Epidemiology and management of heart failure and left ventricular systolic dysfunction in the aftermath of a myocardial infarction

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Robust epidemiological data on the incidence of myocardial infarction (MI) are hard to find, but synthesis of data from a number of sources indicates that the average hospital in the UK should admit about two patients with a first MI and one recurrent MI per 1000 population per year. Possibly the most relevant data on the incidence, prevalence, and persistence of post-MI heart failure can be derived from the TRACE study. Most patients will develop heart failure or major left ventricular systolic dysfunction (LVSD) at some time after an MI, most commonly during the index admission. In up to 20% of cases this will be transient, but such patients still have a poor prognosis. There is likely to be around one patient discharged per thousand population per year with heart failure or major LVSD after an acute MI. It is important to organise care structures to ensure that patients with post-MI heart failure and LVSD are identified and managed appropriately.

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Left ventricular systolic dysfunction (LVSD) is a common and serious complication of myocardial infarction (MI) that leads to greatly increased risks of sudden death and of heart failure. Effective and cost effective treatment is available for such patients that can reduce both morbidity and mortality.[1] Accordingly, it is appropriate to organise care structures to ensure that patients with post-MI heart failure and LVSD are identified and managed appropriately.

The increased risk of sudden death associated with LVSD and heart failure may be caused by either recurrent MI or arrhythmias.[2] Recurrent MI often presents as sudden death if left ventricular function is already impaired and scar tissue is present, either because cardiogenic shock develops rapidly or because of the induction of arrhythmias. Although LVSD is the main reason for heart failure after MI, there are other causes. Myocardial infarction may cause papillary muscle dysfunction and mitral regurgitation or provoke arrhythmias, such as atrial fibrillation, leading to heart failure. However, heart failure may also develop in the absence of major LVSD, valve or rhythm problems. These patients also do not appear to have a good prognosis.[3–6] The mechanisms underlying this phenomenon are unclear and in some patients the diagnosis of heart failure will be wrong. In other patients, the left ventricle may fail to dilate because of pre-existing myocardial fibrosis or hypertrophy or myocardial ischaemia may impair myocardial relaxation. Alternatively, cardiac dysfunction may be only transient due to myocardial stunning, arrhythmias or papillary muscle dysfunction. All of this is poorly documented.[7]

In terms of pharmacological management, there is evidence that β blockers improve the outcome of patients with heart failure whether or not they have LVSD.[8–10] Angiotensin converting enzyme (ACE) inhibitors (fig 1) and at least one aldosterone antagonist can improve outcome in patients with LVSD and may be of benefit even in patients with heart failure but without LVSD.[1] There is no evidence that aspirin is safe or effective beyond 6–12 weeks after an acute vascular event, although there are some data to support the use of warfarin.[11 12] Data on the safety and efficacy of statins in patients with post-MI heart failure are lacking.[13]

Heart failure and LVSD are clearly important targets for which effective treatment exists. The purpose of the article is to try to quantify the size of the problem and to describe contemporary management. It is useful to put epidemiological statistics in context to test their validity against the perceived clinical activity. Approximately 1% of the UK population (about 600 000 people) are cared for by one large hospital trust based in Kingston upon Hull. This provides a context in which to view the statistics discussed.

WHAT IS THE INCIDENCE OF MI AND IS IT CHANGING?

It is probable that the incidence of MI varies around the world, although when age and sex matched populations are compared the differences may not be so great. MI is common in China, Australasia, Europe, and the Americas, as evidenced by large, relevant trials from each of these regions. Robust epidemiological data are hard to find because the majority of studies have restricted their interest either to certain age groups and/or only to patients with a hospital diagnosis and have been retrospective.[14]

The British Heart Foundation estimates that there are about four MIs per thousand population per year, but hospital discharge statistics in

Abbreviations: ACE, angiotensin converting enzyme; LVSD, left ventricular systolic dysfunction; MI, myocardial infarction; MINAP, Myocardial Infarction National Audit Project; NT-proBNP, N terminal pro B-type natriuretic peptide; TRACE, trandolapril cardiac evaluation

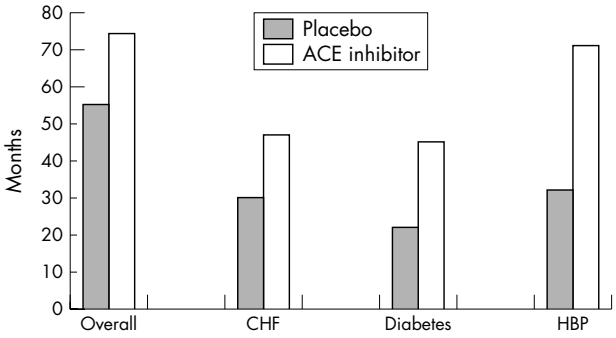

Figure 1 Median life expectancy after a myocardial infarction complicated by major left ventricular systolic dysfunction in the TRACE study.[48] Comparison between the effect of placebo and trandolapril. ACE, angiotensin converting enzyme; CHF, congestive heart failure; HBP, high blood pressure.

the UK suggest only half of that amount (table 1). There were just over 1000 patients with a death or discharge diagnosis of MI in Hull in 1998, very close to the national hospital figure of two MIs per thousand population per year and almost certainly an underestimate of the true figure. The Myocardial Infarction National Audit Project (MINAP) for England (and Wales)—which aims to report the outcome of all patients not just with MI but also other acute coronary syndromes either leading to hospitalisation or developing during admission—recorded 92 988 episodes, but only two thirds of these were reported to be MI, or about 1.2 infarcts per thousand population per year.

There are likely to be several reasons for the above discrepancies. Perhaps 20–30% of people suffering an MI will die before they reach hospital.[15 16] About 25% of patients will have no symptoms or symptoms that are mistaken for a less serious problem and will not seek hospital attention or be referred to a cardiologist.[17–19] It is likely that hospital statistics are an underestimate of hospital activity. We know, from a review of our own case records, that when MI is reported on hospital death and discharge codes it is almost always appropriate. However, it is unclear how often coding is missed. The discrepancy between MINAP and the hospital discharge statistics is of even greater concern and almost certainly reflects selective reporting of obvious infarcts in younger patients with a typical presentation and relatively low co-morbidity; just the sort of patients who go into clinical trials. However, there is good evidence that it is the older patient with atypical presentation who is most likely to develop heart failure, has the worst prognosis, but is least likely to receive effective care.[17–19]

There are some serious consequences of selective reporting. Singling out a few patients and providing them with excellent care, while excluding patients with an intrinsically poor prognosis who have received less investigation and care, is the most efficient way of appearing to give good care when resources are limited. No doubt, as MINAP evolves and matures, the safeguards that have been built into the system will help prevent selective reporting. Using the number of events per hospital per thousand catchment population, together with the mean age and sex of the patients, as part of the published quality assurance for MINAP would be helpful. These data are already being collected.

Synthesising data from a number of sources, it is likely that the average hospital in the UK should admit about two patients with a first MI and one recurrent MI per thousand population (all ages) per year. If these data are true, then, for a city the size of Kingston upon Hull, there should be about 1800 MIs per year, almost double the amount coded for in 1998. Accordingly, the Hull Infarction Project for 2005 is a ''360°'' audit of acute coronary syndromes in Hull hospitals that will provide a benchmark for reporting rates (with confidence intervals) for other hospitals participating in the MINAP project, to identify how selective reporting to MINAP is. Selective reporting may lead to flattering rates of implementation of treatment (and of course vice versa—complete reporting is more honest but less likely to be flattering).

Recent publications suggest that the age adjusted risk of MI and coronary heart disease mortality are falling.[14] It is not clear that this has translated into an overall reduction in either.[16 20] As the proportion of older people in the population increases this may more than offset any gain in terms of a reduction in age related morbidity. Health services need to plan to care for people regardless of age, although taking their age into account when deciding what they need, and should not be unduly distracted by age adjusted epidemiological trends. Moreover, with the recent change in the diagnostic standards for MI, it is likely that the overall rate of MI in the population will increase, especially in people aged $>$ 70 years.[21 22]

WHAT PROPORTION OF PATIENTS WITH AN MI WILL HAVE OR DEVELOP LVSD OR HEART FAILURE ON THE INDEX ADMISSION?

LVSD and heart failure are not synonymous.[23] Some patients will suffer major left ventricular damage and yet be asymptomatic. Between 30–50% of patients who develop

Table 1 Incidence of myocardial infarction

Study	Years of data collection	Age limits	Population served	Cases	Incidence (events/1000/year)	Case fatality
MONICA†[14]	1985–1991	35–64 years	Large	3584	4.3	49% at 28 days
OXMIS[15]	1994–1995	<80 years	568800	1343	2.4	39% at 28 days
ARIC[16 20]	1987–1996	35–74 years	354357	14842	4.2	
BHF/NICE	Uncertain	All ages	58 million	268000	4.6	
Hospital Death and Discharge Statistics (England)	2002–2003	All ages	50 million	105476	2.1	
Hospital Death & Discharge Statistics (Scotland)[49]	1990–2000	All ages	4.8 million	96026 (225512*)	2.0 (4.7*)	
Hospital Death & Discharge Statistics (Scotland)[49]	2000	All ages	4.8 million	~8000 (~27000*)	1.7 (5.7*)	
MINAP	2003	All ages	~50 million	~60000	1.2	

†The definition included definite non-fatal myocardial infarction and possible, probable, or definite coronary heart disease mortality. Cities from 21 countries were included in the study. Belfast and Glasgow represented the UK. They had a much higher than average incidence than the mean but only a slightly lower 28 day case fatality.
*Cardiac chest pain including myocardial infarction and unstable angina.

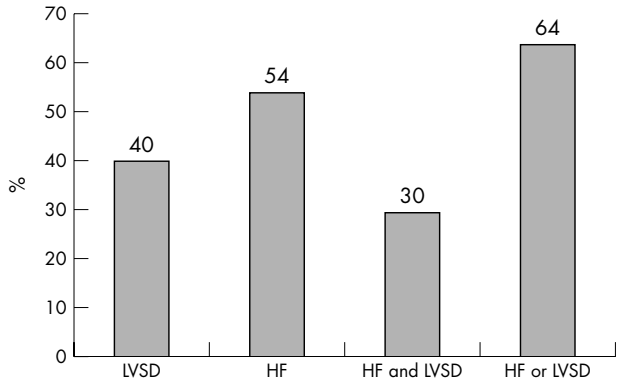

Figure 2 Proportion of patients with heart failure and left ventricular systolic dysfunction within the first few days after a myocardial infarction in the TRACE study.[27]

heart failure will do so in the absence of any LVSD, mitral regurgitation, or arrhythmias.[6 24] LVSD can be measured fairly objectively but symptoms and signs of heart failure are subjective and the threshold for diagnosis will vary widely among clinicians. Both LVSD and heart failure may occur early or develop late and both may recover. Many patients are given loop diuretics during the course of their MI and it is likely that most of these patients have exhibited signs or symptoms of heart failure.[25]

There are few data on the contemporary natural history of these phenomena. Surveys indicate that only about 60% of patients with an MI have their ventricular function assessed.[25] Moreover, it is clear that patients with a non-classical presentation of infarction, who are often not cared for by a cardiologist, are more likely to develop LVSD and heart failure and have a higher mortality.[17–19] Cardiology focused studies and registries are likely to underestimate the incidence of post-MI heart failure. It is hoped that the MINAP project will ensure that such selective reporting is avoided.

Perhaps the study of highest quality is the registry for the TRACE study, a randomised controlled trial comparing placebo and trandolapril in Denmark, predominantly (76%) in patients with a first MI.[23 26–28] Of 6526 patients in whom the wall motion index could be determined, 2606 patients (40%) developed major LVSD. Among those who had LVSD, 74% developed features of heart failure and 30% of all patients had both LVSD and heart failure. However, 24% of patients had features of heart failure but did not have LVSD. Overall, about two thirds of patients had either heart failure or LVSD (figs 2 and 3).

Other population studies corroborate a prevalence of major LVSD acutely after an MI of about 40%, although lower rates are generally reported in clinical trials that recruited patients selectively[25 29] (table 2). Before the widespread use of thrombolysis, ACE inhibitors, and β blockers, studies suggested progressive left ventricular remodelling occurred in a substantial proportion of patients, leading to an increasing prevalence of LVSD over time.[30] However, others focused on the delayed recovery from stunning and reported recovery from LVSD after MI.[31 32] It is likely that more aggressive treatment of MI has reduced the risk of adverse remodelling and improved the chances of recovery from LVSD.[32] However, modern treatment will also have kept a higher proportion of patients with severe LVSD alive but had little impact on those without major LVSD since their prognosis was already good.[33] Overall, it appears that the incidence of post-MI heart failure has changed little.[33–36] Obviously, the complex interactions between disease, outcome, and epidemiology require study rather than uncertain speculation.

The TRACE study suggested that over 50% of patients having an MI will develop symptoms and/or signs of heart failure and in about one third of these cases heart failure will have been present before their MI.[23] This incidence of new onset heart failure of about 40% is consistent with a systematic review of the literature[29] (table 2). Of patients who develop new onset symptoms of heart failure, about 70% will do so by the time of first hospital evaluation, while 30% will develop symptoms later during the index admission.

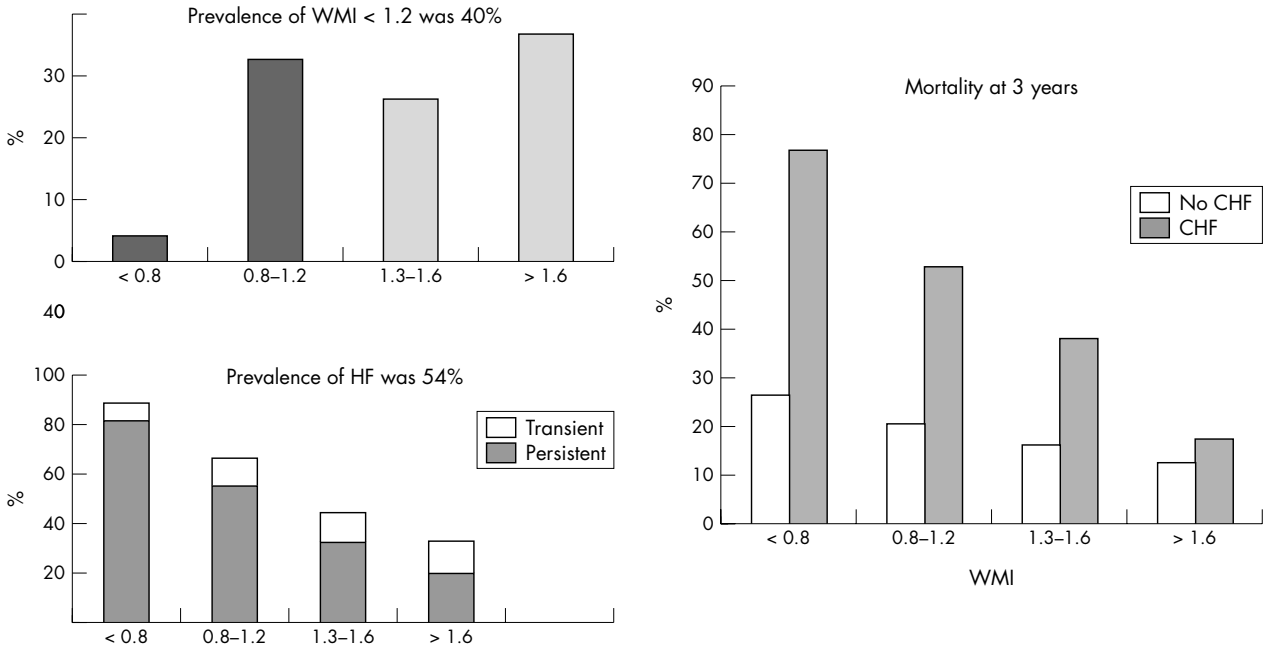

Figure 3 Proportion of patients with left ventricular systolic dysfunction, transient or persistent heart failure (HF) and their outcome in the TRACE study.[28] WMI, wall motion index.

Table 2 Prevalence and incidence of heart failure in patients with myocardial infarction

Study	Collection period	Exclusions	Number	Pre-existing HF	HF developing during index	HF developing after index	Total
US National Registry[36]	1994–2000	Shock or prior HF	606500		20.4%	8.6%*	29.0%
TRACE[23]	1990–1992	Shock or inadequate echo visualisation of LV function	6676	17.7%	36.9% (805 within first 2 days)	NA	54.6% (11.4% transient only)
EHS-ACS[25]	2000	Registry	10484	10%	~25%	NA	35%
Olmsted County[35 39]	1979–1994	Registry	2171	11.8%	24.2% within 30 days	16.8% over 6.6 years	53.1%
Framingham[34]	1950–1989	Registry	546		9.7% within 28 days	16.3% up to 10 years	26%
Hellermann review[29]	NA	Population based	NA	←	37% (95% CI 25% to 48%)	→	NA
	NA	Registry	NA	←	36% (95% CI 19% to 51%)	→	NA
	NA	Trials	NA	←	18% (95% CI 11% to 35%)	→	NA

CI, confidence intervals; HF, heart failure; NA, not applicable or available.
*Duration of follow up not available.

Other methods of data collection, and the clinical experience of some, suggest a lower incidence of heart failure. This could reflect a higher threshold for diagnosis, failure to include transient events, and exclusion of patients with pre-existing heart failure.

Another potential way of assessing the proportion of patients with heart failure after MI is to measure the amount of loop diuretic used, since the predominant use of these agents is for the management of fluid retention caused by heart or renal failure. The EuroHeart survey of acute coronary syndromes suggested that about 35% of all patients with MI will receive inpatient diuretic treatment but did not distinguish loop from thiazide diuretic.[25]

Clinical skills and cardiac imaging are not the only measures of cardiac dysfunction after an MI. Natriuretic peptides provide an alternative simple method of assessing cardiac function, although as the concentrations of these peptides are also dependent on renal function, they should really be considered a marker of cardio-renal dysfunction. Patients who have increased plasma concentrations of N terminal pro B-type natriuretic peptide (NT-proBNP) after an MI have a worse prognosis. The ability to predict a poor outcome is independent and additive to that of LVSD.[4 37 38] Accordingly, patients who have LVSD and elevated NT-proBNP have the worst outcome, those with LVSD alone or elevated NT-proBNP alone an intermediate prognosis, and those without LVSD or an elevation in NT-proBNP a good prognosis. Provided it is accepted that it is important to stratify risk in patients with MI—for example, in order to identify patients who do or do not need intensive treatment—then a combination of cardiac imaging, natriuretic peptide, and stress testing for ischaemia provides a robust strategy for risk profiling.

In summary, there should be about one patient discharged per thousand population per year with heart failure or major LVSD after an acute MI. Translated into the context of Kingston upon Hull, this should be about 500 cases each year.

HEART FAILURE DEVELOPING AND RECOVERING AFTER DISCHARGE FROM THE INDEX MI HOSPITALISATION

Not all patients who develop heart failure in the acute post-MI period will develop CHF. The TRACE study suggested that the signs and symptoms of heart failure would be transient in about 15% of patients with major LVSD and 40% of patients without major LVSD (fig 3).[28]

The incidence of heart failure developing for the first time after the index admission is even more uncertain. The Framingham study (population of Framingham about 65 000), based on rather limited evidence, suggested that although mortality had declined after an MI, the risk of heart failure had not, which the authors ascribed to improved survival among patients who had sustained major ventricular damage.[34] However, late onset heart failure (> 29 days after the event) may have been reduced by up to 50% although this analysis is based effectively on only 15 cases. The incidence of late onset heart failure in Framingham was only 1% per year. The Olmsted County study, which identified 2171 infarcts over 15 years from a population of about 130 000, suggested that 12% of patients had pre-existing heart failure and that 41% of patients would develop new onset heart failure (using the Framingham criteria, which do not require LVSD to be present) over 6.6 years, giving a combined total of 53% for the development of heart failure. Most new cases developed during the index hospitalisation, with an annual incidence thereafter of about 3%.[33 35 39] Recurrent MI was not reported to be an independent determinant of developing heart failure.[33 35 39] However, the Framingham criteria were designed to be specific rather than sensitive to a diagnosis of heart failure[40] and both of these studies are probably a significant underestimate of the risk of developing heart failure after an MI.

Three substantial studies of post-infarction LVSD that excluded patients with more severe heart failure developing during the index admission give some further insights[41–44]

Table 3 Progression of heart failure and mortality in randomised controlled trials of post-infarction left ventricular systolic dysfunction

Study	Year	HF at baseline	Diuretic use at baseline	Follow up	Subsequent HF event	Overall mortality
SAVE[42]	1987–1990	~40%	35%	42 months	15.5%	22.5%
CAPRICORN[43 44]	1996–1999	NA	34%	15 months	13.1%	13.6%
EPHESUS[41]	1999–2001	90%	60%	16 months	11.1%	15.6%

HF, heart failure; NA, not available.

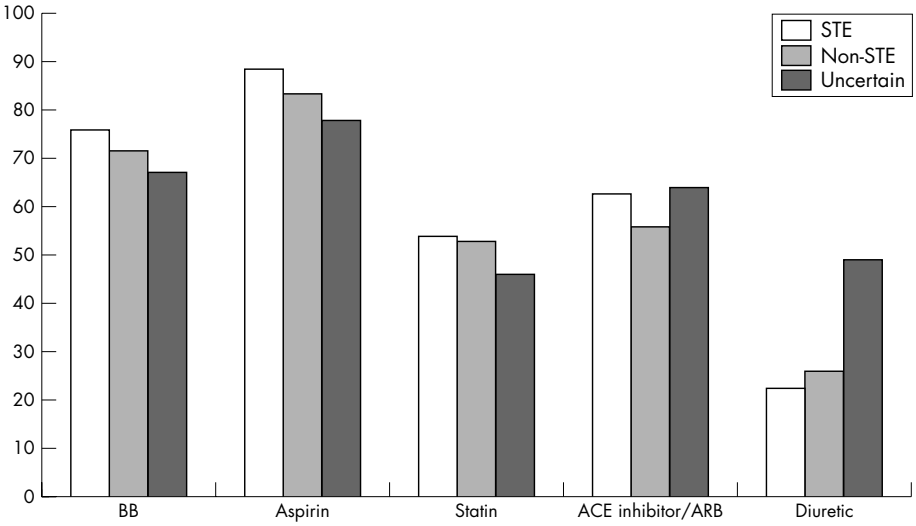

Figure 4 Pharmacological treatment after ST segment elevation (STE), non-ST segment elevation (Non-STE), and "ECG indeterminant" (Uncertain) myocardial infarction in the EuroHeart acute coronary syndrome survey. ACE, angiotensin converting enzyme; ARB, angiotensin II receptor blocker; BB, β blocker.

(table 3). However, patients with "mild" heart failure during the index admission were not excluded from these studies.

TREATMENT OF PATIENTS WITH LVSD AND/OR HEART FAILURE AFTER AN MI

Many contemporary clinical trials of LVSD and heart failure provide information about the treatment given in the aftermath of an MI. However, these trials are usually conducted by centres that have a quality of care above the average and often require patients to be started on optimal treatment before inclusion, and as such represent ideal clinical practice. Most surveys are also done by enthusiasts. National registries including all patients could be a better source of information but have to provide evidence that they are comprehensive. MINAP has the potential to provide an accurate and continuously updated description of the treatment of MI but lacks proof of systematic enrolment. Health insurance databases are another method of acquiring data and could, in the final analysis, be the most accurate way to collect data. However, national registries and health insurance databases rarely provide concomitant information on LVSD or heart failure symptoms. Hopefully, this will be

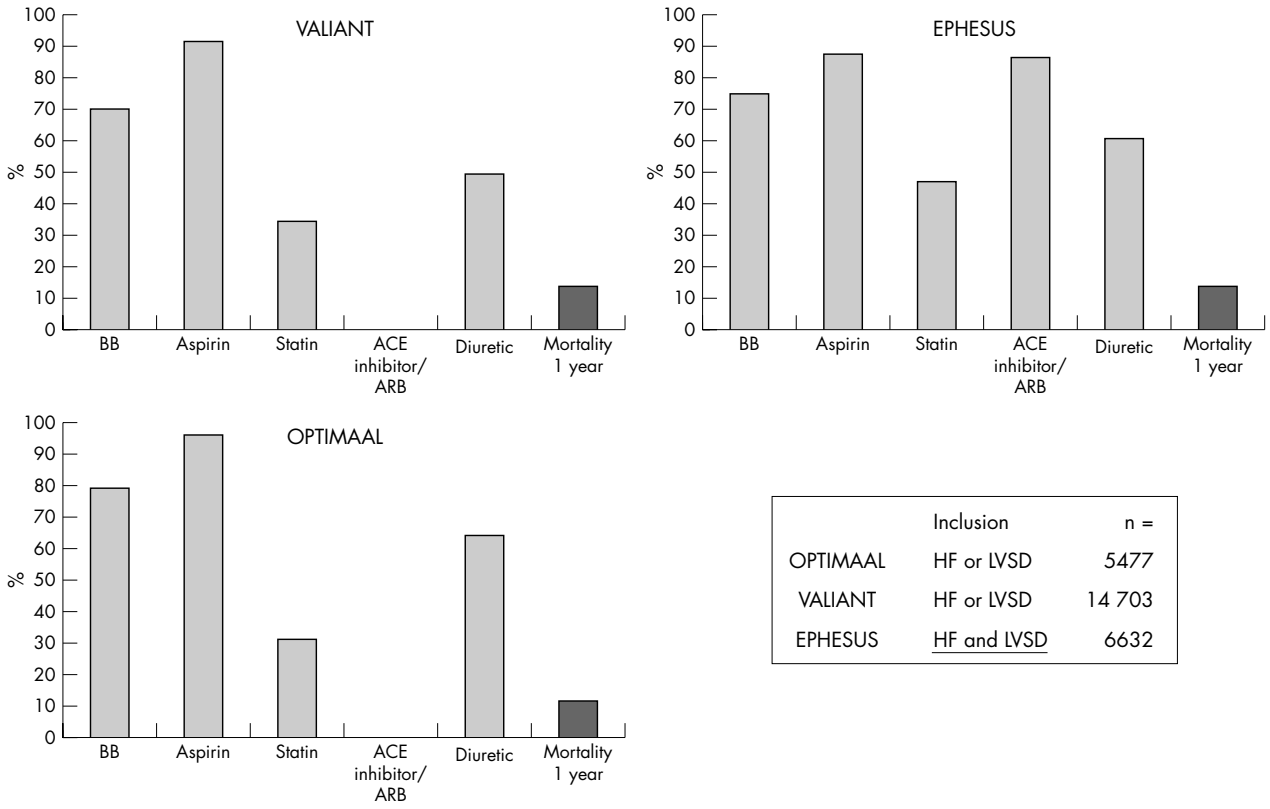

Figure 5 Pharmacological treatment after a myocardial infarction complicated by heart failure and/or left ventricular systolic dysfunction in three contemporary clinical trials.[41 45–47] In VALIANT and OPTIMAAL patients already taking ACE inhibitors or angiotensin receptor blockers were excluded. ACE, angiotensin converting enzyme; ARB, angiotensin II receptor blocker; BB, β blocker; HF, heart failure; LVSD, left ventricular systolic dysfunction.

Learning points

- The average hospital in the UK should admit about two patients with a first myocardial infarction (MI) and one recurrent MI per 1000 population per year
- Patients who develop heart failure or left ventricular systolic dysfunction after an MI, most commonly do so during the index admission
- In some patients, post-MI heart failure or left ventricular systolic dysfunction (LVSD) is transient but these patients still have a poor prognosis
- Care structures should be organised to ensure that patients with post-MI heart failure and LVSD are identified and managed appropriately

rectified in the near future, given that LVSD and heart failure are such powerful prognostic markers and since they influence the choice of treatment. Illustrative information on the contemporary use of therapies after an MI are given in figs 4 and 5.[41 45–47]

CONCLUSION

Most patients will develop heart failure or major LVSD at some time after an MI, most commonly during the index admission. In 10–20% this will be only transient, but such patients still have a poor prognosis.[28] In 30–50%, heart failure will not be accompanied by LVSD.[6 24 39] Although these patients have a better prognosis, they are still at increased risk, especially if they have raised values of natriuretic peptides.[4] However, patients at greatest risk are those most likely to be neglected by existing systems of care. This should be rectified.

Assuming there are approximately 240 000 MIs each year in the UK, probably 80 000 patients die before reaching hospital. Of those that reach hospital, the clinical course of over half will be complicated by heart failure or major LVSD, and one third will have both. Therefore, about 50 000 people each year will develop major LVSD and heart failure as a consequence of an MI. Once heart failure develops, 50% or more of these patients will be dead within five years. Implementation of a treatment that reduces mortality by about 20% could save about 5000 lives each year in the UK, if implemented systematically with adequate support to ensure safety.

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