

Relationship Between Diabetes and Mortality

A population study using record linkage

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OBJECTIVE — To determine patterns and causes of mortality for patients with diabetes in a district health authority.

RESEARCH DESIGN AND METHODS — The study used cross-sectional record linkage, combining an electronic death register with a diabetic patient register constructed from a variety of routine health data sources collected from 1991 to 1997. The study was conducted in Cardiff and the Vale of Glamorgan, Wales, U.K., and included all diabetic deaths between 1993 and 1996.

RESULTS — Of 1,694 deaths in patients with known diabetes, only 674 (39.8%) had diabetes recorded as an immediate or antecedent cause of death. Mortality rates were 41.8 per 1,000 for the diabetic population and 10.1 per 1,000 for the nondiabetic population. The standard mean ratio for the diabetic population was 1.24 (95% CI 1.12–1.35), with the risk of mortality relative to the nondiabetic population decreasing with age. Males with diabetes lost an average of 7.0 years from the year of diagnosis, and females with diabetes lost an average of 7.5 years. The most common cause of death was cardiovascular disease, which accounted for 49.1% of deaths in the diabetic population.

CONCLUSIONS — Diabetes is recorded as a cause of death on a minority of death certificates for patients with diabetes. Using death certificates in isolation, therefore, is a poor method of estimating diabetic mortality, but results can be improved with the use of record linkage techniques. Patients with diabetes have an excess risk of mortality compared with the nondiabetic population. Life-years lost for patients with diabetes is strongly related to age at diagnosis and is a means of expressing mortality without relying on accurate prevalence data.

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Diabetes is widely presumed to predict premature mortality. Within the U.K., recent estimates of increased risk of mortality for various diabetic cohorts have ranged from just over 1 to almost 5 (1–5). The bulk of this excess, which has also been observed in other international cohorts, has been attributed to circulatory diseases. (6,7).

In this study, we examined diabetic mortality using data derived from death cer-

tificates for an entire district population. It is widely acknowledged that studies of diabetic mortality using death certificates in isolation are problematic because diabetes is consistently under-recorded as an immediate or antecedent cause of death. This has been reported in a wide range of settings (8–13), even for deaths from diseases in which diabetes is known to contribute significantly to the etiology. This affects estimates of diabetic

mortality by underestimating the excess risk of macrovascular and microvascular diseases and also by exaggerating any reduced risk of diseases such as cancer, as has been previously reported (14,15).

To overcome these deficiencies, we have used record linkage techniques to create a district-wide diabetes register and then to link this register to mortality data sources.

RESEARCH DESIGN AND METHODS — The study population comprised the resident population in the area that until April 1996 constituted South Glamorgan Health Authority (SGHA), a health district with a population of 434,000 (1996 estimate) (16). Since April 1996, SGHA has been incorporated into the Bro Taf Health Authority.

Data sources, record linkage, and identification of patients

The study used mortality data from the Office of National Statistics for the period of 1993–1996 inclusive. This data set contained details of both primary and contributory causes of death, which were coded using the *International Classification of Diseases, Ninth Revision* (ICD-9) classifications. A diabetes register was created by using record linkage techniques. Record linkage has been described previously (17), but we have recently extended the process to incorporate a wider range of data sources over a longer time period. Briefly, inpatient records (1991–1997), outpatient data (1991–1996), a diabetic outpatient clinic database (ongoing since 1993), mortality data (1993–1997), and a general practice diabetes audit database (1996) covering >80% of the district population (18,19) were used. These data sources were combined using probabilistic algorithms to identify all records relating to unique individuals and also to identify patients with a diagnosis of diabetes from 1 of 4 sources: 1) an immediate or antecedent cause of death on the mortality dataset (ICD-9 classification, 250); 2) an inpatient record with a diagnosis of diabetes recorded in 1 of 6 diagnostic fields (ICD-9 classification, 250; *International*

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Abbreviations: ICD-9, *International Classification of Diseases, Ninth Revision*; SGHA, South Glamorgan Health Authority; SMR, standardized mortality ratio.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

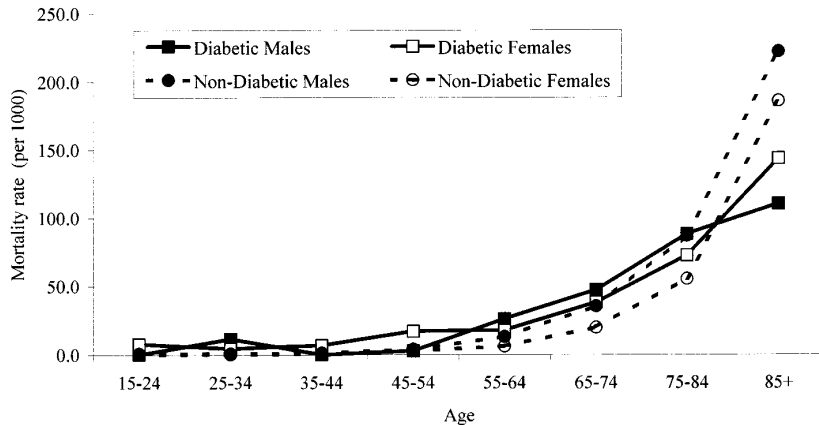


Figure 1—Annual mortality rate for the diabetic and nondiabetic populations, South Glamorgan, 1996.

Classification of Diseases, Tenth Revision (ICD-10) classifications, E10–E14, H36, G59, G63); 3) an outpatient appointment coded for the subspecialty of diabetes; or 4) inclusion in either the general practice audit or outpatient clinic databases. All patients classified as diabetic had to be identified as such by a record from any of the above sources dated earlier than 1 January 1997. Combining routine data in this way to generate a register has been shown to be reliable (20), and routine data have been shown to be as sensitive as data compiled through exhaustive prospective surveys (21).

The critical nature of the value of the population prevalence of diabetes in the calculation of relative rates has been highlighted previously (22). The determination of the denominator diabetic population for this study has been described elsewhere (23).

Year of diagnosis was obtained from either the general practice database or the clinic database. For those patients not listed in either data set, we located hospital patient notes and extracted the relevant information.

Data analysis

Standardized mortality ratios (SMRs) were calculated for patients with diabetes using the entire South Glamorgan population as the reference population for the year 1996. SMRs from specific ICD-9 chapters were also calculated. Because of the smaller numbers within these subcategories, data for all 4 years (1993–1996) were used. For the purpose of this calculation, we assumed that the denominator for both the diabetic and nondiabetic populations was the same for all 4 years. For some ICD-9 chapters, the numbers involved were too small, and these chapters were excluded.

Because the demography of South Glamorgan resembles that of England to a greater degree than that of Wales or the U.K. as a whole, we used sex-specific life tables for England to calculate the years lost to mortality for the diabetic population. The life tables provided the probability of death (q_x) within a given year (x) for each year from 1930 onward, with projections for 1996 onward. Projected data were available until 2036, after which the 2036 death rates were duplicated for each successive year. The values (q_x) allowed us to derive the number of individuals surviving a given year for each original cohort (l_x). Life expectancy (e_x) was then calculated. We were therefore able to estimate the life expectancy for patients with diabetes from the year and

age of diagnosis. This could then be compared with the actual age at death (see APPENDIX).

RESULTS

Actual deaths and crude mortality rates

We estimated that 9,976 diabetic individuals were alive in the study area on 1 January 1996, a prevalence of diabetes of 2.3%. From 1993 to 1996, a total of 17,513 deaths were recorded, 1,694 (9.7%) of which were identified as diabetes related. In 1996, there were 417 deaths in the diabetic population and 3,977 deaths in the nondiabetic population. This represents an annual mortality rate of 41.8 per 1,000 in the diabetic population and 10.1 per 1,000 in the nondiabetic population. Age at diagnosis was available for 1,416 (83.6%) of all deaths for individuals with diabetes.

Recording of diabetes on death certificates

Diabetes was coded on 674 (39.8%) death certificates: 4 (0.2%) as an immediate cause of death and 670 (39.6%) as an antecedent cause of death. Diabetes was also recorded as an underlying cause of death on 134 (7.1%) death certificates.

Age at death

The mean age at death for patients with diabetes was 72.8 years for men and 77.7 for women, compared with 71.3 for nondiabetic men and 78.6 for nondiabetic

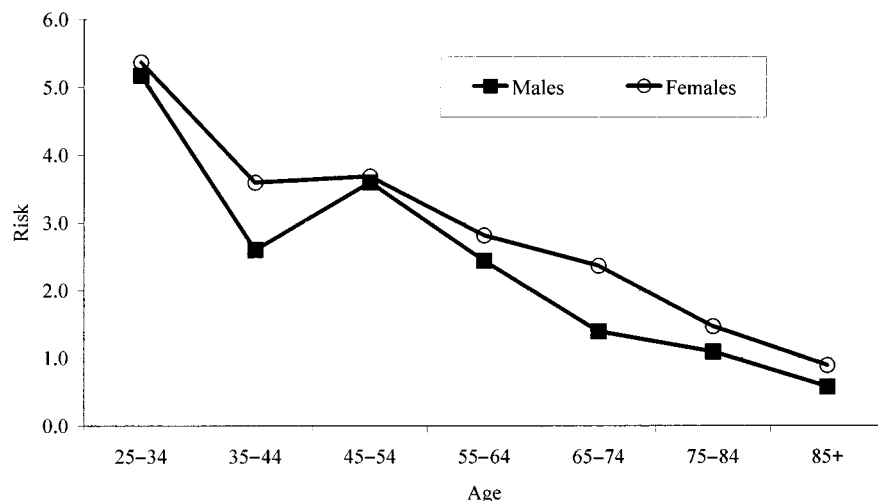


Figure 2—Risk of mortality for patients with diabetes relative to the nondiabetic population.

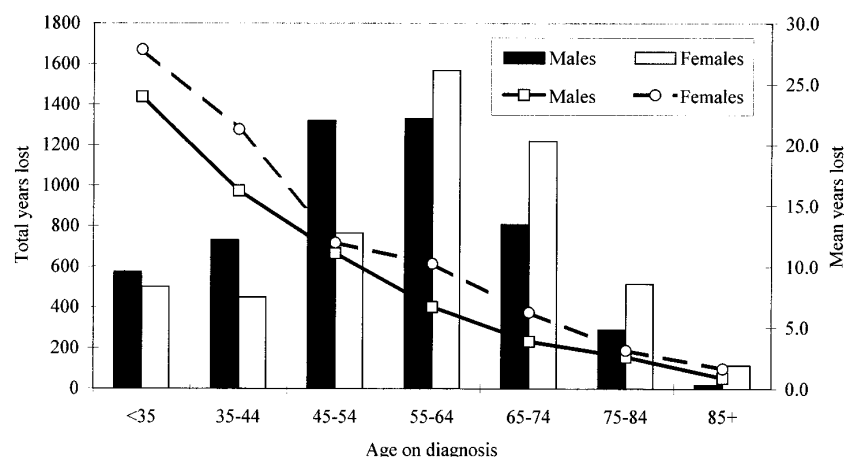


Figure 3—Total and mean life-years lost for patients with diabetes by age at diagnosis.

women. The age- and sex-specific death rates for the diabetic and nondiabetic populations are shown in Fig. 1.

SMR and risk of mortality

For 1996, the SMR for individuals with diabetes, using nondiabetic individuals as the reference population, was 1.24 (95% CI 1.12–1.35). The SMR was 1.15 (1.00–1.31) for diabetic male subjects and 1.35 (1.15–1.51) for diabetic female subjects. Risk of mortality by age using data for all 4 years is shown in Fig. 2.

Life-years lost

By subtracting expected years of life after the year of diagnosis from the actual years lived, we were able to estimate the number of years lost for patients with diabetes. Overall, men lost an average of 7.0 years compared with women, who lost an average of 7.5 years. Mean and total years lost by age at diagnosis and sex are shown in Fig. 3. There is a gradual decline in years lost by age ranging from 25.9 (21.0–30.9) in patients younger than 35 years of age at diagnosis to 0.9 (0.1–1.8) and 1.6

(1.0–2.3) years in patients diagnosed at 85 years of age or over.

Cause of mortality

The most common underlying cause of death by disease group for patients with diabetes was cardiovascular disease, which accounted for almost one-half (49.1%) of all deaths in the diabetic population. In comparison, although cardiovascular disease was the most common cause of death among people without diabetes, it only accounted for 36.2% of total nondiabetic deaths. Total deaths by disease groups, SMRs, and mean life-years lost are shown in Table 1.

The most common underlying cause of death for patients with diabetes was other forms of chronic ischemic heart disease (ICD-9 classification, 414), which accounted for 18.7% of all diabetic deaths; of all deaths from other forms of chronic ischemic heart disease, 17.2% were patients with diabetes.

CONCLUSIONS — Record linkage techniques allowed a population-wide study of mortality identifying diabetic patients for whom diabetes was not recorded on the death certificate. As we have shown above, this represents the majority of deaths for patients with diabetes.

Patients with diabetes have an average reduction in life expectancy of 7.0 years for men and 7.5 years for women. This may

Table 1—Mortality statistics for South Gamorgan by ICD-9 chapter (1993–1996) by underlying cause

ICD-9 chapter	Total deaths (1993–1996)				SMR (95% CI)	Mean life-years lost	
	Diabetic males	Diabetic females	Nondiabetic males	Nondiabetic females		Diabetic males	Diabetic females
Cancer	183	127	2,143	1,920	0.96 (0.85–1.07)	8.1	10.2
Cardiovascular disease	432	400	2,703	3,028	1.63 (1.52–1.75)	6.7	7.3
Diabetes	63	71	0	0	—	6.6	7.0
Diseases of pulmonary circulation	3	11	56	102	—	13.5	12.3
Diseases of the digestive system	23	40	294	377	1.20 (0.90–1.49)	10.4	10.1
Diseases of the skin, subcutaneous tissue, musculoskeletal system, and connective tissue	1	4	22	80	—	17.0	3.5
Infectious and parasitic diseases	6	3	60	45	—	0.0	18.7
Injury and poisoning	10	9	289	187	—	12.5	3.0
Nephritis, nephrotic syndrome, and nephrosis	3	4	33	36	—	–4.0	6.0
Nonspecific and ill-defined causes	2	9	82	220	—	0.5	3.1
Other causes of death	30	32	377	609	0.87 (0.65–1.09)	6.7	7.0
Other diseases	0	2	0	3	—	0.0	3.0
Other forms of heart disease	8	6	57	58	—	15.2	6.3
Other respiratory diseases	23	35	567	455	0.60 (0.45–0.77)	6.4	8.5
Peripheral vascular disease	17	15	247	226	0.76 (0.50–10.2)	8.9	8.3
Pneumonia and influenza	45	77	577	966	0.87 (0.72–1.02)	2.2	3.1
Total	849	845	7,507	8,312	1.29 (1.23–1.35)	7.0	7.5

be confounded by other factors, such as social deprivation, which are linked with both prevalence of diabetes and premature mortality (24).

Attempts to estimate the excess risk of mortality for patients with diabetes relative to the population as a whole face several methodological problems. The accuracy of calculating SMR depends on the accuracy of estimating the denominator population. It is widely accepted that a substantial proportion of individuals with diabetes remains undiagnosed (25). This proportional oversight may be more extreme in the numerator, since undiagnosed individuals with diabetes may endure greater mortality than diagnosed patients (26). Life-years lost allows comparison with the population as a whole without reference to the denominator diabetic population and may therefore offer a more appropriate summary of diabetic mortality. However, life-years lost is based on age at diagnosis rather than onset of diabetes. It has been argued that onset of type 2 diabetes may precede diagnosis by as much as 12 years (27) and, for some cases, age at diagnosis may represent a significant overestimate.

It may appear counterintuitive that patients with diabetes have a similar mean age of death and yet, on average, lose ~7 years of life from age at diagnosis. This paradox is caused by the large number of patients with diabetes who are diagnosed in their 60s and 70s and approach or surpass the mean age of death for their particular life cohort. A man diagnosed with diabetes at 72 years of age (approximately the mean age of death for the general population in 1996) can expect to live for an additional 10 years. If, however, he dies at age 75 years, then despite exceeding the mean age of death, he has lost 7 years from the expected mean age of death from diagnosis.

Unsurprisingly, the most common cause of death for diabetic patients was cardiovascular disease, which represented a significant excess over the population as a whole. The risk of death from cancer for diabetic patients was no different than the risk for the population as a whole, although this does not allow for specific cancers, such as renal and pancreatic, which may represent an excess risk in people with diabetes (28,29).

This study contributes to the debate on the most effective strategy for reducing mortality for patients with diabetes. There is a wide variation of life-years lost among

patients with diabetes, with the bulk of years lost among the older age-group, where mean life-years lost is relatively low. A targeted approach to identifying and treating type 2 diabetes in the younger age-groups would have the most beneficial effect for the individual patient, but the ratio of positive to negative screening tests would be low. Targeting patients in their 60s and 70s (individuals most likely to have the disease) would increase the screening efficacy ratio, but the benefits of aggressive treatment and monitoring would not be as great in terms of added life-years per patient and cost-effectiveness.

APPENDIX

Calculation of life-years lost

The data received from the National Actuary Office was in the form of a simple table with ages (0–105 years) as rows and years (1911–2036) as columns. Each cell contained the probability of death (q) based on observation and projection for each age cohort in any given year (x). From this table, it was therefore possible to derive life expectancy by doing the following:

1. Calculating the survivors for each cohort for each year. For each newborn cohort, we could calculate how many of 100,000 would survive to the first year, second year, and so forth;
2. Calculating the expected years of life. In effect, this is the sum of the diagonal divided by the original cohort. For example, from the original 1925 birth cohort of 100,000, 81,343 were alive in 1970. To calculate life expectancy in this 45-year-old group, it is necessary to add up all of those alive in 1971 (81,343 minus all deaths in 1970) with those in 1972, 1973, and so forth. This sum divided by the 1970 cohort (81,343) will produce the mean life expectancy for this group.

$$e_x = \frac{\sum_{i=x+1}^{\max} 1_x}{1_x} + 1/2$$

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