respond well to atropine. AV block in these situations is usually but not invariably transient. Indications for temporary pacing in these patients include a heart rate of less than 40 beats/minute (BPM) and symptoms of low cardiac output or bradycardia associated with angina or ventricular irritability. In asymptomatic patients with a stable escape rhythm despite complete AV nodal block, temporary pacemakers need not be inserted. The long-term prognosis of patients with inferior MI and high-degree AV block is worse than in patients without AV block.

- New abnormalities of the conduction system occurring distal to the AV node are usually seen with anterior MI. Both high-degree AV block and bundle branch blocks can be observed. In these cases, the escape rhythms are associated with a wide QRS complex, are slower and less stable, and usually do not respond to atropine. Frequently, they progress to complete AV block. These patients also have extensive MI and often have signs of pump failure. As progression to complete AV block contributes independently to morbidity and mortality, temporary cardiac pacing is performed more promptly than for inferior wall infarction.

Pacing is recommended in patients who are at risk of complete AV block and include:

- Type II second-degree AV block.
- New bifascicular block (right bundle branch block with left anterior or left posterior block) or complete left bundle branch block.
- Left or right bundle branch block with first- or second-degree AV block.
- Alternating left or right bundle branch block.
- Pre-existing right bundle branch block with new left fascicular block or first-degree AV block.

Methods of Temporary Cardiac Pacing

Temporary cardiac pacing can be established by transvenous, transthoracic, transesophageal, and epicardial approaches. The choice of a specific route is dependent on factors such as availability of the device, indications for pacing, expertise of the physician, and the clinical situation. The transvenous approach is the most often used method.

TRANSVENOUS

External or internal jugular, subclavian, antecubital, and femoral venous approaches are most often used for introduction of pacing catheter electrodes. Under radiographic control, the electrode tip is positioned in the right atrial appendage or the right ventricular apex for stable atrial and ventricular pacing, respectively. In an emergency or in the absence of radiologic facilities, a balloon-tipped flotation electrode catheter can be used to enter the right ventricle. A pacing threshold of less than 1 V is usually satisfactory. It increases over the next few days, probably a result of tissue edema around the electrode tip. Although invasive when compared with transthoracic and transesophageal approaches, transvenous pacing is rapidly accomplished and is reliable when instituted. Atrial, ventricular, and dual-chamber pacing can be achieved, and atrial and ventricular ECGs can be selectively recorded for diagnostic purposes.

PERMANENT PACING IN ACUTE MI

The management of bradyarrhythmias related to conduction disturbances in acute MI is determined by the site of the culprit MI, hemodynamic consequences of the arrhythmia, and arrhythmia duration after acute MI the requirement for temporary pacing does not, by itself, constitute an indication for permanent pacing.

INFERIOR MI

Conduction disturbances are often seen in patients with acute inferior wall MI. These are a result of ischemia of the AV node or the perinodal regions. Sinus node dysfunction may also occur. First-degree AV block and Mobitz type I second-degree AV block, if present, are usually transient, unassociated with hemodynamic disturbances, and do not require pacing therapy. A minority of patients will develop higher degree or symptomatic AV block. Temporary pacing is indicated, particularly if the patient is hemodynamically

unstable. If symptomatic second- or third-degree AV block persists beyond 2–3 weeks after MI, permanent pacemaking may be indicated.

Conduction disturbances in anterior MI are usually related to ischemic necrosis of conduction tissue distal to the AV node, with involvement of the His-Purkinje system and bundle branches. These arrhythmias most often accompany a relatively large anteroseptal MI. Permanent pacing is generally indicated for new onset bifascicular block, persistent mobitz type II second-degree or complete AV block, or transient mobitz type II second-degree or complete AV block when associated bundle branch block (trifascicular block) is present.

This is performed owing to the substantial potential of these conduction disturbances for the development of complete AV block. Patients with anterior wall MI who have AV conduction and intraventricular conduction disturbances, except left anterior hemiblock, have a poor short- and long-term prognosis and an increased incidence of sudden death. The poor prognosis is primarily related to the extent of MI rather than to the AV block itself. Mortality is high even with pacemaker therapy owing to myocardial failure.

Complications include ventricular arrhythmias, especially in patients with acute MI; pericarditis; ventricular perforation; bleeding; pulmonary embolism; air embolism; pneumothorax when the subclavian vein is used for lead introduction; and local and systemic infections.

MECHANICAL COMPLICATIONS

Mechanical complications should be strongly suspected in patients who develop sudden hemodynamic deterioration, especially from the second postinfarct day onward with no new ECG changes occurring. The incidence and associated mortality of these complications are given in Table 2.8.

Severe Acute Mitral Regurgitation

A transient mitral regurgitant Murmur is often present with acute MI. Severe acute mitral regurgitation is uncommon, however, occurring in fewer than 3% of patients with acute MI and is usually owing to papillary muscle rupture (i.e., partial rupture of the tip or rarely the trunk), or rupture of the chordae tendineae.

Strongly suspect severe mitral regurgitation in the presence of acute inferior infarction on the second to fifth days in patients with pulmonary edema and/or hemodynamic deterioration developing out of proportion to the ECG changes. An EF in the normal range is typical of regurgitant flow. The posterior papillary muscle is most commonly affected with inferoposterior infarction.

Physical signs include the following:

- A new murmur of mitral regurgitation may be loud and, rarely, accompanied by a thrill. The murmur is usually loud, in the presence of papillary muscle rupture, but may be soft in patients with low cardiac output or shock syndrome.
- Papillary muscle dysfunction: mitral regurgitation is not usually severe. The systolic murmur may fluctuate in intensity from hour to hour and may be soft, loud, high, or low pitched; the murmur may stop abruptly well before the second heart sound.
- The murmur caused by ischemia of the posterior papillary muscle radiates anteriorly, whereas that of the anterior papillary muscle radiates posteriorly to the axilla.
- The murmur of a flail leaflet may be well-heard over the spine from the skull to the sacrum.

Table 2.8.
Acute Myocardial Infarction-Mechanical Complications Incidence, Timing, and Mortality

| | <i>% of total acute infarcts</i> | <i>Incidence and timing</i> | <i>% of total rupture</i> | <i>% of total in-hospital mortality</i> | <i>type of infarct</i> |
|-----------------------------|----------------------------------|---|---------------------------|---|------------------------------|
| Cardiac rupture | 3–10 | Up to 50%; 2–3 days Up to 40%; day 1 | | 8–17 ^a | |
| Free-wall | 2–6 ^{ab} | 10%; days 4–7 25%; day 1 | 85 | 7–14 | lateral ^c |
| Papillary muscle rupture | 1 | 75%; 3–5 days 25%; day 1–2 or 6–10 | 5 | 1 | Commonly inferoposterior |
| Ventricular Septal rupture | 1–2 | 75%; 3–5 days 25%; 1–2 or 6–14 | 10 | 1–2 | 60% anterior 40% inferior |
| Severe mitral regurgitation | <2% | 1–5 days | | | |
| LV aneurysm | 7–12 | 3 months | | | 90% anterior 10% inferior |

^aAm Heart J 1989; 117:809.

^bamjcardiol 1991; 68:961.

^cSee text.

Diagnosis and management include the following:

- Echocardiography with continuous wave doppler flow study has an important role.
- If the doppler flow study is in keeping with severe mitral regurgitation, proceed with catheterization. Large V-waves on pulmonary capillary wedge and severe mitral regurgitation are observed on left ventriculography.
- Patients with severe acute mitral regurgitation owing to papillary muscle or chordal rupture require surgery. IABP provides support if needed during catheterization and to the operating room.
- Patients with papillary muscle dysfunction and severe mitral regurgitation who are not hypotensive are managed with afterload-reducing agents. IV nitroglycerin has a role in relieving ischemia, as well as reducing preload, and causes minimal afterload reduction (see Chapter 3). Dobutamine and the use of IABP may be necessary to support blood pressure where needed while considering interventional therapy.

Free-Wall Rupture

The two leading causes of in-hospital postinfarction mortality are cardiogenic shock and myocardial rupture. This catastrophic event accounts for between 8 and 17% of total in-hospital postinfarction mortality.

There have been fewer than 100 reported cases of successful surgical repair despite an incidence of 25,000 cases annually in the US. Myocardial rupture has been found in 38% of patients at autopsy in clinical trials of thrombolytic agents. Several clinical trials indicate that late administration, at 8–21 hours from the onset of symptoms, increases the risk of cardiac rupture, especially in patients over age 70. The Gruppo Italiano per lo Studio della Streptochinasi nell' Infarto Miocardico trial independently confirmed the relation between the risk of cardiac rupture and time to streptokinase therapy. *A meta-analysis of four thrombolytic studies in 1638 patients showed that therapy after the seventh hour was associated with an increased risk of myocardial rupture.*

Peak incidence is within the first 72 hours; up to 40% of cases occur within the first 24 hours of symptoms (Table 2.8.) and about 85% occur within 1 week.

Free-wall rupture presents in four scenarios:

- Acute free rupture.
- Acute limited rupture.
- Subacute rupture.
- Chronic rupture.

Associated factors include the following:

- Vigorous contraction of surviving myocardium appears to be an important contributing factor.
- Most commonly occurs after first infarction.
- Mainly Q-wave transmural infarcts and mainly lateral wall infarction, particularly inferolateral, posterolateral, and anterolateral. Rupture does not usually occur with inferior infarction that does not involve the lateral or posterior wall.
- Patients are usually over age 70.
- Preexisting hypertension.
- More common in women.
- Thrombolytic therapy is given more than 7 hours after the onset of symptoms, when necrosis is complete. Cardiac rupture is caused by extensive infarction and dissection of blood through the regions of transmural necrosis. Thrombolytic therapy may cause hemorrhage into areas of fresh necrosis and may promote dissection that could result in free-wall rupture.
- Use of anticoagulants or NSAIDs. NSAIDs and Cox-2 inhibitors cause vasoconstriction and may alter myocardial healing. Also, sodium and water retention adds to ventricular strain.
- Early ambulation is an unproven association.

Prevention plays a major role:

- Early use of thrombolytic agents to ensure reperfusion in less than 6 hours of onset of symptoms to prevent transmural infarction.
- Avoid late use of thrombolytic agents in patients, particularly women, over age 75 with first infarction seen after the sixth hour with completed Q-wave infarction, except where a stuttering pain pattern persists (*see* Indications for Thrombolytic Therapy in Patients Over Age 75, Chapter 1).
- Reduce the force and velocity of ventricular contractility with the use of β -blocking agents. β -blockers are the only available cardiac medications that have shown modest protection from myocardial free-wall rupture. There are good theoretic reasons to justify their salutary effects in preventing this catastrophic occurrence in patients with first infarction (*see* Fig. 1.1.). In the international study of infarct survival trial, causes of myocardial rupture were over 2.5-fold more frequent in the placebo group than in those

administered IV atenolol. The Goteborg Metoprolol and Miami trials showed a similar trend. The β -blocker heart attack trial (BHAT) showed a 43% decrease in early morning sudden deaths not believed to be caused by arrhythmias. Because it is rare to prevent death after free wall rupture has occurred, prevention of rupture is of utmost importance. An IV β -blocker, such as esmolol, metoprolol, or atenolol, should be given at the earliest opportunity, preferably within the first 2 hours of onset of symptoms particularly to patients with lateral wall involvement.

- ACE inhibitors decrease afterload and may reduce ventricular work; although these agents are reported to favorably alter postinfarction remodeling, the effect in preventing myocardial rupture needs to be confirmed by multicenter randomized clinical trials.
- Nitrates cause moderate yet important sinus tachycardia and an increase in ejection velocity. Thus, these agents are not indicated in prevention and should be avoided after the first 6 hours of infarction, except where recurrence of ischemia is documented.

Acute free-wall rupture is a catastrophic event; death occurs within the hour.

Acute limited rupture of the thick spiral muscular layer may occur, but an intact outer longitudinal layer of muscle causes a precarious containment of the rupture. Transient cracks may occur in the thin longitudinal layer, causing not only pericardial effusion and tamponade, but also closure of the small leak.

Immediate pericardiocentesis with derived benefit excludes the confounding diagnosis of pulmonary embolism, which may occur between days 2 and 8 and may occasionally present catastrophically and with electromechanical dissociation. Hemodynamic support using IABP may be necessary; the patient may be rushed to the operating room for correction of a defect, making survival possible.

Subacute Rupture

Subacute rupture may cause hemorrhagic pericarditis owing to a slow leak of blood and can present during the 2- to 8-day period. In this condition, a few hours are available to rapidly define the underlying lesion. As in other forms of pericarditis, the patient usually complains of severe chest pain increased on inspiration and recumbent posture with some relief by leaning forward. Increasing signs of cardiac tamponade may be manifest (*see* Chapter 13). Initially, this condition may be difficult to differentiate from benign postinfarction pericarditis, but the latter does not cause hemodynamic compromise.

A study of 70 cases reported by Oliva et al. provides the following important observations:

- The most common site of rupture was the mid or basal lateral wall (41%); this is in accordance with other series that show a preponderance of lateral and postero-lateral ruptures. Because only 20–25% of fatal and 15% of nonfatal infarctions involve the lateral wall, there is about a threefold increased tendency of the lateral wall to rupture.
- The wide belief that most ruptures are sudden and cannot be recognized in a timely fashion to allow successful intervention is incorrect.
- This study indicates that subacute rupture is not rare; it presents in a stuttering pattern and can be anticipated because of hallmark symptoms and signs and relevant electrocardiographic findings.

Two of the following three cardinal symptoms occurred in 80% of patients versus 3% of patients without rupture:

- Pleuritic positional chest pain caused by pericarditis.
- Repeated vomiting over 1–24 hours without an obvious cause (not narcotic-induced).
- Agitation and marked restlessness, indicating internal distress similar to that observed in patients with severe pulmonary embolism.

Only one abnormal physical sign was noted: abrupt transient episode of hypotension (SBP <90 mmHg) with bradycardia in 21% of patients with rupture.

Hallmark ECG findings that should be useful in suspecting underlying rupture include a deviation from the expected evolutionary T-wave pattern that occurred in 94% of patients with rupture versus 34% of control patients ($p < 0.02$). Characteristic evolutionary T-wave changes normally expected in the first 48 hours failed to occur; initial T-wave inversion was followed by gradual reversal.

If rupture is suspected, and pericardial fluid is confirmed by echocardiography and pericardiocentesis reveals a bloody effusion, rapid surgical intervention can produce salutary results in these patients. Coronary bypass surgery or angioplasty in selected patients improve survival.

Chronic rupture with or without pseudoaneurysm is a rare occurrence. Circumferential adhesions and a layer of thrombus formation between the visceral and parietal pericardium may cause containment of the hemopericardium for days to weeks.

The abnormal bulge on the cardiac border, chest discomfort, or increasing HF may alert suspicion. Echocardiographic visualization and, occasionally, CT and left ventriculography are indicated on an emergency basis to exclude this potentially correctable lesion.

Papillary Muscle Rupture

Papillary muscle rupture occurs infrequently and accounts for approximately 1% of mortality from acute MI (Table 2.8.). Rupture of one of the smaller heads of the papillary muscle occurs much more commonly than rupture of a main trunk. Diagnosis and therapy include the following:

- Sudden deterioration of the patient's hemodynamic status, with pulmonary edema or cardiogenic shock out of proportion to the extent of ECG changes, is common in patients with inferoposterior infarction. A high index of suspicion is crucial for this diagnosis. This form of rupture can occur with non-ST elevation MI (subendocardial infarction).
- A new mitral regurgitant murmur is usually loud, but may be just audible.
- The catastrophic event is usually fatal, but if severe mitral regurgitation and partial rupture of a papillary muscle are quickly detected by bedside doppler echocardiography or transesophageal echocardiography and catheterization confirms the diagnosis, then surgery is the only hope of survival. Surgical mortality is 10–25%. Hemodynamic support using IABP may be required during catheterization and transport to the operating room.
- Surgery involves replacement of the mitral valve, because the mitral apparatus is usually severely damaged and beyond repair.
- Rupture of a papillary muscle main trunk is a catastrophic event and death ensues within the hour, a situation that is, fortunately, rare.

Ventricular Septal Rupture

Prior to thrombolytic therapy, ventricular septal rupture occurred in 1–3% of patients with acute infarction. Thrombolytic therapy appears to have reduced the incidence to approximately 0.2%.

Associated features and hallmarks include the following:

- Occurs in both anterior and inferior infarctions with concomitant infarction of the inter-ventricular septum.
- More common with first Q-wave anterior or anteroseptal infarction.

- Peak occurrence in 2–5 days, but up to 30% occur within 24 hours or up to 2 weeks postinfarction (Table 2.8.).
- Abrupt onset of hemodynamic deterioration often with cardiogenic shock from 12 hours to 14 days postinfarction, in the absence of signs of tamponade or new ECG changes of reinfarction.
- A new, loud, harsh holosystolic murmur maximal at the left and right lower sternal border, often with spoke-wheel radiation.
- A thrill occurs in up to 50% of cases but murmur and thrill are often difficult to identify if cardiogenic shock develops.
- The murmur may be maximal at the apex without a thrill and may be difficult to differentiate from acute mitral regurgitation; an s3 gallop is usually present, but pulmonary edema is not as prominent as with acute mitral regurgitation.
- Rupture usually occurs at the junction of the septum with anterior or posterior LV free wall.
- Right HF is more prominent than pulmonary edema.
- Severe HF, yet a normal, supernormal, or only mild decrease in EF should be a clue to the diagnosis of the cause of cardiogenic shock occurring between days 2 and 14.
- Doppler ECG should confirm the diagnosis particularly with the application of tee.
- Right-sided catheterization with oximetry should show an oxygen step-up in the right ventricle.

The degree of hemodynamic compromise and the general health and age of the patient dictate the urgency and selection of pharmacological and interventional therapy. Patients often come through angioplasty without problems on the IABP. Mortality exceeds 80% with medical therapy.

Surgery should not be delayed for some weeks as was formerly recommended, even if the IABP produces some stability. This improvement is usually temporary, and although surgical mortality is high, repair of the lesion that is causing hemodynamic compromise gives the only hope of survival. Some centers use intraoperative angiography or angioscopy to define coronary occlusions for added management with cabs.

LV Aneurysm

An angiographic LV demarcated diastolic deformity with systolic dyskinesia defines a ventricular aneurysm.

Associated features and implications include the following:

- LV aneurysm is observed in 10–15% of patients within 3 months postinfarction.
- ECG at this stage shows ST segment elevation greater than 1.5 mm in two or more of the following leads: V₁ to V₅ in approximately 33% of cases.
- Usually seen with large Q-wave anterior infarction and absence of LV hypertrophy.
- More than 75% involve the apical anteroseptal region.
- Severe HF is often refractory to intensive cardiac drug therapy. Thus, these patients have a poor quality of life.
- Three-month and 1-year mortalities are greater than 50 and 75%, respectively.
- Most deaths are owing to HF and lethal arrhythmias.
- Low cardiac output state because of steal of stroke volume.
- Elevated LV end diastolic pressure and pulmonary congestion owing to LV diastolic volume overload.
- Increased LV wall stress imposed by global remodeling secondary to aneurysmal dilatation; thus, angina may worsen.

- The thinned myocardial wall is densely fibrotic, and variable calcification occurs.
- Although significant benefit from surgery is far from invariable, aneurysmectomy carries advantages over medical therapy in patients under age 75 who are healthy enough to undergo aneurysmectomy and any necessary CABG if clear indications are present.
- The thin, yet tough, fibrocalcific aneurysmal walls are not prone to rupture.

Aneurysmectomy

Indications:

- Surgery may not attain symptomatic benefit or prolong life and is carefully considered in younger patients with severe angina or intractable HF, refractory to optimal doses of digoxin, furosemide, and ACE inhibitor.
- Patients with lethal or potentially lethal arrhythmias: recurrent sustained VT, VF, patients resuscitated from cardiac arrest. This group will include patients whose arrhythmias have not responded to amiodarone or in whom adverse effects and intolerance to amiodarone exist. Some patients in this category may benefit from multiple programmable pacemaker–cardioverter–defibrillator. Aneurysmectomy and map-guided focus resection are offered at some centers, whereas a few use aneurysmectomy and extensive cryoablation applied to surrounding areas.

Contraindications:

- Elderly patients, infirmity, or underlying disease.
- Large aneurysm with no effective LV cavity to generate adequate stroke volume following aneurysmectomy.
- Poor contractility of the nonaneurysmal LV.

MEDICAL THERAPY FOR VENTRICULAR ANEURYSM

A large percentage of patients with LV aneurysm must be managed with drug therapy because of contraindications to surgery.

- Management entails the judicious use of digoxin, furosemide, and ACE inhibitor, and is discussed in Chapter 5.
- Recurrent sustained VT or resuscitation from VF is best managed with low-dose amiodarone (*see* Chapter 6). All antiarrhythmic agents, with the exception of amiodarone, mexiletine, and quinidine have marked negative inotropic effects and may precipitate HF, especially in patients with poor contractility, poor LV systolic function, and an EF less than 25%. Quinidine is relatively safe in patients with low EF, but has poor efficacy. The unsatisfactory nature of the results obtained with class 1 agents is undoubtedly amplified by a high incidence of proarrhythmic effects with most of these agents, especially in the presence of poor LV function. Amiodarone has low proarrhythmic effects and has a role in patients with life-threatening arrhythmias. The dose of amiodarone and adverse effects are given in Chapter 6.

LV thrombus occurs in over 80% of patients. The thrombus is usually laminated and well-attached to the endocardium, and embolization occurs in less than 3%. If there is no contraindication, warfarin is given to increase the prothrombin time ratio 1.25 to 1.5 times the control or to achieve an international normalized ratio of 2:3, for a period of 6 months in patients with nonlaminated thrombus protruding into the LV cavity and for 3 months with nonlaminated nonprotruding thrombi. Thereafter, enteric-coated aspirin is given. There is some evidence that aspirin can prevent occurrence of atrial and LV mural thrombi and it is advisable to give aspirin to patients with LV aneurysm.

Table 2.9.

Deep Venous Thrombosis, Ventricular Thromboembolism After Acute Myocardial Infarction

| <i>Parameters</i> | <i>Approximate incidence (%)</i> |
|--|----------------------------------|
| DVT patients | |
| Age >70 years | 72 |
| <50 years | 12 |
| Timing of occurrence | |
| <4 days | 15–25 |
| 5–15 days | 5–15 |
| 1–15 days | 20–40 |
| Effect of early heparin therapy | <4 |
| Pulmonary embolism | 4 |
| Early heparin | <1 |
| Mural thrombus | |
| Anterior infarcts | 30 |
| Large anterior infarcts | 50 |
| Systemic embolism | <4 |
| Effect of heparin (10,000–12,500 units SC 12 hourly) | <1 |
| Effects of early aspirin | To be defined |

Prevention of Thromboembolism

Antithrombotic therapy is required during the first 5 days of acute MI. Thereafter, aspirin is continued indefinitely.

Antithrombotic therapy is required to prevent deep vein thrombosis (DVT) and pulmonary embolism; LV mural thrombus formation and systemic embolization; reinfarction, especially among patients with non Q-wave infarction, because these patients are at high risk for reinfarction within 3 months; and reocclusion after successful coronary reperfusion with thrombolytic therapy.

Within 4 days of acute MI, DVT occurs in the lower limbs in some 15–25% of patients (Table 2.9.). An additional 10–15% of patients develop DVT in the ensuing 10 days. This early occurrence of DVT suggests the presence of a hypercoagulable state similar to that observed postsurgery. Table 2.10. gives ambulation advice.

The postinfarction incidence of DVT increases with the presence of cardiogenic shock, HF, and prolonged immobilization beyond the fifth day. Age over 70 years carries a sixfold increase with an incidence of about 70%; this may be compared with an incidence of only 12% among patients under age 50.

Three randomized clinical trials with a total of 130 patients using subcutaneous heparin, started within 18 hours of the onset of acute MI and given for 10 days, showed a reduction of DVT from 24 to 4% in the treated patients.

Studies done before the current era of early mobilization and use of aspirin plus or minus thrombolytic therapy have indicated a 4–5% incidence of post-MI pulmonary embolism. Thus, patients considered at low risk for developing DVT or pulmonary embolism (i.e., patients under age 65 with non-Q-wave infarcts, small infarcts, absence of heart failure, and ability to mobilize on day 2) can be given aspirin only to prevent DVT or pulmonary embolism. Patients given IV streptokinase should continue on aspirin; low-

Table 2.10.
Uncomplicated Postmyocardial Infarction Ambulation Day

| <i>Day</i> | |
|------------|--|
| 2 | Lower limb exercises, sit in chair, use bedside commode |
| 3 | Bed to chair, walk to shower, walk in room; transfer from CCU |
| 4 | Bathroom privileges, walk 100 feet supervised |
| 5 | Walk in corridor 200–600 feet; blood pressure pre and post 600 feet and one flight stairs. If stable, discharge on day 5–6. If no contraindications, predischarge (Naughton or similar protocol) exercise test is done prior to discharge. |

dose subcutaneous heparin is continued from day 2 to discharge if the patient is considered at high risk for thromboembolism. Dosage: enoxaparin 1 mg/kg every 12 hours subcutaneously (SC).

Prevention of Systemic Embolism

Mural thrombus occurs in approximately 20% of patients, but large anterior infarcts have an incidence as high as 60%. Systemic embolism occurs in fewer than 4%, and the incidence can be reduced to about 1% with subcutaneous low-molecular weight heparin (LMWH) given SC for 10 days. The incidence of mural thrombus and systemic embolism is reduced by the early use of aspirin and streptokinase. Continued aspirin therapy appears to decrease the incidence of mural thrombus and systemic embolism.

If heparin is not contraindicated and thrombolytic therapy has not been given, it is advisable to give subcutaneous LMWH to patients with large anterior infarcts or infarction, which include the apex of the heart.

Pericarditis

Approximately 40% of fatal MI show acute fibrinous pericarditis. The incidence of clinical pericarditis ranges from 5–25%. Pericarditis usually manifests during the second and fifth day postinfarction, localized in the area overlying the infarct, but may diffusely involve the pericardial sac. Approximately 50% are symptomatic.

CLINICAL HALLMARKS

Diagnostic features include the following:

- Mild-to-moderate pleuritic positional pain. Maximal over the precordium or sub-sternal area with occasional or typical involvement of the trapezius ridges (one or both).
- Pain is made worse with recumbency, deep breathing, and body movement and is improved by leaning forward.
- Pain can be confused superficially with postinfarction angina. It is of paramount importance to distinguish the two conditions because the latter usually requires interventional therapy beginning with coronary angiography, whereas pericarditis requires conservatism, except when it is associated with myocardial rupture (*see* Subacute Rupture). The pain of angina or infarction does not radiate to the trapezius ridges. This is an important differential point because radiation to the trapezius muscles is virtually never seen with myocardial ischemia.
- A pericardial friction rub is heard in 10–30% of cases. The rub is typically evanescent and may come and go over 1–2 days, may increase with inspiration or expiration, coughing,

or swallowing, and is best heard with the diaphragm of the stethoscope with the patient leaning forward. The rub usually has two diastolic components: early, during the early diastolic phase, and late, owing to atrial systole. A third component occurs during ventricular systole. Occasionally, only one component may be heard, and the rub must be distinguished from acute mitral regurgitation, in which a soft murmur is produced as a result of papillary muscle dysfunction. Pericardial friction rub has a superficial scratchy characteristic.

- ECG changes may be difficult to interpret: j-point elevation, concave upward ST elevation, and PR segment depression.
- Echocardiography is helpful in revealing pericardial effusion in over 33% of patients.
- Pericarditis is more common in patients with Q-wave infarction.

THERAPY

- Discontinue heparin.
- Treatment is indicated for pain even when no friction rub is present.
- Aspirin in full doses, 650 mg three times daily, is useful; NSAIDs or corticosteroids should be avoided because indomethacin and similar agents may cause vasoconstriction and alter myocardial healing and appear to increase the incidence of myocardial rupture. Also, these agents cause retention of sodium and water.

Pericarditis, presenting between 2 weeks and 6 months of infarction, and Dressler's syndrome, reported in the 1970s, occur in about 0.1% of patients and is now exceedingly rare. Fever, pleuritic positional pain, increased sedimentation rate, and increased titer of heart reactive antibodies may be present; NSAIDs are best avoided because they cause pericardial vasoconstriction and increase stress on the myocardium. Dressler's syndrome appears to be caused by an autoimmune autoantibody response. This type of pericarditis is currently no longer observed, probably because of the use of aspirin in virtually all patients with acute MI.

This late pericarditis is treated with aspirin. Failure to respond or relapses should be managed with a short course of prednisone with aspirin overlapping at least 2 weeks before prednisone is withdrawn.

DISCHARGE MEDICATIONS

β-Blockers

If β-blockers were commenced during the early hours of MI and no adverse effects were apparent, then β-blockers should be continued. If not given at that time, β-blockers should be administered before discharge and maintained for at least 2 years. Studies indicate that this approach is highly beneficial and cost-effective.

β-BLOCKER CLINICAL TRIAL RESULTS

More than 15 β-blocker trials have been conducted on post-MI patients. Several of these trials, however, lack the methodology that is consistent with current practice in clinical trial design. Unacceptable metaanalyses have been carried out using β-blocker trials that included few patients, some nonrandomized trials, and trials in which β-blocker therapy was commenced later than 1 month postinfarction. Also, the β-blocker used in several trials was inappropriate; oxprenolol has intrinsic sympathomimetic activity that negates cardioprotective effects (*see* discussion: Which β-blockers to choose in Chapter 1, p. 56 and Chapter 4).

Table 2.11.
Mortality Reduction in Long-Term β -Blocker Trials

| <i>Trial</i> | <i>Placebo mortality</i> | <i>Drug mortality</i> | <i>Relative reduction (%)</i> | <i>p</i> |
|--|--------------------------|-----------------------|-------------------------------|----------|
| Norwegian (1981) 20 mg timolol daily | 152/939 16.2% | 98/945 10.4% | 35.5 | <0.001 |
| BHAT 180/240 mg propranolol daily | 188/1921 9.8% | 138/1916 7.2% | 26.5 | <0.01 |
| Salathia (1985) 200 mg metoprolol daily | 43/364 11.8% | 27/391 6.9% | 41.5 | <0.05 |
| APSI trial (1988) 400 mg acebutolol daily | 34/309 11.0% | 17/298 5.7% | 48 | 0.019 |
| Capricorn 25 mg carvedilol twice daily | 15% | 12% | 23% | 0.031 |

Clinical trials that meet most current acceptable standards are listed in Table 2.11. These trials indicate an impressive 33% reduction in mortality owing to β -blocker therapy. Mortality reduction with propranolol is significantly less than that observed with timolol in smokers. The efficacy of hepatic-metabolized β -blockers is blunted by cigarette smoking. It is necessary to prescribe metoprolol or timolol to refractory smokers.

If there is no contraindication to β -blockade, virtually all post-MI patients should receive carvedilol 25–50 mg twice daily; 10 mg of timolol twice daily; 400 mg of acebutolol daily, or 100–200 mg of metoprolol daily. Propranolol (180–240 mg daily) is advisable only in nonsmokers. The American College of Cardiology/American Heart Association task force recommends treatment to commence within the first few days of infarction and to continue for at least 2 years in virtually all patients if there are no contraindications to β -blockers. Timolol has been shown to cause a 67% reduction in sudden death in post-MI patients and a 35% reduction in total mortality in patients followed for 2 years postinfarction.

It is estimated that 70% of postinfarction patients are suitable for β -blocker therapy. Up to 20% of postinfarction patients are unable to receive β -blockers because of contraindications, and a further 10% have relative contraindications.

Contraindications to long-term β -adrenergic blockade include:

- Severe LV failure; *see* Chapters 5 and 14, for use in HF.
- SBP less than 100 mmHg.
- Heart rate less than 50/minute.
- Type I, II, or III AV block.
- Asthma or severe chronic obstructive pulmonary disease.

β -Blockers are of particular value in post-MI patients with mild LV dysfunction or mild HF. Because β -blockers are capable of producing about a 28% reduction in reinfarction rates, up to 67% reduction in sudden death, and a 33% decrease in mortality, it is advisable to prescribe these medications to virtually all patients who can tolerate the effects at the dosage indicated previously. Carvedilol, metoprolol, and timolol are better

Table 2.12.
 β -Blocker Reduction of Early Morning Sudden Cardiac Death

| <i>Sudden deaths</i> | <i>Control</i> | <i>Propranolol</i> | <i>Decrease</i> |
|----------------------|----------------|--------------------|------------------|
| Total | 78 | 60 | 23% ^a |
| 5–8 AM | 6 | 0 | |
| 5–11 AM | 25 | 11 | 56% |
| 11–4 AM | 33 | 31 | Similar |

^aTimolol; 67% reduction in sudden death.

Modified from β -Blocker Heart Attack Study Data. *Am J Cardiol* 1989;65:1518.

tolerated than propranolol and are preferred. If mild adverse effects occur, the drug dosage should be decreased slightly or a switch should be made to another β -blocking agent. Subtle but important differences of various β -blockers are discussed in Chapters 4 and 8. Patients should be encouraged to persist with therapy except when adverse effects are bothersome.

Protective effects of β -adrenergic blockade appear to relate to their ability to actuate:

- A decrease in early morning sudden cardiac death (*see* Fig. 1.1. and Table 2.12.).
- A decrease in the incidence of myocardial free-wall rupture.
- A decrease in lethal arrhythmias, causing only a modest suppression of ventricular premature beats (VPBS).
- An increase in VF threshold and a decrease in the incidence of VF.
- Proven decrease in the incidence of fatal and nonfatal MI rates, possibly by decreasing hydraulic stress at the site of atheroma, thus preventing plaque fissuring and subsequent thrombosis. The action of β -blockers to attenuate the hemodynamic effects of catecholamine surges may protect a vulnerable atheromatous plaque from rupture and consequent “coronary thrombosis that leads to fatal MI, sudden death, or nonfatal MI, (*see* Fig. 1.1.).
- Prevention of early morning platelet aggregation induced by catecholamines and decreased early morning peak incidence of acute MI and sudden death (Table 2.12.).
- Decreased renin activity. This may have salutary effects on ventricular remodeling. Decreased aneurysmal expansion may occur.

In the United States, β -blocker usage in the postinfarction patient can prevent more than 15,000 deaths in the first year and up to 60,000 deaths over 5 years in patients at medium or high risk. The effectiveness of β -blockers in the low-risk postinfarction population is modest but worthwhile because it is occasionally difficult to correctly assign risks based on prognostic parameters, including postdischarge exercise stress testing and nebulous results provided by spect scintigraphy. In addition, β -blocking agents prevent sudden cardiac death, and it must be emphasized that aspirin has little effect on the prevention of sudden cardiac death. β -Blockers interfere with dipyridamole cardiac nuclear imaging and the β -blocking drug must be slowly discontinued if this test must be performed, so caution is necessary.

Adverse effects and dosage of β -blockers are given in Chapter 4.

Acetyl Salicylic Acid (Aspirin)

With chewable aspirin, patients must be advised that 160–320 mg taken within an hour of the onset of chest pain can prevent the occurrence of MI or death in a significant number of patients, whereas sublingual nitroglycerin does not offer protection. This advice will motivate patients to carry chewable aspirins for use at the crucial period.

Indications for 75–325 mg of daily coated aspirin include:

- Unstable angina.
- Stable angina.
- Post-MI prophylaxis.
- Prevention of systemic embolization from atrial or ventricular thrombi.
- Prevention of pulmonary embolism.
- Prevention of fatal or nonfatal strokes in patients with cerebral transient ischemic attacks or poststroke.
- Post-CABS to prevent graft occlusion.
- Lone AF in patients under age 65.

The action of aspirin irreversibly acetylates the platelet enzyme cyclooxygenase, thus preventing platelets from forming the powerful aggregating agent thromboxane A₂, resulting in a decrease in platelet aggregation. One dose of 80 mg of aspirin inhibits cyclooxygenase for the 1-week lifespan of the circulating platelets. This action abolishes platelet aggregation that would occur in response to stimuli, such as collagen, arachidonate, second-phase aggregation by ADP and epinephrine, and aspirin, which unfortunately reduces the formation of the potent vasodilator prostacyclin, of which the smallest possible dose is advisable—75–160 mg daily—so as not to inhibit prostacyclin. Further studies will clarify the dose range. Currently, a dose of 81–325 mg daily is widely used in post-MI patients.

Aspirin causes a reduction of the early morning incidence of acute MI but does not prevent sudden death (*see* Table 2.13.). The incidence of gastrointestinal bleeding is shown in Table 2.14.

Nitrates

Nitroglycerin is given to all patients upon hospital discharge, including patients with uncomplicated infarction at a dosage of 0.3-mg sublingual tablet or 0.4-mg nitrolingual spray. Two chewable aspirins can be conveniently carried in the cap of the spray. If pain occurs, the patient is advised to take the drug sublingually while sitting or propped up in bed to allow sufficient pooling of blood in the periphery. The drug must not be taken while standing because presyncope or syncope may occur, especially in patients on concomitant therapy with ACE inhibitors, diuretics, or calcium antagonists.

Oral nitrates are not prescribed routinely to post-MI patients, except for patients with postinfarction angina, who are unable to undergo coronary angioplasty or bypass surgery because of contraindications, such as advanced age or serious underlying disease. Where required, oral nitrates are best used in combination with a β -blocker because they do not prevent reinfarction and have not been shown to decrease mortality. Dosage and other effects of nitrates are given in Chapter 4.

Calcium Antagonists

Calcium antagonists do not have a role during the early phase (days 1–4) of acute MI (*see* Chapter 1). Calcium antagonists have not been shown to significantly decrease mortality in the postinfarction patient and are advisable only when β -blockers are contraindicated for the management of postinfarction angina). A meta-analysis indicates that calcium antagonists do not reduce infarct size or mortality, and in some categories of patients, these agents increase the risk of death.

Table 2.13.
Aspirin Reduction of Early Morning Myocardial Infarction
But Not Sudden Death^a

| | <i>Aspirin</i> | <i>Placebo</i> | <i>p</i> |
|------------------------------|----------------|----------------|----------|
| Fatal MI | 10 | 26 | 0.007 |
| Nonfatal MI | 129 | 213 | 0.0001 |
| Sudden death | 22 | 12 | 0.08 |
| Other coronary heart disease | 24 | 25 | |
| Stroke death | 9 | 6 | |
| Total cardiovascular death | 81 | 83 | |

^a22,071 physicians aged 50–80: 325 mg of aspirin alternating days over 5 years.
Modified from The Physician's Health Study. N Engl J Med 1989;321:129.

Table 2.14.
Gastrointestinal Bleeding in the Physicians Study^a

| | <i>Aspirin</i> | <i>Placebo</i> | <i>p</i> |
|------------------------|----------------|----------------|----------|
| Upper gastrointestinal | 38 | 28 | |
| Melena | 364 | 246 | 0.00001 |
| Transfusion | 48 | 28 | |

^a22,071 physicians.
Modified from The Physicians' Health Study. N Engl J Med 1989;321:129.

There is no role for routine prophylactic use of diltiazem or verapamil during the first 2 years in patients with non-ST elevation MI.

The Danish study group on verapamil in MI showed an 18-month mortality rate of 11.1% and 13.8% in the verapamil- and placebo-treated groups, respectively ($p = 0.11$).

Numerous postinfarction patients have been given diltiazem. This practice has been based on a small non-Q-waves infarction study. In the 1986 non-Q-wave infarction study, performed on 288 control patients and 288 patients given high-dose diltiazem, 360 showed a 51% reduction in reinfarction rates in patients with non-Q-wave infarction treated from day 1 for 14 days. This small study group did not show a decrease in mortality. A large multicenter study, however, involving 2466 patients, was completed in 1988 (Table 2.15.). This study showed no decrease in total cardiac mortality, and there was no significant decrease in reinfarction rates in patients with Q-wave versus non-Q-wave infarction. A significant increase in mortality attributable to diltiazem was observed in patients with pulmonary congestion and LVEF below 40%. The increase in mortality persisted during long-term therapy beyond 1 year.

In patients with an EF below 40%, HF occurred in 12% (39/326) of patients on placebo and in 21% (61/297) of patients receiving diltiazem ($p = 0.004$).

Only 514 patients with non-Q-wave were enrolled in this study. The cumulative 1-year cardiac event rate (death and/or nonfatal reinfarction) was 9% in diltiazem-treated and 15% in placebo-treated patients. There was a small decrease in reinfarction rates only in patients treated up to 6 months. Reinfarction after 6 months occurred in 13 patients in the

Table 2.15.
Diltiazem in Acute Long-Term Myocardial Infarction

| | <i>Placebo patients</i> | <i>Diltiazem patients</i> | <i>Comments</i> |
|--------------------------|-------------------------|---------------------------|---|
| Cardiac deaths | 124 | 127 | |
| Noncardiac deaths | 43 | 38 | |
| Total mortality | 167 | 166 | |
| Reinfarction | 116 | 99 | |
| Total cardiac events | 226 | 202 | 11% decrease $p = 0.26$ |
| Ejection fraction < 40% | | | |
| Heart failure occurrence | 39 12% | 61 21% | $p < 0.004$ ↑heart failure owing to diltiazem |

Modified from N Engl J Med 1988;379:385; and Circulation 1991;83:52.

↑, increase.

placebo group and in 14 in the treated group. Firm conclusions cannot be made from subgroup analysis of an overall negative study. Also, these studies were done before the era of widespread aspirin use in patients with non-Q-wave infarction.

Contraindications to calcium antagonists postinfarction include pulmonary congestion of all grades, EF of less than 40%, bradyarrhythmias, suspected sinus, or AV node disease, hypotension, and dihydropyridine should not be used in the first 6 months post-MI without added β -blocker therapy because survival may be unfavorably influenced.

Caution: do not combine β -blockers with calcium antagonists, except in carefully selected patients, to avoid HF and bradyarrhythmias (*see* Chapter 4). The evidence indicating that diltiazem decreases reinfarction rates and non-Q-wave infarction is weak. Meta-analysis of therapy with calcium antagonists in postinfarction patients has revealed an excess mortality (averaging 6%). This mortality is markedly increased if pulmonary congestion, LV dysfunction, or bradyarrhythmia is present.

ACE Inhibitors and ARBs

The beneficial effects of ACE inhibitors in the acute phase of infarction were discussed earlier in this chapter under HF. A detailed discussion of these agents is given in Chapters 1 and 5. Only their prophylactic role is considered in this section.

The renin angiotension aldosterone system is stimulated during acute infarction, and the degree of stimulation relates to the size of the infarct. Increase in renin activity appears to relate to an increase in mortality. This finding is, of course, to be expected because patients with large infarcts and of less than 35% have high in-hospital and 1-year mortalities. LV dysfunction or concomitant decrease in BP stimulates the renin angiotensin system.

Some degree of ventricular enlargement is detectable in over 40% of patients with Q-wave transmural anterolateral infarction and is observed as early as 1 or 2 weeks after the event. Physical slippage and reorientation of myocyte bundles in the infarcted area occur, causing thinning and expansion. The left ventricle appears to undergo a variable amount of dilatation with some hypertrophy of the noninfarcted area.

Stimulation of the renin angiotensin system plays an important role in augmenting diastolic and systolic wall stresses, producing further LV enlargement. The structural

changes in the left ventricle, termed remodeling, appear to have some detrimental effects that may later increase the incidence of HF.

Fortunately, ACE inhibitors favorably influence remodeling and improve EF, and their use may be considered in postinfarct patients without overt HF, but with EF less than 35%. The results of the SAVE, AIRE,trandolapril, and SMILE studies were discussed earlier.

Ramipril 5 to 10 mg or captopril therapy (25–75 mg daily) is advisable, commencing between day 2 and discharge provided the SBP remains greater than 110 mmHg. ACE inhibitors are continued in patients with HF or in those without HF with anterior infarction, or EF less than 40%. Patients are discharged on an equivalent dose or enalapril 10–20 mg daily, ramipril 5–10 mg, perindopril or other ACE inhibitor; therapy in these patients reduces the incidence of hospitalization for heart failure and improves survival. ARBs (particularly candesartan and valsartan are advisable when there is intolerance to ACE inhibitors.

Cholesterol-Lowering Agents

The in-hospital diet should reflect the dietary advice given to the patient. Instructions on the value and use of a low saturated fat diet with an increase in polyunsaturated fatty acids, as outlined in the AHA guidelines or similar instructions, are appropriate for all patients.

Serum cholesterol and high-density-lipoprotein (HDL) and low-density-lipoprotein (LDL) cholesterol should be evaluated before discharge from hospital. A statin is administered to maintain the LDL cholesterol less than 80 mg/dL (2.0 mmol/L) and C-reactive protein (CRP) at low levels regardless of LDL goal levels.

Dietary measures include a mediterranean-type diet and increased consumption of almonds and walnuts.

PSYCHOSOCIAL IMPACT OF THE HEART ATTACK

The emotional distress to the individual in the months after an acute MI is often as severe as the heart attack itself. The intense apprehension concerning an impaired quality of life, returning to work, and the ability to meet financial obligations poses a threat to the patient's well-being and must be considered of paramount importance by the treating physician and the medical, nursing, and social teams. Thus, psychological intervention should be commenced from day 3 or 4 after admission.

The patient and the family must be given information concerning diagnosis and proposed therapy. The patient should be reassured, especially if HF is not present with uncomplicated MI. The removal of an oxygen mask or nasal prongs if hypoxemia is absent serves to reassure the patient and family that improvement is underway. Anxiety and depression may center around concerns about long-term disability or death and may persist for weeks to months in more than 50% of patients with infarction. It is imperative that the patient be allowed to discuss fears and inner feelings at this early stage and again before discharge. The reassuring tone of the patient's cardiologist or treating physician helps allay anxiety. Information to the patient and family that the damage affected the inferior surface, an inferior MI, and that this indicates a small heart attack, an excellent outcome for now and years to come, are most encouraging news.

Decisions concerning the length of hospital stay and, with uncomplicated infarction, an approximate date of return to work should be given as early as day 3, with the understanding that these are rough estimates of the timing that will materialize as long as

the expected progress is continued. Early ambulation from day 2 also helps to allay anxiety.

A trainee, nurse, or social worker may attend to other aspects of discussion regarding family matters. Stress associated with the patient's employment should be thoroughly explored and advice and assistance should be given. Advice must be consistent to avoid discrepancies between the physician's recommendations and those of trainees or the nursing staff.

Although small doses of anxiolytic agents may be required during the first 2 days post-MI, patients should be quickly weaned off of these agents. Patients can usually overcome their emotional hurdles by clear advice from the nursing staff, and few patients require antidepressant drugs.

Uncomplicated infarct patients are usually discharged on day 4, 5, or 6. Patients with HF usually require more time, and those with complications not requiring PCI are often ready for discharge on the 6th, 7th, or 8th day. Patients with uncomplicated infarction are advised to return to nonstressful work in 6–8 weeks; depending on complications, 10 weeks to 3 months may be required.

Sexual activities should be permitted within 3 weeks of returning home. Risk stratification should suffice to assure the patient that sexual activity can be resumed within weeks of discharge. Further advice should be given after the results of the 3- or 6-week post-MI exercise test.

For most sexually active individuals, intercourse is one of the most enjoyable, satisfying, and stress-relieving activities that life provides. The treating physician should encourage sexual activity, except in the obviously complicated cases, because this advice may convince the patient that all is proceeding well. This reassurance serves to control the fear of impending doom. Males must be reassured that heart attacks do not cause impotence and that the lack of intercourse for 3–6 weeks will not alter later sexual performance. It is important to explain to the patient that there is no reason to change to a different position; the most familiar position is usually best. This advice increases confidence in the male and allays anxiety in the female. The patient may also be reassured to learn that by 3 months after infarction, more than 80% of patients are able to engage in sexual performance with normal intensity and frequency.

Rehabilitation

Some patients require vocational and stress management counseling. Resumption of prior physical and sexual activity and engagement in some form of exercise program improves the patient's morale and emotional, psychological, and vocational status.

Walking is the most commonly prescribed exercise activity for patients. Uncomplicated infarct patients are expected to increase from 0.25 mile at week 2 to 1 mile at 3 weeks and, after a 3-month period, to have regular 1–2-mile brisk walks at least 6 days a week, in addition to normal activities. A brisk 1-mile walk twice daily, climbing three flights of stairs, and stretching exercises are advisable. Also advised is a 1-mile walk in 20–30 minutes over the first few weeks, followed, in energetic individuals, by the same distance covered in about 15 minutes. Healthy patients up to age 75 have improved their peak oxygen consumption status by walking outdoors and/or in shopping or rehabilitation centers.

Riding a stationary bike, simulated cross-country skiing, stretching exercises, or similar activities are common inexpensive modes of exercise. Many patients take pride in their ability to exercise, and this must be encouraged. The 3- or 6-week exercise test helps reassure the patient and indicates the level of activity desired and its safety.

Table 2.16.

Contraindications to Exercise Training Programs for Postmyocardial Infarction Patients^a

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|--|
| Patients with suspected ischemia are deferred pending interventional therapy |
| Inability to manage about 5 METS at 3 or 6 weeks exercise stress testing |
| Overt or treated heart failure ^a |
| Suspect left ventricular systolic dysfunction, ejection fraction <35% ^a |
| Systolic blood pressure <100 mmHg |
| Bradycardia pulse <60 mmHg not owing to β -blockade, sinus, or atrioventricular node dysfunction |
| New left bundle branch block during recent infarction; difficult to assess ischemic changes ^a |
| Ventricular arrhythmias (uncontrolled) |
| Uncontrolled systolic hypertension: systolic > 200, diastolic hypertension > 105 mmHg |
| Significant valvular heart disease ^a |

^aindividual exercise prescriptions.

Jogging and swimming, for interested patients, should commence after a 6-week exercise test. Jogging is built up slowly, 1 mile daily, increasing over months to 3 miles daily. Regular exercise is encouraged for at least 4 days per week. Patients should refrain from weight lifting, rowing, and other static exercises.

SUPERVISED REHABILITATION PROGRAMS

These important programs require the services of a physician, a nurse coordinator, a physical therapist, and a social worker/psychiatrist.

There is no proof from randomized trials that exercise training programs improve survival. Improvement of muscle tone and the ability to perform employment activities and engage in a sporting hobby, however, enhance quality of life.

Patients with ST elevation MI who are able to do greater than 6 metabolic equivalents (METs) at 3 or 6 weeks exercise testing may participate in rehabilitation exercise programs. The patient should achieve 20 BPM above heart rate resting.

Peak blood pressure should not exceed 140 mmHg, and heart rate should not exceed 140 BPM.

Only patients with moderate to severe HF, angina, inability to manage about 6 METs, VT, or complex ventricular arrhythmias are denied access to exercise programs (Table 2.16.). Participation is not allowed until residual ischemia has been managed by angioplasty or CABG, if feasible, and hypertension or arrhythmia has been controlled.

Patients should learn to take their pulse rate. An increase in pulse rate to 120–130 BPM should suffice. Patients on β -blockers should be advised not to exercise beyond the point of shortness of breath. The physician should also recognize the minority of patients in whom a very gradual program with only mild exercise is appropriate (*see* Table 2.16. for these categories and contraindications to exercise training programs).

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