Completion of annual diabetes care processes and mortality

Completion of annual diabetes care processes and mortality: A cohort study using the National Diabetes Audit for England and Wales

Short running title: Care processes and mortality

Naomi Holman PhD[1], Peter Knighton MPhys[2], Jackie O'Keefe MSc[2], Sarah H Wild PhD[3], Sarah Brewster MRCP[4], Hermione Price FRCP[4], Kiran Patel PhD[5,6,7], Wasim Hanif MD[8], Vinod Patel MD[6,9,10], Edward W Gregg PhD[11], Richard IG Holt PhD[12], Roger Gadsby MB[6], Kamlesh Khunti MD[13], Jonathan Valabhji MD[14,15,16], Bob Young MD[17], Naveed Sattar MD[1]

[1] Institute of Cardiovascular and Medical Sciences, University of Glasgow, Glasgow, UK
[2] Analytical Services – Population Health, Clinical Audit and Specialist Care, NHS Digital, Leeds, UK
[3] Usher Institute, College of Medicine and Veterinary Medicine, University of Edinburgh, Edinburgh, UK
[4] West Hampshire Community Diabetes Service, Southern Health NHS Foundation Trust, Lyndhurst, UK
[5] University Hospitals Coventry & Warwickshire NHS Trust, Coventry, UK
[6] Warwick Medical School, University of Warwick, Warwick, UK
[7] Coventry University, Coventry, UK
[8] University Hospitals Birmingham NHS Foundation Trust, Birmingham, UK
[9] Diabetes and Endocrinology Centre, George Eliot Hospital NHS Trust, Nuneaton, UK
[10] West Midlands Clinical Networks & Clinical Senate, NHS England and NHS Improvement – Midlands, UK
[11] School of Public Health, Imperial College, London, UK
[12] Human Development and Health , Faculty of Medicine, University of Southampton and Southampton National Institute for Health Research Biomedical Research Centre, University Hospital Southampton NHS Foundation Trust, Southampton, UK
[13] Diabetes Research Centre, University of Leicester, Leicester, UK
[14] NHS England and NHS Improvement, London, UK
[15] Department of Diabetes and Endocrinology, St Mary's Hospital, Imperial College Healthcare NHS Trust, London, UK
[16] Division of Metabolism, Digestion and Reproduction, Imperial College London, London, UK
[17] Diabetes UK, London, UK

Corresponding author:
Naomi Holman
c/o RC214 Level C2, Institute of Cardiovascular & Medical Sciences, BHF Glasgow Cardiovascular Research Centre, University of Glasgow, 126 University Place, Glasgow G12 8TA, United Kingdom
Tel: 07986563124
Email: naomi.holman@glasgow.ac.uk

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Abstract

Aims: Guidelines recommend that diabetes care processes (HbA_{1c}, creatinine, cholesterol, BP, BMI, smoking habit, urinary albumin, retinal and foot examinations) are performed at least annually. This analysis assesses if their completion is associated with mortality.

Materials and Methods: A cohort from the National Diabetes Audit of England and Wales comprising 179,105 people with type 1 and 1,397,790 with type 2 diabetes, aged 17-99 years on 1st January 2009, diagnosed before 1st January 2009 and alive on 1st April 2013 was followed to 31st December 2019. Cox proportional hazards models adjusting for demographic characteristics, smoking, HbA_{1c}, BP, serum cholesterol, BMI, duration of diagnosis, eGFR, prior myocardial infarction, stroke, heart failure, respiratory disease and cancer, investigated whether care processes recorded 1st January 2009 to 31st March 2010 were associated with subsequent mortality.

Results: Over a mean follow-up of 7.5 and 7.0 years there were 26,915 and 388,093 deaths in people with type 1 and type 2 diabetes respectively. Completion of five or less, compared to eight, care processes (retinal screening not included as data not reliable) had a mortality hazard ratio of 1.37 (95% CI 1.28 - 1.46) in people with type 1 and 1.32 (95% CI 1.30 - 1.35) in people with type 2 diabetes. The hazard ratio was higher for respiratory disease deaths and lower in South Asian ethnic groups.

Conclusions: People with diabetes who have fewer routine care processes have higher mortality. Further research is required into whether different approaches to care might improve outcomes for this high-risk group.

Introduction

Optimal management of blood glucose, lipids and blood pressure reduces microvascular and macrovascular complications of diabetes.[1–3] Accordingly, measurement and management of HbA_{1c}, blood pressure and lipid profile are at the centre of national and international diabetes care guidelines.[4–7] Regular review of these and other risk factors for complications, including weight and smoking habit are recommended, as are early detection of kidney, foot and eye disease.

In England the National Institute for Health and Clinical Excellence (NICE) recommends that people with type 1 diabetes[4] and type 2 diabetes[5] are offered nine annual processes (measurement of HbA_{1c}, lipids, creatinine, albuminuria, blood pressure and body mass index, ascertainment of smoking status, and examination of the feet and retinae) and their completion has been incentivised in primary care.[8] Most international guidelines also stress the importance of these care processes. However, whilst their regular completion might seem intuitively sensible, the level of evidence to support the guidelines, including their effect on clinical outcomes, is usually not known or rated at the lowest standard of evidence ("expert consensus" or "clinical experience").[7]

In England and Wales, the National Diabetes Audit (NDA) collects patient level data on people with diagnosed diabetes. This study assesses whether recorded care processes completion was associated with mortality over the subsequent decade after adjustment for the risk factors that the care processes uncover, individual demographic characteristics and co-morbidities.

Materials and Methods

Data sources

The NDA has collated data on people with diagnosed diabetes registered with a primary or specialist healthcare provider in England since 2003. Individuals receiving care from general practice and specialist outpatient services based in acute and community trusts are included if they have a valid code for diabetes mellitus (excluding gestational diabetes) in their electronic health record.[9] The 2009/10 NDA data collection included data from 6700 (76%) general practices and was estimated to include data on 81.1% people aged 17 years and older with diagnosed diabetes in England and Wales.[10]

These data were linked to Hospital Episode Statistics (HES) and Patient Episode Database for Wales (PEDW) which record all hospital admissions in England and Wales respectively, and to civil death registrations in both countries collated by the Office for National Statistics.

The legal basis for the NDA data collection and linkage is a 'direction' from NHS England to NHS Digital according to section 254 of the Health and Social Care Act for England 2012; in Wales it is granted under section 270 of the Health and Social Care Act. To protect confidentiality all data with a final digit of 1, 2, 8 or 9 are rounded to 0 and 3, 4, 6 or 7 are rounded to 5. Numbers with a final digit of 0 or 5 are unchanged.

Study population and observation period

The study population was people aged between 17 and 99 years old on 1st January 2009, diagnosed with type 1 diabetes and type 2 diabetes before 1st January 2009 who were included in the 2009/10 NDA data collection and still alive on 1st April 2013. Analysis was restricted to individuals that survived three years after the exposure period to reduce potential bias from the clinically appropriate suspension of diabetes care processes for people in end of life care. Individuals were followed up from 1st April 2013 until death or 31st December 2019.

Outcomes

The outcomes were death from all causes and underlying (primary) cause of death from cardiovascular disease (ICD-10 codes I01-I99), cancer (ICD-10 codes C01-C99), respiratory disease (ICD-10 codes J01-J99), diabetes specific causes (ICD-10 codes E10-14) and renal disease (ICD-10 codes N17-19).

Exposures

Data secondarily recorded in general practice systems for retinal examinations for this period are not considered reliable. The primary exposure was, therefore, the number of eight care processes (blood tests for HbA_{1c}, cholesterol, creatinine, measurement of blood pressure, body mass index, albuminuria, smoking habit assessment and the examination of feet) recorded as undertaken between 1st January 2009 and 31st March 2010. As initial exploratory analysis identified that only a minority of people had five or fewer care processes recorded and that people receiving six or seven care processes had similar characteristics and outcomes these categories were used in the analysis. People who had all eight care

processes recorded formed the primary reference group to reflect current national guidelines.

Age and duration of diagnosed diabetes at baseline were calculated using date of birth and date of diagnosis respectively. Ethnicity was based on self-reported ethnic group as recorded by healthcare providers and classified as White, Mixed, South Asian, Black, other or missing. Type of diabetes was attributed based on the most recent type recorded by a healthcare provider and notified to the NDA. Data from a specialist healthcare provider were assigned precedence over the type of diabetes in the primary care health record.

Deprivation was measured using the area-based Index of Multiple Deprivation 2007[11] based on the home postcode recorded in the 2009/10 NDA data collection and split into quintiles for analysis.

The latest reported risk factor measurements in the period 1st January 2009 to 31st March 2010 for HbA_{1c}, systolic blood pressure, total cholesterol, creatinine, body mass index and smoking habit were identified. Estimated glomerular filtration rate (GFR) was calculated using the Modification of Diet in Renal Disease formula.[12]

Hospital admissions for myocardial infarction (ICD-10 codes I21-22), stroke (ICD-10 codes I61, I63-64, I67.9), heart failure (ICD-10 codes I50), respiratory disease (ICD-10 codes J01-99), cancer (ICD-10 codes C01-99) between 1st January 2004 and 31st December 2008 were identified.

Statistical methods

The differences in mean age, duration of diagnosed diabetes, HbA_{1c} and body mass index by the number of care processes recorded as undertaken were tested using analysis of variance (ANOVA) with Levene's test to identify differences in variance. Differences in the proportion of people recorded as receiving care processes for categorical variables (sex, social deprivation, ethnicity, smoking habit) were tested using the chi-squared statistic. Crude mortality rates and mortality rates per 1000 person years standardised for age and sex to the European Standard population were calculated with 95% confidence intervals using Byar's method.[13]

Cox proportional hazard models were created to assess the associations between the number of recorded care processes and mortality for people with type 1 diabetes and type 2 diabetes. A series of models were created consisting of sequentially more covariates to examine potential confounding factors.

Separate models, adjusting for all risk factors, were created for mortality from cardiovascular disease, cancer, respiratory disease, diabetes specific causes and renal failure for type 1 diabetes and type 2 diabetes separately. Models adjusted for all risk factors and stratified by sex, age (less than 65 years old and 65 years and older), ethnic group, quintiles of deprivation and whether or not the individual had an acute hospital admission in the year prior to the exposure period were constructed for all-cause mortality in people with type 1 diabetes and in people with type 2 diabetes.

Two models (one for type 1 diabetes and one for type 2 diabetes) adjusted for age, sex, ethnic group, deprivation and whether or not each of the eight care processes

had been completed were created to identify if the association with all-cause mortality varied by type of care process. All variables were defined as categorical variables and included a category for missing data. A sensitivity analysis was undertaken in which everyone included in the 2009/10 NDA and still alive on 1st January 2011 to explore whether the survival bias introduced by excluding deaths shortly after the exposure period altered the findings.

Statistical analysis was undertaken in SAS Enterprise Guide 7.1.

Results

179,105 people with type 1 diabetes and 1,397,790 with type 2 diabetes were followed up for a mean of 7.5 (SD 1.4) and 7.0 (SD 1.8) years respectively. Among those with type 1 diabetes 80,635 (45.0%) had received all eight care processes at least once between 1st January 2009 and 31st March 2010, 61,230 (34.2%) received six or seven care processes whilst 37,235 (20.8%) received five or fewer care processes in the same period. The corresponding figures for people with type 2 diabetes were 878,605 (62.9%), 387,060 (27.6%) and 132,125 (9.5%) respectively.

Characteristics by number of care processes received

Care process completion variation showed little relation to deprivation but was associated with age, ethnicity, HbA_{1c} and smoking status (Table 1). The mean age of those with type 1 diabetes recorded as having received five or fewer care processes was 40.6 years compared to mean ages of 46.3 and 51.0 years for those recorded as receiving six or seven care processes and all eight recommended care processes respectively ($p<0.005$). For those with type 2 diabetes mean ages were 60.9, 63.5

and 65.0 years respectively ($p<0.005$). 97.6% of those with type 1 and 97.6% with type 2 diabetes had a valid ethnic group recorded. Among those with type 1 diabetes 89.1% of those recorded as receiving five or fewer care processes and 87.9% recorded as receiving all eight care processes were from White ethnic groups ($p<0.005$); the corresponding proportions in those with type 2 diabetes were 73.3% and 80.8% ($p<0.005$). Latest mean HbA_{1c} recorded between 1st January 2009 and 31st March 2010 was higher in those recorded as receiving fewer care processes: in people with type 1 diabetes 72 mmol/mol (8.7%) for five or fewer, 70.3 mmol/mol (8.6%) for six or seven compared to 68 mmol/mol (8.4%) for eight care processes ($p<0.005$); and in those with type 2 diabetes 62 mmol/mol (7.8%) for five or fewer, 58.4 mmol/mol (7.5%) for six or seven and 57 mmol/mol (7.4%) for eight care processes ($p<0.005$). Smoking prevalence recorded between 1st January 2009 and 31st March 2010 was higher among those receiving fewer care processes at 32.9% for five or fewer compared to 19.9% for eight care processes in type 1 diabetes ($p<0.005$) and 26.8% vs. 13.7% in type 2 diabetes ($p<0.005$).

A breakdown of the individual care processes received is provided in Supplemental Tables S1 and S2.

Mortality by number of care processes received

Over the period 1st January 2012 to 31st December 2019 there were 26,915 deaths over 1,431,940 person years follow up in people with type 1 diabetes and 388,093 deaths over 9,853,914 person years follow up in those with type 2 diabetes. The all-cause age and sex standardised mortality rate for people with type 1 diabetes with five or fewer care processes was 33.5 (95% CI 32.3-34.8) compared to 34.4 (95% CI

33.5-35.9) for those with six or seven care processes recorded and 30.7 (95% CI 29.6-31.8) for those with eight care processes recorded. The corresponding figures for people with type 2 diabetes were 30.8 (95% CI 30.4-31.1), 27.5 (95% CI 27.2-27.7) and 25.2 (95% CI 25.0-25.4) (Table 2).

After adjustment for age, sex, ethnicity and deprivation five or fewer than five care processes recorded and having six or seven care processes recorded during the period 1st January 2009 to 31st March 2010 was inversely associated with higher all-cause mortality (HR compared to those receiving all eight care processes 1.17, 95% CI 1.14-1.20 for six or seven, 1.35, 95% CI 1.29-1.41 for five or fewer in Type 1 diabetes and 1.15, 95% CI 1.14-1.16 for six or seven, 1.36, 95% CI 1.34-1.38 for five or fewer in Type 2 diabetes). Further adjustment to include smoking habit, HbA_{1c}, systolic blood pressure, serum cholesterol, body mass index and duration of diagnosed diabetes increased the HR for all-cause mortality associated with having five or fewer care processes to 1.38 (95% CI 1.29-1.47) for type 1 diabetes and decreased it to 1.33 (95% CI 1.30-1.35) for type 2 diabetes. Adding in eGFR and prior hospital admissions for myocardial infarction, stroke, heart failure, respiratory disease and cancer slightly attenuated these HRs (Table 3).

After adjustment for all covariates, the gradient of the inverse association of mortality in people with type 2 diabetes with number of recorded care processes was lower for cancer deaths (Table 3). In contrast, the gradient for respiratory disease deaths is higher; HR of 1.45 (95% CI 1.19-1.76) in type 1 diabetes and 1.41 (95% CI 1.33-1.49) in type 2 diabetes for five or fewer care processes compared to those with eight care processes recorded.

Among people with type 2 diabetes the inverse association between recorded care processes completion is steeper in women than men (HR for five or fewer compared to eight care processes 1.36 (95% CI 1.32-1.40) for women compared to 1.29 (95% CI 1.25-1.33) for men) (see Figure 1b). The HRs for death associated with different numbers of recorded care processes were similar in people aged under or over 65 years in both type 1 diabetes and type 2 diabetes. (see Figure 1a and 1b).

In people with type 2 diabetes the HRs for death associated with the number of recorded care processes were similar in White and Black ethnic groups but significantly lower in South Asian ethnic groups (Figure 1). In people with type 1 diabetes confidence intervals were much broader and no differences between ethnic groups were identified. In both type 1 diabetes and type 2 diabetes the HRs associated with numbers of recorded care processes were similar across all deprivation quintiles (see Supplemental Table S3). In people who had one or more acute hospital admission in the year prior to the exposure period the all-cause mortality HR associated with receiving fewer than five care processes was lower than for those who did not have an acute hospital admission (1.29, 95% CI 1.14-1.45 compared to 1.36, 95% CI 1.26-1.47 in type 1 diabetes and 1.27, 95% CI 1.21-1.32 compared to 1.32, 95% CI 1.29-1.35 in type 2 diabetes).

Individual care processes

Associations adjusted for age, sex, ethnicity and deprivation were investigated by individual care process (Supplemental Table S4). Not having BMI measured was associated with the greatest HR for all-cause mortality (1.36, 95% CI 1.30-1.43 for type 1 diabetes and 1.40, 95% CI 1.38-1.42 for type 2 diabetes) followed by not

having a cholesterol measurement (1.21, 95% CI 1.14-1.28 for type 1 diabetes and 1.22, 95% CI 1.20-1.25 for type 2 diabetes). By contrast, for both type 1 diabetes and type 2 diabetes no record of blood pressure (0.64, 95% CI 0.60-0.69; 0.67, 95% CI 0.65-0.68), smoking status (0.86, 95% CI 0.83-0.89; 0.91, 95% CI 0.90-0.92) or serum creatinine (0.66, 95% CI 0.62-0.71; 0.82, 95% CI 0.80-0.84) were associated with lower mortality hazards. Not having a HbA_{1c} measurement recorded was associated with higher all-cause mortality in type 1 diabetes (HR 1.24, 95% CI 1.16-1.33) but lower mortality in type 2 diabetes (HR 0.91, 95% CI 0.89-0.93).

Discussion

This large national population-based cohort of people with type 1 diabetes and type 2 diabetes followed up for means of 7.6 and 6.9 years, respectively, following 15 months of routine care finds that having five or fewer recorded care processes during that baseline period was associated with subsequent 7 year hazards of all-cause mortality approximately one third higher compared to those who had all eight care processes after accounting for demographic characteristics. This higher mortality persists after adjustment for clinical factors known to affect the risk of diabetes-related complications (HbA_{1c}, systolic blood pressure, serum cholesterol, body mass index, smoking habit), and cardiovascular and renal co-morbidities were taken into account.

The associations were similar between people with type 1 diabetes and type 2 diabetes, at all ages and across socioeconomic groups. In England and Wales most people with type 1 diabetes have specialist led care while for type 2 diabetes, most people are managed in a primary care setting.[14] Accordingly, the association

between the number of recorded care processes and mortality was independent of the type of care setting. During periods of acute illness or palliative care the medium to long term management of diabetes associated risk may not have clinical priority. Nonetheless, the association of higher mortality persists in people who had one or more acute hospital admission in the year prior to the assessment of care processes although the HRs for this group are lower than for those without an acute hospital admission, perhaps reflecting a partial de-prioritisation of routine diabetes care at times of acute illness. This finding combined with the exclusion from the analysis of people who died in the three-year period after the care processes were assessed suggest that the association with higher mortality in those not receiving all eight care processes is not solely due to care processes being suspended for clinical reasons. Furthermore, a sensitivity analysis including all people included in the 2009/10 NDA and still alive on 1st January 2011 did not significantly alter the fully adjusted results of this analysis (see Table S6).

For those with type 2 diabetes, but not type 1 diabetes, there were differences by ethnicity in the association between fewer care processes recorded and higher mortality. Among people with type 2 diabetes the HR of death from all causes amongst those receiving five or fewer annual care processes was 1.29 (95% CI 1.26-1.32) for White ethnicity, 1.13 (95% CI 1.03-1.23) South Asian ethnicity and 1.34 (95% CI 1.19-1.52) for Black ethnicity. The lower HR in people of south Asian ethnicity may link to their higher risks of developing type 2 diabetes, but lower subsequent mortality. A study using the CPRD cohort reported that the additional risk of dying attributable to diagnosed diabetes was lower in people from South Asian ethnic groups than in those from White ethnic groups,[15] despite a greater

diagnosed incidence of cardiovascular disease.[16,17] Thus, the smaller additional diabetes related mortality risk experienced by people from South Asian ethnic groups compared to White ethnic groups may narrow the additional mortality associated with not receiving care processes. Equally, other factors such as health related behaviours, health beliefs and cultural differences may influence attitudes to healthcare, in particular routine and preventative care, and thereby play a role in explaining this difference.

No previous study has investigated whether the number of recorded care processes is associated with future outcomes in people with diabetes. Non-attendance at clinics and non-completion of care processes clearly overlap. A recent comprehensive review of the literature on non-attendance at diabetes outpatient appointments[18] found relationships to both logistical and psychosocial factors. It also found associations with non-attendance at diabetes clinics that were similar to those recognised in other medical specialties such as young age, social deprivation and smoking. Very few studies of non-attendance at diabetes clinics have studied subsequent outcomes.[19] Those that did mostly found associations between infrequent attendance and higher levels of glucose, body mass index, blood pressure and lipids; a few documented higher emergency hospital use and diabetes-related complications; and just one study using a composite measure of non-attendance and treatment non-compliance found higher mortality in people with type 1 diabetes.[18,19]

As compared to the collective results analysis of the associations between mortality and non-completion of individual care processes showed variation from higher risk (e.g., BMI, cholesterol and foot examinations) to lower risk (e.g., blood pressure,

smoking enquiry, serum creatinine). Only one individual care process association with mortality differed between type 1 diabetes and type 2 diabetes. Non completion of HbA_{1c} measurement was associated with higher risk in type 1 diabetes but not in type 2 diabetes perhaps reflecting the greater severity and dominance of hyperglycaemia as a risk factor for complications in type 1 diabetes.

It should be noted that the adjustment of these associations was restricted to age, sex, deprivation and ethnicity as missing data on the risk factors uncovered by the individual care processes hinder more comprehensive adjustments. This means it is plausible that residual confounding and differing risk factor profiles explain these associations. In addition, when carrying out the care processes, previous measurements may influence clinical prioritisation, with greater effort being expended on reaching those at previously identified higher risk. It is possible that the proportion of care processes completed is strongly influenced by logistic issues that result in missed appointments whereas omission of individual items such as weight and surveillance for early complications may be influenced also by psychosocial factors. Additionally, it may be that some factors recorded as satisfactory and stable at recent visits (e.g., HbA_{1c} in people with type 2 diabetes, or blood pressure and kidney function in younger people), are not always repeated, and that a smoking status enquiry may be omitted in long-term non-smokers although one the primary care pay for performance system (Quality and Outcomes Framework) is designed to mitigate against this. Qualitative studies have shown the therapeutic relationship between patient and healthcare professional to be an important determinant of attendance[18] but the NDA cannot capture this aspect of care.

The present analysis identifies an association between low numbers of annual care processes completed and subsequent 7year mortality. Therefore, it identifies a group of people who have a higher risk of mortality. But observational analyses cannot establish cause and effect and we cannot rule out residual confounding. One can only speculate on what any mechanism might be. The prominence of respiratory disease among those who died after low rates of care process completion raises one possibility. Respiratory deaths in younger people are predominantly due to pneumonia for which diabetes is a known risk factor.[20] Our analysis has tried to account for known pneumonia risks such as smoking, which was more common in the low care process group, and elevated BMI but we have not been able to include other known factors such as high alcohol intake, poor diet and low physical activity. Conceivably, these unmeasured risks triangulate with the likelihood of missing care processes. Alternatively, individuals more engaged with self-care and lower risk lifestyles may attend clinics more often and be keener to complete all the care processes. Equally, the findings may be due to reverse causality, whereby people with multimorbidities, particularly mental illness, will be less likely to engage with routine follow up and self-management.

Strengths of this study are the size of the cohort included in the analysis covering 76% of practices in England and Wales, the fact that it is drawn from a comprehensive selection of real-world population-based healthcare records and the length of the follow up. An important limitation is that neither medication data nor influenza and pneumonia immunisations were available for this analysis which could have shed

some light on healthcare interactions. The nature of this analysis means that if people have not received a specific care process the risk factor data arising from that process is missing. In this analysis all variables included in the Cox proportional hazard regression models are treated as categorical variables and have a category for 'missing' data. Whilst this does not completely eradicate residual confounding due to missing data it is much reduced. It is not possible to distinguish the separate or joint contributions of inertia from patients or health care professionals to undertaking care processes and therefore the recording of risk factors. To better understand the nature of the associations between the receipt of care processes and disease outcomes and the roles of associations between health beliefs, health behaviours and interactions with health care providers requires further qualitative and quantitative work in people with diabetes and their care providers. In addition, the identification of care processes received is limited to a single 15-month period. Variation in interactions with healthcare and organisational changes to the health service over the follow-up period may have influenced mortality. Data on prescriptions for glucose lowering drugs was not available for the time period of this analysis. This means that it is not possible to identify whether the associations found in people with type 2 diabetes vary by treatment regimen.

In summary, even when many possible contributory risks for death are taken into account, people with diabetes have a higher mortality risk if their records of routine care indicate several missing annual care processes. Although further evidence is needed on whether efforts to specifically engage this group would yield worthwhile health benefits, health economies should consider how to minimise barriers to receiving the recommended care processes. These observations may be particularly

pertinent in contemporary health care provision as professionals consider how to organise routine diabetes reviews in the face of the backlog attributable to the direct and indirect effects of COVID-19. It would be all too easy to overlook this high-risk group.

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Author contributions

The study was designed by RG, BY, NH and NS. NH undertook the statistical analysis. All authors reviewed the methods, assisted in writing the paper, reviewed the final manuscript, and gave approval for publication. NH is the guarantor and accepts full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

Conflicts of interest

NH, BY, NS, KK, SHW, EWG and JV are members of the National Diabetes Audit Research Advisory Group. NS has received grant and personal fees from Boehringer Ingelheim, and personal fees from Amgen, AstraZeneca, Eli Lilly, Merck Sharp & Dohme, Novartis, Novo Nordisk, Pfizer, and Sanofi outside the submitted work. KK has acted as a consultant, speaker or received grants for investigator-initiated studies for Astra Zeneca, Novartis, Novo Nordisk, Sanofi-Aventis, Lilly and Merck Sharp & Dohme, Boehringer Ingelheim, Bayer, Berlin-Chemie AG / Menarini

Group, Janssen, and Napp. JV is the National Clinical Director for Diabetes and Obesity at NHS England & NHS Improvement. All other authors declare no relationships or activities that could appear to have influenced the submitted work.

Data accessibility

Information governance rules for the National Diabetes Audit prevent the raw or processed data used in this analysis being made publicly available.

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Figure Legends

Figure 1a: Forest plot of HR for all-cause mortality associated with number of care processes recorded between 1st January 2009 and 31st March 2010 stratified by sex, age and ethnicity for people with type 1 diabetes

Figure 1b: Forest plot of HR for all-cause mortality associated with number of care processes recorded between 1st January 2009 and 31st March 2010 stratified by sex, age and ethnicity for people with type 2 diabetes

Table 1: Baseline characteristics by number of care processes received and type of diabetes

	Type 1 diabetes						Type 2 diabetes					
	≤ 5 care processes		6-7 care processes		8 care processes		≤ 5 care processes		6-7 care processes		8 care processes	
	n	%	n	%	n	%	n	%	n	%	n	%
Number	37,235		61,230		80,635		132,125		387,060		878,605	
Mean (SD) follow up, years	7.6 (1.32)		7.5 (1.38)		7.4 (1.48)		6.9 (2)		7 (1.9)		7.1 (1.8)	
Sex												
Female	16,105	43.2%	27,610	45.1%	34,555	42.9%	60,700	45.9%	181,170	46.8%	384,930	43.8%
Male	21,130	56.8%	33,620	54.9%	46,080	57.1%	71,425	54.1%	205,890	53.2%	493,675	56.2%
Age												
<40 years	19,710	52.9%	22,750	37.2%	21,595	26.8%	10,655	8.1%	15,695	4.1%	22,685	2.6%
40-49 years	8,050	21.6%	14,465	23.6%	17,300	21.5%	21,915	16.6%	46,300	12.0%	81,125	9.2%
50-59 years	4,675	12.6%	10,840	17.7%	15,785	19.6%	30,390	23.0%	85,015	22.0%	176,495	20.1%
60-69 years	2,700	7.3%	7,660	12.5%	14,385	17.8%	30,500	23.1%	108,930	28.1%	268,360	30.5%
70-79 years	1,485	4.0%	4,300	7.0%	9,305	11.5%	24,140	18.3%	94,170	24.3%	247,015	28.1%
≥80 years	620	1.7%	1,210	2.0%	2,260	2.8%	14,525	11.0%	36,955	9.5%	82,925	9.4%
Mean (SD), years	40.6 (16)		46.3 (16.2)		51 (16.4)		60.9 (14.8)		63.5 (12.9)		65 (11.9)	
Deprivation												
Most deprived	7,770	21.5%	11,625	19.6%	16,475	21.1%	33,345	26.1%	88,140	23.5%	198,075	23.4%
2nd most deprived	7,510	20.8%	11,755	19.8%	15,540	19.9%	28,720	22.4%	78,635	20.9%	176,765	20.9%
3rd most deprived	7,270	20.2%	11,915	20.1%	16,075	20.6%	25,220	19.7%	75,255	20.0%	172,680	20.4%
2nd least deprived	6,915	19.2%	12,035	20.3%	15,375	19.7%	21,645	16.9%	70,110	18.7%	158,250	18.7%
Least deprived	6,620	18.3%	12,070	20.3%	14,760	18.9%	19,040	14.9%	63,540	16.9%	139,585	16.5%
Missing	1,150		1,830		2,415		4,155		11,380		33,255	
Ethnic group												
White	30,000	89.1%	50,365	89.6%	65,885	87.9%	83,910	73.3%	265,790	79.1%	627,640	80.8%
Mixed	340	1.0%	430	0.8%	630	0.8%	1,635	1.4%	3,200	1.0%	6,520	0.8%
South Asian	1,430	4.2%	2,515	4.5%	3,985	5.3%	15,235	13.3%	37,715	11.2%	78,585	10.1%
Black	1,020	3.0%	1,530	2.7%	2,670	3.6%	7,165	6.3%	14,525	4.3%	32,580	4.2%
Other	875	2.6%	1,345	2.4%	1,820	2.4%	6,590	5.8%	14,865	4.4%	31,220	4.0%
Missing	3,565		5,040		5,645		17,590		50,960		102,060	
Smoking status												
Current smoker	5,335	32.9%	12,120	25.2%	15,725	19.9%	12,820	26.8%	50,060	17.4%	120,035	13.7%
Ex-smoker	3,165	19.5%	11,450	23.8%	22,180	28.0%	14,255	29.8%	98,530	34.3%	333,940	38.1%
Non-smoker	470	2.9%	1,415	2.9%	2,350	3.0%	1,445	3.0%	6,860	2.4%	17,755	2.0%

Never smoked	7,250	44.7%	23,045	48.0%	38,895	49.1%	19,340	40.4%	132,215	46.0%	404,100	46.1%
Missing	21,020		13,205		1,480		84,270		99,400		2,775	
Duration												
< 1 year	1,215	3.3%	1,575	2.6%	2,165	2.7%	13,370	10.1%	39,385	10.2%	89,805	10.2%
1 - 2 years	2,755	7.4%	3,655	6.0%	4,845	6.0%	24,890	18.8%	72,640	18.8%	167,735	19.1%
3 - 5 years	2,920	7.8%	4,220	6.9%	5,590	6.9%	23,500	17.8%	69,535	18.0%	159,015	18.1%
5 - 9 years	8,350	22.4%	12,470	20.4%	16,310	20.2%	40,390	30.6%	122,070	31.5%	277,675	31.6%
10 -14 years	6,325	17.0%	10,025	16.4%	13,310	16.5%	15,725	11.9%	46,635	12.0%	104,610	11.9%
15 - 19 years	5,150	13.8%	8,765	14.3%	11,005	13.6%	7,670	5.8%	21,880	5.7%	47,480	5.4%
≥ 20 years	10,520	28.3%	20,515	33.5%	27,410	34.0%	6,585	5.0%	14,920	3.9%	32,280	3.7%
Mean (SD), years	16.1 (17.4)		17.5 (15.7)		17.8 (16.5)		8.7 (19.7)		7.5 (13.2)		7.4 (13.3)	
HbA_{1c}												
<48mmol/mol	1,365	8.5%	4,545	7.7%	6,715	8.5%	13,600	27.0%	100,765	27.3%	239,035	27.6%
48-53 mmol/mol	1,270	7.9%	5,155	8.8%	8,395	10.6%	8,330	16.5%	78,880	21.4%	206,900	23.9%
54-58 mmol/mol	1,705	10.6%	6,925	11.8%	10,425	13.1%	6,430	12.8%	54,750	14.8%	137,880	15.9%
59-74 mmol/mol	5,785	36.1%	22,735	38.6%	31,185	39.3%	11,505	22.8%	81,915	22.2%	186,265	21.5%
75-85 mmol/mol	2,585	16.1%	9,305	15.8%	11,620	14.7%	4,215	8.4%	23,955	6.5%	46,945	5.4%
≥86 mmol/mol	3,325	20.7%	10,205	17.3%	10,980	13.8%	6,315	12.5%	29,095	7.9%	47,900	5.5%
Mean (SD), mmol/mol	72 (20.2)		70.3 (18.6)		68.1 (17.3)		61.5 (20.1)		58.4 (17.1)		56.8 (15.2)	
Missing	21,205		2,365		1,317		81,730		17,700		13,680	
Body mass index												
<20 kg/m^2	855	5.9%	2,050	3.6%	2,345	2.9%	680	1.8%	3,905	1.1%	7,990	0.9%
20-24.9 kg/m^2	5,105	35.5%	16,965	29.7%	21,860	27.3%	5,100	13.3%	46,370	12.9%	114,065	13.1%
25-29.9 kg/m^2	4,910	34.1%	21,240	37.2%	30,120	37.6%	11,425	29.8%	118,935	33.2%	304,275	34.9%
30-34.9 kg/m^2	2,260	15.7%	10,775	18.9%	16,550	20.6%	10,245	26.7%	101,520	28.3%	252,845	29.0%
35-39.9 kg/m^2	790	5.5%	3,930	6.9%	6,230	7.8%	5,990	15.6%	52,455	14.6%	121,025	13.9%
≥40 kg/m^2	475	3.3%	2,150	3.8%	3,075	3.8%	4,860	12.7%	35,360	9.9%	72,870	8.3%
Mean (SD), kg/m^2	26.9 (5.8)		27.8 (5.8)		28.2 (5.7)		31.8 (7.3)		31.2 (6.6)		30.9 (6.2)	
Missing	22,840		4,125		453		93,825		28,515		5,530	
Systolic blood pressure												
<120 mmHg	5,290	25.7%	13,550	22.4%	16,170	20.1%	8,435	11.9%	45,110	11.8%	101,330	11.5%
120-129 mmHg	5,025	24.4%	14,915	24.7%	19,560	24.3%	13,010	18.3%	77,300	20.2%	180,965	20.6%
130-139 mmHg	4,905	23.8%	15,695	26.0%	22,270	27.7%	18,590	26.2%	115,735	30.2%	278,080	31.7%
≥140 mmHg	5,395	26.2%	16,285	26.9%	22,525	28.0%	30,945	43.6%	145,220	37.9%	317,195	36.1%
Missing	16,625		790		105		61,145		3,695		1,035	

Cholesterol												
<5 mol/l	6,605	66.4%	40,465	71.0%	60,935	75.7%	31,690	68.5%	290,895	78.1%	719,025	82.0%
≥5 mol/l	3,345	33.6%	16,525	29.0%	19,545	24.3%	14,595	31.5%	81,550	21.9%	158,140	18.0%
Missing	27,285		4,240		155		85,840		14,615		1,445	
eGFR												
≥90	5,445	45.7%	25,340	44.1%	31,945	40.0%	15,875	30.3%	108,095	29.0%	228,940	26.1%
60-89	4,650	39.1%	24,385	42.4%	35,280	44.2%	24,440	46.6%	188,230	50.5%	453,280	51.7%
45-59	925	7.8%	4,470	7.8%	7,975	10.0%	7,205	13.7%	50,665	13.6%	133,305	15.2%
30-44	480	4.0%	2,045	3.6%	3,410	4.3%	3,510	6.7%	19,420	5.2%	50,740	5.8%
15-29	220	1.8%	795	1.4%	1,045	1.3%	1,085	2.1%	4,690	1.3%	9,910	1.1%
<15	190	1.6%	445	0.8%	250	0.3%	350	0.7%	1,325	0.4%	1,175	0.1%
Missing	25,335		3,750		725		79,655		14,640		1,255	
Prior hospital admission												
Myocardial infarction	340	0.9%	785	1.3%	1,285	1.6%	2,445	1.9%	7,750	2.0%	17,425	2.0%
Stroke	355	0.9%	595	1.0%	810	1.0%	2,895	2.2%	6,140	1.6%	11,090	1.3%
Heart failure	420	1.1%	850	1.4%	1,315	1.6%	3,290	2.5%	8,845	2.3%	19,065	2.2%
Respiratory disease	4,245	11.4%	6,615	10.8%	8,575	10.6%	13,825	10.5%	39,045	10.1%	87,765	10.0%
Cancer	450	1.2%	1,040	1.7%	1,895	2.4%	3,975	3.0%	14,350	3.7%	36,615	4.2%

Table 2: Number, crude rate and age and sex standardised of deaths by number of care processes received and type of diabetes

		≤ 5 care processes			6-7 care processes			8 care processes		
		N	Crude rate per 1000 person years	Age and sex standardised rate per 1000 person years	N	Crude rate per 1000 person years	Age and sex standardised rate per 1000 person years	N	Crude rate per 1000 person years	Age and sex standardised rate per 1000 person years
Type 1 diabetes	All causes	4,512	16 (15.5-16.5)	33.5 (32.3-34.8)	8,660	18.8 (18.4-19.2)	34.4 (33-35.9)	13,743	22.9 (22.5-23.3)	30.7 (29.6-31.8)
	Cardiovascular disease	1,503	5.3 (5.1-5.6)	11.1 (10.5-11.8)	2,922	6.3 (6.1-6.6)	11.2 (10.4-12)	4,808	8 (7.8-8.3)	10 (9.4-10.5)
	Diabetes specific causes*	765	2.7 (2.5-2.9)	4.6 (4.1-5)	1,317	2.9 (2.7-3)	4.9 (4.4-5.5)	1,709	2.9 (2.7-3)	4 (3.5-4.4)
	Renal failure	26	0.09 (0.06-0.14)	0.2 (0.1-0.3)	51	0.11 (0.08-0.15)	0.2 (0.1-0.2)	59	0.1 (0.07-0.13)	0.1 (0.1-0.2)
	Cancer	570	2 (1.9-2.2)	4.4 (4-4.9)	1,371	3 (2.8-3.1)	4.7 (4.3-5.1)	2,518	4.2 (4-4.4)	4.7 (4.5-4.9)
	Respiratory disease	452	1.6 (1.5-1.8)	4.1 (3.6-4.5)	999	2.2 (2-2.3)	4.9 (4.2-5.5)	1,602	2.7 (2.5-2.8)	3.9 (3.5-4.4)
Type 2 diabetes	All causes	37,586	41 (40.6-41.4)	30.8 (30.4-31.1)	107,006	39.3 (39-39.5)	27.5 (27.2-27.7)	243,501	39.2 (39-39.4)	25.2 (25-25.4)
	Cardiovascular disease	11,689	12.8 (12.5-13)	9.4 (9.2-9.5)	33,265	12.2 (12.1-12.3)	8.3 (8.2-8.4)	75,399	12.1 (12.1-12.2)	7.7 (7.6-7.8)
	Diabetes specific causes*	2,536	2.8 (2.7-2.9)	2.1 (4.1-2.2)	6,237	2.3 (2.2-2.3)	1.8 (1.8-1.9)	12,432	2 (2-2)	1.5 (1.5-1.6)
	Renal failure	230	0.25 (0.22-0.29)	0.2 (0.2-0.2)	672	0.25 (0.23-0.27)	0.2 (0.2-0.2)	1,417	0.23 (0.22-0.24)	0.2 (0.1-0.2)
	Cancer	6,281	6.9 (6.7-7)	4.8 (4.7-4.9)	22,833	8.4 (8.3-8.5)	5.1 (5-5.2)	58,621	9.4 (9.4-9.5)	5.2 (5.2-5.3)
	Respiratory disease	5,000	5.5 (5.3-5.6)	4 (3.9-4.2)	14,699	5.4 (5.3-5.5)	3.9 (3.8-4)	33,477	5.4 (5.3-5.4)	3.6 (3.5-3.6)

* Diabetes Mellitus (ICD-10 codes E10-E14), drug induced hypoglycaemia without coma (E16.0) and unspecified hypoglycaemia (E16.2)

Table 3: Hazard ratios for mortality associated with the number of care processes recorded between 1st January 2009 and 31st March 2010 for people with type 1 diabetes and type 2 diabetes, all-cause mortality with different adjustments and cause-specific mortality

Cause of death	Care processes received	Type 1 diabetes	Type 2 diabetes
All causes[1]	≤ 5	1.35 (1.29 - 1.41)	1.36 (1.34 - 1.38)
	6 or 7	1.17 (1.14 - 1.2)	1.15 (1.14 - 1.16)
	All 8	1.00	1.00
All causes[2]	≤ 5	1.38 (1.29 - 1.47)	1.33 (1.3 - 1.35)
	6 or 7	1.12 (1.09 - 1.16)	1.1 (1.09 - 1.11)
	All 8	1.00	1.00
All causes[3]	≤ 5	1.37 (1.28 - 1.46)	1.32 (1.3 - 1.35)
	6 or 7	1.11 (1.08 - 1.14)	1.1 (1.09 - 1.11)
	All 8	1.00	1.00
Cardiovascular disease[3]	≤ 5	1.32 (1.18 - 1.48)	1.28 (1.24 - 1.33)
	6 or 7	1.06 (1.01 - 1.11)	1.09 (1.07 - 1.1)
	All 8	1.00	1.00
Cancer[3]	≤ 5	1.23 (1.04 - 1.46)	1.06 (1.01 - 1.12)
	6 or 7	1.03 (0.95 - 1.1)	1 (0.98 - 1.02)
	All 8	1.00	1.00
Respiratory disease[3]	≤ 5	1.45 (1.19 - 1.76)	1.41 (1.33 - 1.49)
	6 or 7	1.19 (1.1 - 1.3)	1.14 (1.12 - 1.17)
	All 8	1.00	1.00
Diabetes specific causes[3]	≤ 5	1.16 (0.98 - 1.36)	1.37 (1.26 - 1.49)
	6 or 7	1.15 (1.06 - 1.24)	1.18 (1.14 - 1.22)
	All 8	1.00	1.00
Renal failure[3]	≤ 5	1.52 (0.66 - 3.51)	1.27 (0.98 - 1.66)
	6 or 7	1.24 (0.81 - 1.89)	1.13 (1.01 - 1.25)
	All 8	1.00	1.00

[1] – Adjusted for age, sex, ethnicity, deprivation, smoking

[2] – Adjusted for Age, sex, ethnicity, deprivation, smoking, HbA_{1c}, systolic blood pressure, cholesterol, BMI, duration of diagnosis

[3] – Adjusted for age, sex, ethnicity, deprivation, smoking, HbA_{1c}, systolic blood pressure, cholesterol, BMI, durations of diagnosis, eGFR, prior hospital admission for myocardial infarction, stroke, heart failure, respiratory disease and cancer

Figure 1a: Forest plot of HR for all-cause mortality associated with number of care processes recorded between 1st January 2009 and 31st March 2010 stratified by sex, age and ethnicity for people with type 1 diabetes

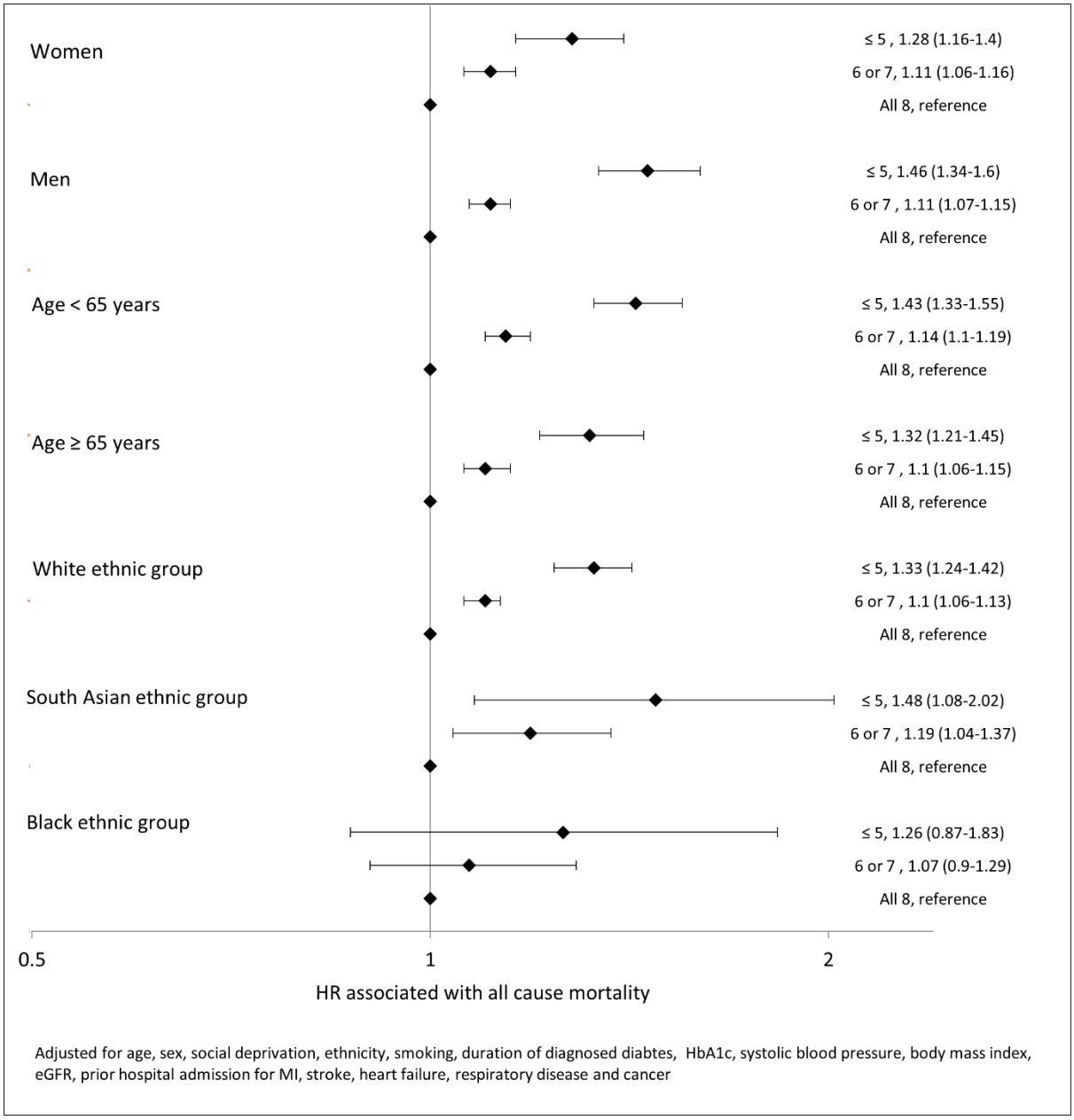

Figure 1b: Forest plot of HR for all-cause mortality associated with number of care processes recorded between 1st January 2009 and 31st March 2010 stratified by sex, age and ethnicity for people with type 2 diabetes