Long-Term Prognostic Importance of Diabetes After a Myocardial Infarction Depends on Left Ventricular Systolic Function

Charlotte Andersson, mb[1]
Gunnar H. Gislason, md, phd[1]
Charlotte Mérie, md[1]
Ulrik M. Mogensen, mb[2]
Scott D. Solomon, md[3]
Christian Torp-Pedersen, md, dsc[1]
Lars Køber, md, dsc[2]

OBJECTIVE—This study was performed to understand how left ventricular function modulates the prognostic importance of diabetes after myocardial infarction (MI).

RESEARCH DESIGN AND METHODS—Consecutively hospitalized MI patients screened for three clinical trials were followed for a median of 7 years. Multivariable Cox regression models were used to assess the risk of mortality associated with diabetes, and the importance of diabetes was examined independently within defined left ventricular ejection fraction (LVEF) subgroups.

RESULTS—A total of 16,912 patients were included; 1,819 (11%) had diabetes. Diabetes and 15% unit depression in LVEF were of similar prognostic importance: hazard ratios (HRs) were 1.45 (95% CI 1.37–1.54) and 1.41 (1.37–1.45) for diabetes and LVEF depression, respectively. LVEF modified the outcomes associated with diabetes, with HRs being 1.29 (1.19–1.40) and 1.61 (1.49–1.74) in patients with LVEF <40% and LVEF ≥40%, respectively ($P = 0.03$).

CONCLUSIONS—Patients within the higher LVEF categories have a greater mortality risk attributable to diabetes than patients within the lower LVEF categories.

Diabetes Care 34:1788–1790, 2011

Diabetic patients without myocardial infarction (MI) and MI patients without diabetes have a high and equally adverse long-term risk of cardiovascular death compared with the general population (1,2). As well as diabetes, the presence of systolic dysfunction and heart failure are major risk factors for mortality after MI. A recent study suggested that diabetes may be regarded as a risk equivalent to low left ventricular ejection fraction (LVEF) and that ordinary LVEF risk stratification may not be valid in these patients (3). This study was performed to further clarify their interrelationship.

RESEARCH DESIGN AND METHODS

The current study population comprised Danish patients consecutively screened for entrance in the Trandolapril Cardiac Evaluation (TRACE) study (4), the Danish Investigations of Arrhythmia and Mortality on Dofetilide Myocardial Infarction (DIAMOND-MI) study (5), and the Bucindolol Evaluation in Acute MI Trial (BEAT) study (6). Full study designs have been described previously (4–6). In brief, departments participating in any of the studies were required to screen consecutive patients admitted with acute MI. All screenings included a transthoracic echocardiogram, which was analyzed in a core laboratory by independent investigators. LVEF was estimated through a global wall motion index, a nine-segment model in the TRACE study (7), and a 16-segment model in the DIAMOND-MI and BEAT studies (8). This way of obtaining LVEF has a good correlation with outcomes (7).

All comorbidities including the diagnosis of diabetes were by patient history, patient files, and investigator's determination. The outcome analyzed was the risk of all-cause mortality. Survival status was obtained from the National Population Register on 28 May 2008, giving a maximal observational time of 18 years.

Statistical analysis

Continuous variables were compared with a *t* test and discrete variables with the χ^2 test. Cox proportional hazards models were used for analyses of mortality rates. All models were adjusted for age, sex, LVEF, chronic obstructive pulmonary disease, hypertension, presence of clinical heart failure, a variable indicating the wall motion index scoring system (9 vs. 16 segments), and calendar year of hospitalization. Test for interaction between LVEF and diabetes was done by inclusion of an interaction term in the Cox model with LVEF included as a continuous variable. The relative importance of diabetes was examined independently in patients within defined groups according to LVEF. All analyses were done using SAS version 9.1 (SAS Institute, Cary, NC).

Ethics

All studies were approved by the relevant ethical committees and were conducted in conformity with the Declaration of Helsinki.

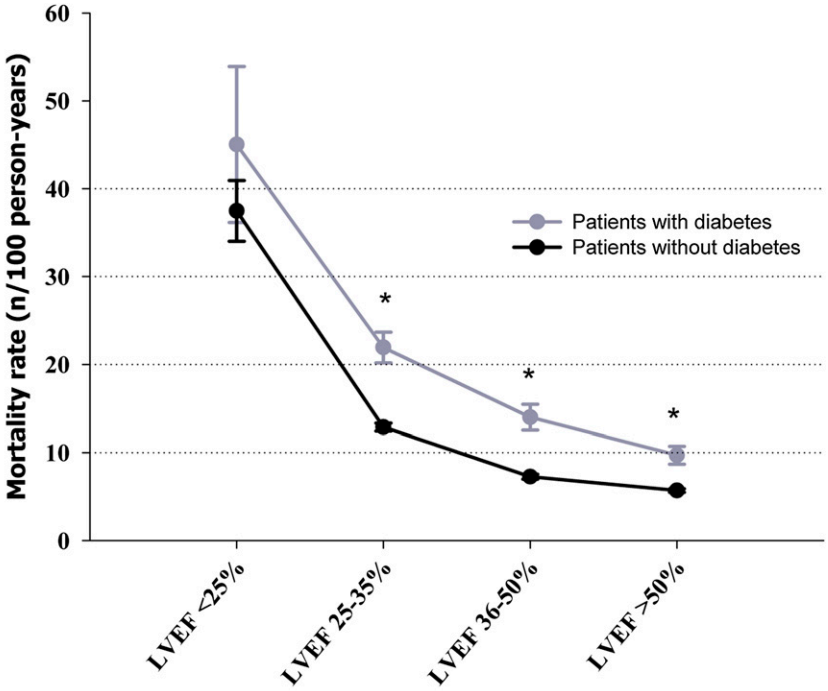
RESULTS

A total of 16,912 patients were included in the present analysis. Patients with diabetes were found to be older (69 ± 11 [SD] vs. 67 ± 12 years), have a lower LVEF (41 ± 12 vs. 45 ± 12%), a higher frequency of women (38 vs. 30%), a higher prevalence of clinical heart failure (62 vs. 44%), lower creatinine clearance (69 ± 1 vs. 72 ± 1 mL/min/1.73 m^2), and higher BMI (26.9 ± 0.1 vs. 25.9 ± 0.1 kg/m^2) than patients without diabetes.

From the [1]Department of Cardiology, Gentofte University Hospital, Hellerup, Denmark; [2]The Heart Centre, Rigshospitalet, Copenhagen University Hospital, Copenhagen, Denmark; and the [3]Brigham Cardiovascular Division, Brigham & Women's Hospital, Harvard Medical School, Boston, Massachusetts.
Corresponding author: Charlotte Andersson, ca@heart.dk.
Received 24 January 2011 and accepted 14 May 2011.
DOI: 10.2337/dc11-0154

During a median observational time of 2,609 days (interquartile range 820–3,937), 1,396 (77%) patients with diabetes and 8,985 (60%) patients without diabetes died, respectively. Figure 1 presents the unadjusted mortality rates for some given intervals of LVEF in patients with and without diabetes. Decreasing LVEF subgroup was associated with increasing hazard ratios (HRs) (adjusted for age, sex, wall motion index analysis method, and calendar year): 1.02 (0.81–1.27), 1.46 (1.34–1.60), 1.84 (1.64–2.06), and 1.61 (1.44–1.80) in the LVEF <25%, LVEF 25–35%, LVEF 36–50%, and LVEF >50% subgroups, respectively. In multivariable Cox analysis, diabetes and a 15% unit depression in LVEF were found to be of similar prognostic importance: HRs 1.45 (95% CI 1.37–1.54) and 1.41 (1.37–1.45) for diabetes and LVEF depression, respectively. The prognostic importance of diabetes was modulated by LVEF; *P* for interaction between diabetes and LVEF = 0.03. Among patients with low LVEF (<40%), diabetes was associated with HR 1.29 (1.19–1.40), which corresponded to the importance of having 10% unit depression in LVEF (HR 1.26 [1.24–1.28] in the overall analysis). Among patients with a high LVEF (≥40%), diabetes was associated with HR of 1.61 (1.49–1.74) and was of similar prognostic importance as 20% unit depression in LVEF (HR 1.58 [1.53–1.64]).

CONCLUSIONS—This study demonstrated that the prognostic importance of diabetes depends on left ventricular function, with diabetes having a stronger negative influence with preserved ventricular function. This result was also found in another study (3) and may appear counterintuitive given the detrimental influence of diabetes in patients with heart failure (9). However, the relationship between diabetes and heart failure is bidirectional, and diabetes may not always contribute causally to the adverse prognosis. For example, it is known that a great proportion of patients with severe heart failure will develop diabetes over time (10).



Numbers events / total:				
Diabetes	99/103	596/689	350/476	351/551
No diabetes	451/478	3152/4240	2425/4312	2957/6063

Figure 1—*Mortality rates per 100 person-years according to LVEF in patients with and without diabetes. Error bars represent 95% CIs.* *P < *0.0001 for differences between patients with and without diabetes (obtained from unadjusted Cox analyses); LVEF <25% subgroup* P *for difference = 0.6.*

Other studies have in accordance with our finding reported the risk of dying from diabetes after MI to be greatest among patients with lowest baseline mortality risk (11) and among patients with mildest coronary artery lesions (12). In our study, diabetes was associated with a 60% increase in relative risk of mortality among patients with preserved LVEF. Although in the current study it was impossible to investigate what exactly may have driven this increase in risk, complications such as incident heart failure are common over time and are associated with a poor prognosis (13,14).

Finally, as previously reported (3), the protective effect on mortality associated with good left ventricular function after MI was found to be attenuated by diabetes, with diabetes conferring a risk equivalent to 10–20% unit depression in LVEF. With regards to prognostic stratification, this is clinically important because predischarge assessment of LVEF should be interpreted differently in patients with diabetes.

Limitations

The diagnosis of diabetes relied on patient history, and oral glucose tolerance tests were not performed on a routine basis. LVEF was estimated by wall motion index, which is observer-dependent and an approximation of LVEF. The current study did not have information on diabetes duration, HbA_{1c} values, incident diabetes, use of glucose-lowering agents, or diastolic function, which may have influenced outcomes. Finally, the subgroup of patients with LVEF <25% was small; therefore, a small true increase in HR associated with diabetes cannot be excluded.

Acknowledgments—No potential conflicts of interest relevant to this article were reported.

C.A. wrote the initial draft of the manuscript and participated in data analysis. Study design came from S.D.S., C.T.-P., and L.K., who also analyzed data. All authors contributed equally to discussion and critical review of the manuscript.

References

1. Haffner SM, Lehto S, Rönnemaa T, Pyörälä K, Laakso M. Mortality from coronary heart disease in subjects with type 2 diabetes and in nondiabetic subjects with and without prior myocardial infarction. N Engl J Med 1998;339:229–234
2. Norgaard ML, Andersen SS, Schramm TK, et al. Changes in short- and long-term cardiovascular risk of incident diabetes

and incident myocardial infarction: a nationwide study. Diabetologia 2010;53:1612–1619
3. Shah AM, Uno H, Køber L, et al. The interrelationship of diabetes and left ventricular systolic function on outcome after high-risk myocardial infarction. Eur J Heart Fail 2010;12:1229–1237
4. Køber L, Torp-Pedersen C, Carlsen JE, et al. A clinical trial of the angiotensin-converting-enzyme inhibitor trandolapril in patients with left ventricular dysfunction after myocardial infarction. N Engl J Med 1995;333:1670–1676
5. Køber L, Bloch Thomsen PE, Møller M, et al. Effect of dofetilide in patients with recent myocardial infarction and left-ventricular dysfunction: a randomised trial. Lancet 2000;356:2052–2058
6. Torp-Pedersen C, Køber L, Ball S, et al. The incomplete bucindolol evaluation in acute myocardial infarction Trial (BEAT). Eur J Heart Fail 2002;4:495–499
7. Køber L, Torp-Pedersen C, Carlsen J, Videbaek R, Egeblad H. An echocardiographic method for selecting high risk patients shortly after acute myocardial infarction, for inclusion in multi-centre studies (as used in the TRACE study): TRAndolapril Cardiac Evaluation. Eur Heart J 1994;15:1616–1620
8. Berning J, Steensgaard-Hansen F. Early estimation of risk by echocardiographic determination of wall motion index in an unselected population with acute myocardial infarction. Am J Cardiol 1990;65:567–576
9. Gustafsson I, Brendorp B, Seibaek M, et al. Influence of diabetes and diabetes-gender interaction on the risk of death in patients hospitalized with congestive heart failure. J Am Coll Cardiol 2004;43:771–777
10. Andersson C, Norgaard ML, Hansen PR, et al. Heart failure severity, as determined by loop diuretic dosages, predicts the risk of developing diabetes after myocardial infarction: a nationwide cohort study. Eur J Heart Fail 2010;12:1333–1338
11. Singer DE, Moulton AW, Nathan DM. Diabetic myocardial infarction: interaction of diabetes with other preinfarction risk factors. Diabetes 1989;38:350–357
12. Ishihara M, Sato H, Kawagoe T, et al. Impact of diabetes mellitus on long term survival after acute myocardial infarction in patients with single vessel disease. Heart 2001;86:133–138
13. Gottdiener JS, Arnold AM, Aurigemma GP, et al. Predictors of congestive heart failure in the elderly: the Cardiovascular Health Study. J Am Coll Cardiol 2000;35:1628–1637
14. de Simone G, Devereux RB, Chinali M, et al. Diabetes and incident heart failure in hypertensive and normotensive participants of the Strong Heart Study. J Hypertens 2010;28:353–360