Practice-level quality of care and hospital readmissions for type 2 diabetes complications: A multivariate failure time analysis

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Abstract

Aims

The aim of the paper is to investigate the relationship between quality of primary care for patients with Type 2 diabetes and the rate of hospital readmissions for patients admitted with a Type 2 diabetes related complications.

Methods

Extended Cox proportional hazard model for recurrent events were estimated to assess the impact of quality delivered in primary care on an individual patient's risk of re hospitalization for diabetes related complications. The outcome of interest was the time in years from discharge following a Type 2 diabetes related admission to subsequent readmission. We controlled for patient demographics, socio-economic characteristics, morbidity, secondary care provider and access to primary and secondary care.

Data

A cohort of 3942 patients aged 18 and over, from 60 GP practices in England, hospitalized with a diagnosis of a Type 2 diabetes complication between 1 April 1997 and 30 March 2006 were identified using the Hospital Episode Statistics database and retrospectively followed up. Practice level quality indicators for diabetes care were available from the Quality Assessment in Primary Care study for the years 1998, 2003 and 2005.

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Results

After controlling for hospital effects, practice clinical quality was not associated with the likelihood of readmission. Providers confounded the association previously found after controlling for socio-demographic characteristics of the patients, clinical and geographical effects.

Conclusion

It is important to control for hospital unobservable characteristics when assessing the impact of primary care quality on the risk of readmission in order to remove the effect of secondary care. Policy makers should take into account that crucial role played by secondary care sector in order to design appropriate interventions to reduce readmissions for ambulatory care sensitive conditions such as diabetes.

1. Introduction

Diabetes is a common chronic condition with an estimated prevalence in the UK of 3.9% (NHS Health and Social Care Information Centre, 2008). However the true prevalence may be much higher since it is thought that up to half of all cases of diabetes may be undiagnosed (NHS Health and Social Care Information Centre, 2007; Holt, 2008). Diabetes is more prevalent in the older, non-whites and in more deprived areas (YHPHO, 2008). The inability of the pancreas to produce sufficient insulin needed to maintain a normal blood glucose level can result in acute events due to poor short term such as diabetic ketoacidosis, diabetic coma and hypoglycaemia control as well as chronic complications due to poor long term control including cardiovascular disease, stroke, blindness, amputations, kidney disease, and nerve damage. Hospital admission rates for diabetes related complications are considered to be an ambulatory care sensitive condition where timely and effective management in primary care can prevent and reduce hospitalizations and re-hospitalizations for diabetes specific and related complications (Weissman et al., 1992; Benbassat et al. 2000; AHRQ, 2004; Bo et al. 2004; Greisinger et al, 2004; Jiang, 2005; Robbins, 2006; Ansari et al, 2006; Bottle, 2008; Tomlin, 2008). For instance, intensive blood glucose control may significantly reduce the risk of cardiovascular and micro-vascular complications in diabetes patients (UKPDS, 1998a; UKPDS, 1998b).

With an aging population, the number of individuals living with chronic conditions is increasing. This is likely to lead to greater pressures on emergency hospital services.

During the last decade the UK NHS has implemented a number of policies intended to improve the quality of chronic disease management in primary care, and thereby reduce hospital admissions for patients with chronic diseases. National Chronic Disease Management Programs in the early 1990s were followed by National Service Frameworks (Department of Health, 2002) in the late 1990s and in early 2000. These were superseded by the Quality and Outcomes Framework, a major pay for performance scheme which rewards General Practitioners (GPs) financially for achieving indicators of clinical quality in chronic disease management including diabetes and related conditions. The new GP contract incentives quality of care for individuals with chronic conditions. There is evidence that these reforms have lead to increased clinical quality in diabetes care (Campbell BMJ, Campbell et al, 2007; Doran et al, 2006; Q-Research database), however, hospital admissions for diabetes complications have increased during this period and are a major concern to the health care system (NHS National Diabetes Support Team, 2008). The preventability of these hospitalizations through good primary care quality is well recognized in the medical literature on ambulatory care sensitive conditions (AHRQ, 2004), however more evidence is required to empirically assess their association.

Alongside policies aimed at improving the quality of clinical care, the UK NHS has introduced systematic models of care designed to achieve this target based on early detection of high risk groups and associated community matron expansion; Evercare case management by advanced GP practice or community nurses as well as The Patients at Risk of Readmission Tool policies designed to identify and treat patients considered at increased risk of emergency hospital admission. Routine hospital data is used to identify patients with multiple hospital admissions, of which diabetic complications are a specific subgroup, requiring investigation and if necessary monitoring in order to reduce their risk of emergency hospital admission (Billing et al, 2006; Gravelle et al., 2006). The analysis of hospital readmission rates can help identify high risk patients in which may direct resources to appropriate outpatient management interventions that could improve health outcomes and possibly reduce hospital readmissions (Curry et al., 2005).

This study tests the hypothesis that better clinical quality measured at GP practice level is associated with a reduced risk of re-admissions for patients admitted with specific or related diabetic complications. We also look to identify the clinical and non-clinical characteristics of patients associated with an increased risk for hospital readmissions. A

sample of 3942 patients aged ≥18, from 60 GP practices in England, hospitalized with a diagnosis of a Type 2 diabetes complication between 1 April 1997 and 30 March 2006 were identified using the Hospital Episode Statistics database and retrospectively followed up. Practice level quality indicators for diabetes care were available from the Quality Assessment in Primary Care study for the years 1998, 2003 and 2005. We use a Cox proportional hazard model for recurrent events to estimate the impact of quality on the time to readmission following discharge for Type 2 diabetes related admissions to the next and subsequent readmissions for a diabetes-related complication.

2. Background

Literature review on the association between quality in primary care and hospitalisations.

The existing research has provided contrasting evidence on the relationship between hospital readmissions and the quality of outpatient care. Weissman et al. (1992) found that repeat admissions were related to barriers to care access, especially post-discharge follow up in the community. Weinberger et al (1996) and Odonne et al. (1999) showed that greater access to primary care after discharge from the hospital were associated with increased readmissions.

Interventions such as Case Management to improve the support of patients with long-term conditions were reviewed by Hutt et al (2004) and Roland et al. (2007) in a recent review of the effectiveness of case management approaches concluded that there was only weak evidence for its effectiveness in reducing unplanned hospital admission in older people. Finally, Gravelle et al (2007) showed that a modified Evercare case management approach of older people by nurses in primary care, piloted in 64 general practices in England, had not reduced unplanned admission rate, length of stay, or mortality in comparison to control practices.

Among the studies which focused on diabetes, Bo et al (2004) found that patients with Type 2 diabetes, and particular younger women, had higher rates for hospitalization than the general population. Greisinger et al. (2004) documented the benefit of participating in

primary care diabetes management programs in terms of reduced subsequent hospitalization risk. In particular, they showed that the greatest benefit derives from both glycaemic control and patient education. The study by Kampan (2006) indicates that counseling and implementation of clinical pathway on diabetic patients hospitalized with hypoglycemia can reduce the length of hospital stay and decrease subsequent readmission rates of recurrent hypoglycemia significantly. Robbins (2006) showed a very substantial decrease in risk of re-hospitalization after the first hospitalization during which a patient was coded for diabetes. The results suggest that some actions taken as a result of this event—whether by the hospital staff, the patient, or the providers of follow-up care—may be effective in improving post discharge outcomes. Held et al (2007) suggest that any level of hyperglicaemia is associated with increased rates of hospital admission, even in patients without manifest diabetes. Bottle et al. (2008) investigated the association between quality of care for diabetes across 300 Primary Care Trusts in England using aggregated quality indicators reported by GP practices. They found a significant negative association between improved glycaemic control and Hospital admission rates in patients aged 60 years and older. Tomlin et al (2008) examined the role of both demographic and clinical risk factors such as urine albumin, creatinine ratio, body mass index, triglycerides and high density lipoproteins in affecting the likelihood of developing diabetic complications and concluded that attention to all these factors in the primary care setting is indicated if hospitalisations due to diabetes complications is to be minimized. Several other previous works found that other relevant clinical factors such as glycemic and blood pressure levels are predictors of hospitalisations for diabetes complications (American diabetes association, 1998; UKPDSG, 1998a; UKPDSG, 1998b).

Factors outside the control of the GP may also contribute to multiple hospitalisations which include demographic, socio-economic status, secondary supply policy and patient compliance (De Castro, 2005). For example, readmissions for diabetes were found to be higher among Black and Hispanics which were more likely to develop complications preventable by proper post discharge, among the elderly and in lower-income communities (Jiang et al., 2005).

This paper tries to investigate to which extend GPs clinical care reduces the risk of hospital readmissions among types 2 diabetes suffering from various complications, after controlling for other factors which are not under his control and may be responsible for rehospitalisation. From a policy perspective this research question may provide an insight on the resource allocation process between primary and secondary care.

3 Data

We extracted records of inpatient elective and emergency hospital episodes from the English Hospital Episode Statistics (NHS Health and Social Care Information Centre, 2008) for patients aged 18 years and over, with any diagnosis of Type 2 diabetes, and registered with to one of the 60 nationally representative English GP practices in our study for the financial years 1997/8-2005/6. We then found all hospital episodes for 3942 patients during the study period using the individual patient records over time using the unique *hesid* patient identifier. Bottle et al. (2006) have shown that routine HES records can be used to correctly identify patients at high risk of readmission. We grouped all finished consultant episodes into spells of care (completed hospital stays including any transfers) for all diabetes specific and related conditions as well as all unrelated admissions. Diabetes specific complications were identified using the primary diagnosis of type 2 diabetes and related complications used a secondary diagnosis of type 2 diabetes with a primary diagnosis of a condition for which diabetes has been associated with an increased risk (Jiang et al 2005). This approach overcomes some o the limitations found in earlier research, which defined diabetes admission on the basis of either a principal diagnosis of diabetes or presence of diabetes in any diagnosis field. The former approach underestimated, and the latter overestimated the incidence of diabetes hospitalizations. All admission were sorted by patient and date of admissions and the first diabetes or diabetes related admission identified as the index admission.

As well as containing the date of admission, discharge, and GP practice we were able to obtain the date of death for all admitted patients (both inside or outside of hospital) from the Office of National Statistic's mortality registrar.

HES data contained the patient's age, gender, ethnicity, ICD-10 diagnostic codes, Health Care Resource Group (HRG), procedure codes, length of stay and their resident, type of admission, and Lower Super Output Area code. We used the ICD-10 diagnostic codes to derive the Charlson Index for comorbidity, and derived the number of previous admissions before each hospital spell, and the number of emergency admissions, time from the start of the study to the index admission, and whether the patient was admitted from or discharged to local authority housing or care (*admisorc*, *dissorc*).

We attributed patient socio-economic and geographic characteristics using the Indices of Multiple Deprivation 2004, census variables (home ownership, car ownership, qualification, general health, limiting long standing illness, Social class/occupational groups, attributed income (ONS neighbourhood statistics)), ONS rurality indicators; measures of access to the GP and to the hospital (distance from the LSOA centroid to the nearest GP practice, beds weighted distance to hospital index from the AREA resource allocation formula). Yearly time indicator variables were included to control for trends and hospital fixed effects to allow for secondary care effects. See Table 1 for a full description of all the variables used and their summary statistics. Multiple imputation methods were used to impute missing age and ethnicity data (less than 5% of records contained incomplete data). Individual demographic characteristics (gender, age, ethnicity) are directly available from the HES.

GP practice clinical quality data were available from the Quality Assessment in Primary Care study (Campbell et al. 2002, 2005). This was a longitudinal observational study of 60 nationally representative GPs in six geographical areas of England for the years 1998, 2003, 2005. The quality indicators were developed using a modification of the RAND-UCLA evidence based review criteria (Campbell, 1999). Quality of care was assessed by clinical audit of patient records from a random sample of patients aged over 18 with a confirmed diagnosis of type 2 diabetes against the predefined and validated indicators of quality. Separate random samples of 20 patient records (or the maximum number of eligible patients in practices with fewer than 20 patients) were drawn in 1998 from all 60 practices, in 2003 for 43 practices, and in 2005 for 42 of the practice. The mean number of patients sampled in each practice was 18 [range 9-20]. The reduction in the number of practices was due partly to attrition and partly to the retirement of solo physicians and the closing of other practices. The 42 practices were still nationally representative in terms of socioeconomic status, but solo practitioners were underrepresented (Campbell et al, 2005). Quality indicators included visual examination of: feet, fundi or visual acuity; documentation of education; recording of: peripheral pulses, vibration sense, serum creatinine, urine proteinuria, weight, blood pressure, hypoglycaemia symptoms, smoking status and serum cholesterol; advice given to smokers; offered treatment to under 80 years if average of last 3 readings showed diastolic >100 or systolic >150 and diastolic >90; prescription of an ACE inhibitor if patient was being treated for hypertension and had proteinuria (macro- but not micro-albuminuria); measurement of creatinine and potassium

if patient was started on ACE inhibitor within 1 month of starting treatment; therapeutic intervention to improve glycaemic control for patients under 70, where the last HbA1c was >9; blood pressure level < 140/85; cholesterol level <5 and HBA1c level <7.4. A quality of care score for each patient was calculated as the percentage of 'necessary' quality indicators met, and the quality score for each practice was calculated as the average patient quality score. The individual level patient records were anonymous, hence we were unable to link them to the specific patient's hospital admissions data. Hence quality of care is attributed at the practice level. We also included other characteristics of the GP practice to which the patient was registered to control for other factors that might be associated with quality and have a direct effect on admission. These included, number of patients per WTE GP, GP ages, gender, training status, whether they perform minor surgery.

4 Methods

4.1 Study design

This was a retrospective cohort study of patients who were hospitalized for a specific or related diabetes complication (as defined in the previous section) at any time between 1st April 1997 and 31st March 2006. The outcome variable is the time to readmission, treating it as a recurrent event. Follow-up for each patient began on the date of live discharge from their first observed hospitalization after the start of the study period 01 April 1997 (the index hospitalization), and continued until the end of the study period 31st March 2006. Hence the length of follow up differs for each patient according to the date of the index admission. Censoring may occur in three ways 1) termination of the study before the event occurs; 2) death; 3) loss to follow-up, which occurs if the patient changes practice to one outside of our study (Appendix, Figure 1).

We used two definitions of time at risk. The gap time formulation calculates the time to first readmission as the time between the date of discharge of the index admission and the admission date of the subsequent admission for diabetes related complications. The time to subsequent readmission has been estimated as the difference between the last discharge date and the admission date of the current hospitalization. The counting time formulation measures the time at risk for each hospital readmission from the index admission as opposed to the time since the last hospital readmission in the gap time formulation. We

believe that the counting process formulation is theoretically more appropriate to model hospital readmission for diabetes complications since the risk of readmissions develops simultaneously and not sequentially. If a patient was hospitalized for a non-diabetes related event, this period in hospital was not counted as time at risk of diabetes hospitalization. This also ensured we dealt appropriately with spells consisting of more than one episode for both diabetic and non-diabetic related complications.

3.4 Statistical Analysis

To estimate the association between GP clinical quality and risk of hospital readmissions we fit variance-corrected Cox proportional hazard models for ordered events using partial maximum likelihood estimation (Box-Steffensmeier, 2004; Twisk et al., 2005). For the statistical analyses, STATA software version 10.0 was used to generate parameter estimates and associated standard errors. We followed the methods proposed by Andersen and Gill (AG) (1982) and Prentice, Williams and Peterson (PWP) (1981) to deal with recurrent events. For a point of comparison on the question of multiple failures, we also estimated a model that considers only first readmission assuming that this is representative of all events and a frailty random effect model. The Cox semi parametric approach implies that the shape of the baseline hazard function is a non-parametric specification. The cost of this semi-parametric approach is a loss in efficiency.

3.5 The model

Following the notation from Kelly and Linn (2000), let T_{ij} be the time to the j th hospital re-admission of the i th subject from the index admission, where $i = 1,2,\ldots N$ and $j = 1,2,\ldots J$. In addition, let C_{ij} be the corresponding censoring time and X_{ij} the corresponding follow up time, that is, $X_{ij} = \min\left(T_{ij}, C_{ij}\right)$. T_{ij} and C_{ij} are assumed independent, conditional on the covariate vector Z_{ij}. Let $\delta_{ij} = I_{(X_{ij}=T_{ij})}$ be a binary indicator for recurrent admissions which is 0 if the observation is censored and 1 if T_{ij} is observed. Similarly, we denote T_i^* the last follow-up time for subject i. Let $\lambda_{ij}(t)$ denote the hazard function for the j th readmission of the i th subject at time t, $\lambda_0(t)$ represents

the common unspecified baseline hazard for all events and $\lambda_{0j}(t)$ is an event-specific baseline hazard for the j th readmission.

The Andersen-Gill counting time model (1982) specifies a common baseline hazard across events *j*:

$$\lambda_{ij}\left(t, Z_{ij}(t)\right) = h_0(t)\exp Z_{ij}(t)\beta$$

This model assumes that multiple hospitalisations are conditionally independent i.e. the risk of hospital readmission for a given individual is unaffected by previous admissions. In order to introduce a rudimentary form of event dependence, however, we included in a count of previous events as a covariate in the model to allow the hazard change proportionately with each hospital admission (Beck et al, 1998).

The Prentice-Williams-Peterson model (PWP) (1981) uses a 'stratified' risk set i.e. it allows the baseline hazard to differ for each readmission *j*, each of which has a distinct unspecified baseline hazard function but common values for the coefficients β (Mahè, 2001; Therneau and Grambsch, 2000). This framework enables two definitions for the time at risk of readmission 1) the time since the onset of the risk of hospital readmission (counting time (CT) formulation) and 2) the time since the previous event (gap-time (GT) formulation). Both were used to define the duration variable in the PWP model. The first approach assumes we are interested in the evolution of the risk as a function of time since the index admission while the gap time approach by 'resetting the clock' to zero after each readmission is more applicable when the risk process varies as a function of the time since the occurrence of the previous readmission. The PWP-CT model is as follows:

$$h\left(t, Z(t) \mid n(t) = k\right) = h_{0k}(t)\exp\left(Z_{ij}(t)\beta\right)$$

whereas the PWP-GT is given by:

$$h\left(t, Z(t) \mid n(t) = k\right) = h_{0k}\left(t - t_{(n(t)-1)}\right)\exp\left(Z_{ij}(t)\beta_k\right)$$

where $k = 0, 1, \ldots, K$ is the number of preceding readmissions, $h_{0k}(t)$ and $h_{0k}\left(t - t_{(n(t)-1)}\right)$ are the corresponding baseline hazard function for the two possible time scale and β is the vector of stratum specific regression coefficients. When a subject has experienced no readmission she resides in stratum 0 $\left(number\ of\ failure\ (nf = 0)\right)$, and when the first readmission occurs the subject moves to the second stratum $(nf = 1)$. In general, the

individual moves to stratum k immediately following the $(k-1)^{st}$ readmission and remains there until the n^{th} readmission. We combined individuals with $K \geq 10$ into one strata to ensure a sufficient sample size for the analysis.

An overall association of clinical quality with all hospitalisations (Common effect model) as well as an individual association of quality with each hospitalisation (Uncommon effect model) which was built by interacting quality and hospitalisation previous number were also estimated. Possible dependencies across spells for individuals in the same practice which may lead to biased standard errors and test statistics were accounted for by adjusting the covariance matrix of the estimators and clustering within practices. As an additional robustness check we re-estimate the models where a latent random effect, or 'frailty', enters multiplicatively on the hazard function to check if practice's readmissions were correlated due to a characteristic not being measured. The frailties are unobservable and are assumed to follow a gamma distribution with mean one and variance to be estimated from the data. If the variance differs significantly from zero, then the null hypothesis of no unobserved heterogeneity cannot be maintained.

Time varying covariates. As clinical quality varied over time and because there was significant improvement in quality during our study we allowed for time varying covariates by splitting the time at risk intervals in the data to incorporate different covariate values during different periods at risk. Quality splitting occurred at the following dates when quality scores were recorded: the 1st of June 1999, the 1st of July 2003 and the 1st of July 2005. We also splitted on calendar year and age to control for years dummies and attained age. We also treated the number of previous failures (overall and emergency) and the comorbidity Charlson index as a time varying covariate.

3.6 Model specification

The proportionality assumption was tested using log–log negative plots and the Schoenfeld residual test. The functional form of continuous variables was assessed using smoothed scatter plots of the martingale residuals for the model against the continuous variable of interest. We plotted deviance residuals against time to assess the fit of the data and to identify aberrant cases. We developed subsets of covariates according to three explanatory themes: 1) socio-demographics 2) severity and comorbidity 4) geographical

and provider effects. We test for clinically relevant interactions. We also used plots of the cumulative Cox-Snell residuals to assess the general fit of the models. Variables highly correlated with each other were not included in the analysis. We compared models using the Akaike information criterion to prevent over-fitting the data.

5 Results

Descriptive statistics

3942 subjects met the inclusion criteria of our study. Among subjects who had no previous readmission, median survival time was 3.20 years (95% CI, 2.95 years to 3.78 years) while among those who had one previous readmission median survival time was 0.32 years (95% CI, 0.11 years to 0.68 years). Descriptive characteristics of the study population are presented in Table 1. This is a predominantly male (53%), white (87%) and old population (mean age 68; SD, 12). 36% of the study cohort with no previous readmissions had a Charlson comorbidity index of one or more. Cardiovascular complications were listed as the first more responsible reason for hospitalisation in 61% of the index hospitalisations while ophthalmic complications were listed as the second one in 21% of the index hospitalisations. 1198 (30%) subjects had a very short hospital length of stay (0 days) and 2414 (61%) had an emergency index admission.

There were a total of 3646 hospital readmissions during the study interval, 2057 (56%) of which were emergency hospitalisations. During the 9-year follow-up period, 1717 (44%) patients had at least one readmission and 1578 were still at risk of the second readmission; 792 (20%) had two readmissions and 727 (40%) remain at risk of the third readmission; among them 430 (11%) had three readmissions and 394 (10%) were at risk of the fourth readmission; 224 (6%) had four readmissions and 226 (6%) had five or more readmissions. The number of readmissions per patient varied from none to 26 (with a median of 0). Hospitalisations beyond the fifth occurrence were combined into one. This cut-off accounted for more than 97% of the cumulative number of hospitalisations. The smoothed hazard estimates plot gives an idea of the shape of the underlying hazards for the number of previous events (Figure 1). Overall, there were 899 (23%) censored observations due to death, 347 (8.8%) due to missing quality scores, 47 (1.1%) due to emigration to another practice and 2458 (62%) reaching the end of the study period.

Table 2 shows sample means, standard deviations, and minimum and maximum values of practice quality scores in 1998, 2003 and 2005. Means quality score increase over time and the rate of increase is greater since 2003 (Figure 2).

Multivariate analysis

Table 2 shows the hazard ratios and robust standard errors of the extended Cox models estimating the association between practice clinical quality and hazard of rehospitalisation (AG, PWP-CP and PWP-GT). Each model was stratified by calendar year and diagnosis at index admission, which allows the underlying hazard function to vary by years and initial diagnoses respectively (AG, PWP-CP, PWC-GT). Stratification was necessary to deal with non-proportionality. Each model was subsequently stratified by hospital to allow the underlying hazard function to vary between hospitals and adjusts for unmeasured hospital factors (AG, PWP-CP, and PWP-GT with hospital effects). The adjustment for covariates was assumed to be the same over all strata (no interaction between strata and covariate of interest). To adjust for dependence among patients within a practice we clustered on practices. Overall, the three models give similar results. Comparing the final variance corrected models with time to first event model and random-effects approaches (not shown) gives fairly similar results as well. Contrasting the model with and without including hospital effects we found that the effect of quality was distorted by the effect of hospital of treatment. Estimated hazard ratio was stable across models without including provider effects. The increase of one standard deviation decreased the risk of admission by 0.03% in the AG and PWP-CP models and by 0.04% in the PWP-GT formulation and the effect was statistically significant at 5%. However, after including provider effects through stratification the magnitude of the HR changed and the effect was not statistically significant anymore.

The probability of readmission over time increases with each subsequent admission showing that the readmissions were correlated with each other and suggesting that the risk set should be stratified by number of previous readmissions. This implies that among the variance corrected models the PWP model is the most appropriate theoretically. We also considered the counting process formulation more suitable than the gap time formulation being diabetes a chronic condition that is incurable.

Of the socio-demographic characteristics, females had a lower hazard ratio. Increased age was associated with higher hazard ratio. No statistically significant disparities were found between ethnicity groups. Higher deprivation employment status was independently associated with higher readmission risk. Charlson comorbidity index was strongly associated with an increased risk of hospitalization, longer initial hospital stays were associated overall with a higher likelihood of readmission. An 1-fold increase in the number of previous emergency readmissions had a 1.2-fold increase in their readmission

risk as compared to those with no prior events. There is no evidence that the effect of quality is confounded by sex, age, trend and clinical variables. Access to hospitals, measured as weighted distance to hospital, showed a positive effect. In other terms, more beds available at a shorter distance increase the risk of readmission. Bed supply was also found in previous studies to be associated to hospitalisation rates particularly for ambulatory care sensitive conditions, such as diabetes (Brown and Barnett, 1992). Finally, statistically significant health authority effects on the risk of readmission showed the importance to control for geographical factors to reflect aspects related with the health care services. Other practice characteristics which could influence patient admission directly such as number of patients per WTE, GP gender, GP ages, training status, minor surgery were found not be informative.

Discussion

The primary objective of this research was to investigate the effect of GP clinical quality and other risk factors for diabetes specific and related hospitalizations in the recurrent event setting. Our study does not absolutely establish that better practice clinical care delivered to diabetes Type 2 patients being discharged after index admission reduces the risk of being re-hospitalised. Although the effect of quality was smaller than other factors and statistically insignificant, our findings are still important. The type of hospital at discharge is an important risk factor as it indicates how the disease was managed and therefore is potentially influential on the probability of readmission. An investigation of the effect that hospital physician follow-up has upon patient outcomes requires further research.

The major limitation of this study is the retrospective design and the intrinsic limitations in such methodology. Secondly, our analysis relys on the uninformative right censoring assumption. The failure from death is treated as censored at time it occurs. However censorship due to death may impose bias. If better clinical quality is effective in reducing mortality, the relative risk of re-hospitalization may appear larger for those receiving better quality than those receiving lower quality because the former live long enough to be hospitalized, whereas the latter who die will be censored and event-free. When informative censoring exists, a competing risks framework can be used to obtain unbiased effect estimates. The same applies to the other types of censoring. Therefore, next step will be to check the hypothesis of informative censoring in a competing risk framework.

Conclusions

Overall, our data suggested that both patient and disease characteristics as well as health system-related factors independently influence the risk of readmission. In particular, secondary care is potentially influential on the probability of readmission rather than primary care quality. A clearer understanding of the exact mechanisms responsible for readmissions is crucial for policy measures aiming at reducing adverse outcome such as readmission for diabetes specific and related complications.

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Figure 1 Log cumulative hazard function by number of previous admissions

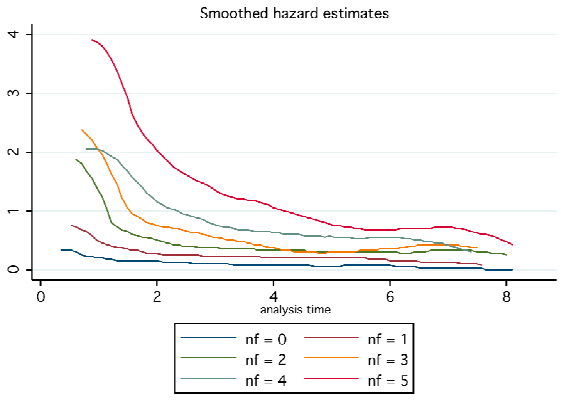


Figure 2 Means for clinical quality scores at each occasion and SE bars

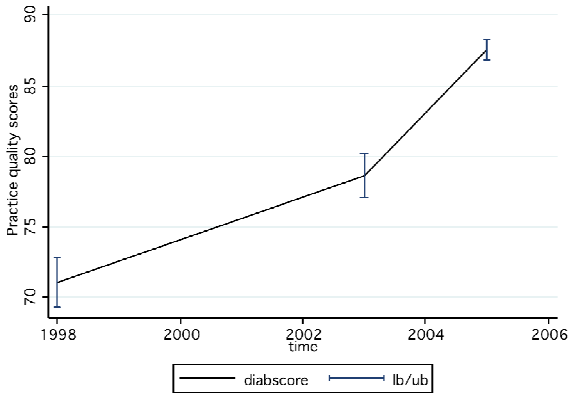


Table 1 Characteristics of individuals discharged alive after a first hospitalization (n=3942) for diabetes complications between 1997 and 2006 and practice characteristics.

Demographics	
Gender - n male, %	2079 (52.7)
Age (y) - mean, SD	68 (12)
Ethnicity .- Whites - n (%)	3430 (87.0)
Ethnicity – Asian n (%)	286 (7.3)
Ethnicity – Black n (%)	132 (3.3)
Ethnicity – Other n (%)	94 (2.4)
Practice clinical quality score	
1998 – n, mean, SD	60, 71.0 (14.0)
2003 – n, mean, SD	43, 78.7 (10.2)
2005 – n, mean, SD	42, 87.5 (4.9)
Practice characteristics	
Number of patients per WTE (Avg)- mean SD	3.1 (2.1)
GP gender (avg prop)- mean female, SD	0.3 (0.3)
GP ages (prop) – mean, SD	
<40 y	0.33 (0.33)
41-50 y	0.32 (0.31)
51-60 y	0.31 (0.38)
>60 y	0.04 (0.15)
Training status – , n (%)	21 (35)
Minor surgery (prop) – , n, (%)	53 (88)
Comorbidity Conditions	
Charlson Index - n, % nf==0	
0 - Total comorbid score = 0	2528 (64.1%)
1 - Total comorbid score = 1	906 (23.0%)
2 - Total comorbid score = 2	292 (7.4%)
3 - Total comorbid score = 3+	216 (5.5%)
Index Hospitalization Data	
Diabetes complications-Diagnostic groups	
Cardiovascular complications	2395 (60.7%)
Ophthalmic complications	845 (21.4%)
Renal complications	271 (6.9%)
Without complications	202 (5.1%)
Neurological complications	94 (2.4%)
Ketoacidosis	31 (0.8%)
With unspecified complications	26 (0.7%)
Coma	22 (0.6%)
Arthropaty	14 (0.4%)
Other complications	42 (1%)
Length of Stay (days) 1 day – median, (range)	3 (0, 261)
Method of admission: emergency – n (%)	2414 (61%)
Socio-economic characteristics	
Index of multiple deprivation 2004 – employment, mean SD	0.12 (0.7)
Low level of education (level 2+1+noqual+other; prop) – mean SD	74.4 (13.7)
General health status	
Limiting long standing illness (%) – mean SD	19.3 (5.1)
General health (not good) (%) – mean SD	9.9 (3.4)
Access measures	
Access to acute hospital (index)- mean, SD	3 (0.72)

Table 2: Maximum Partial Likelihood Estimates for Fitted Cox Models

VARIABLES	AG[¶] w/o Hospital Effects		AG w/ Hospital Effects		PWP-CP[¶] w/o Hospital Effects		PWP-CP w/ Hospital Effect		PWP-GT[¶] w/o Hospital Effects		PWP-GT2 w/ Hospital Effects	
Practice quality score[§]	0.97**	*(0.02)*	0.98	*(0.02)*	0.97**	*(0.02)*	1.00	*(0.02)*	0.96**	*(0.02)*	0.99	*(0.02)*
1 previous readmission	2.06***	*(0.14)*	1.85***	*(0.12)*								
2 previous readmissions	3.36***	*(0.25)*	2.84***	*(0.21)*								
3 previous readmissions	4.22***	*(0.48)*	3.64***	*(0.41)*								
4 previous readmissions	5.57***	*(0.83)*	4.18***	*(0.58)*								
≥5 previous readmissions	8.46***	*(1.45)*	7.56***	*(1.18)*								
Female	0.92**	*(0.03)*	0.87***	*(0.04)*	0.89***	*(0.03)*	0.87***	*(0.03)*	0.93*	*(0.03)*	0.90***	*(0.03)*
Age[§]	1.04*	*(0.02)*	1.04	*(0.03)*	1.04*	*(0.02)*	1.05**	*(0.03)*	1.03	*(0.02)*	1.03	*(0.02)*
Comorbidity index=1	1.25***	*(0.05)*	1.23***	*(0.06)*	1.30***	*(0.05)*	1.31***	*(0.05)*	1.26***	*(0.05)*	1.23***	*(0.06)*
Comorbidity index=2	1.39***	*(0.07)*	1.27***	*(0.08)*	1.38***	*(0.07)*	1.14*	*(0.08)*	1.37***	*(0.06)*	1.16**	*(0.07)*
Comorbidity index≥3	1.29***	*(0.10)*	1.24***	*(0.10)*	1.36***	*(0.10)*	1.35***	*(0.10)*	1.23***	*(0.07)*	1.14	*(0.09)*
Length of hospital stay at index admission (log)	1.04***	*(0.01)*	1.05***	*(0.02)*	1.05***	*(0.01)*	1.06***	*(0.02)*	1.05***	*(0.02)*	1.07***	*(0.02)*
IMD employment domain[§]	1.06***	*(0.02)*	1.05***	*(0.02)*	1.06***	*(0.02)*	1.08***	*(0.02)*	1.05***	*(0.02)*	1.06***	*(0.02)*
Access to acute hospitals[§]	1.04	*(0.03)*	1.07*	*(0.04)*	1.05*	*(0.03)*	1.11***	*(0.04)*	1.02	*(0.04)*	1.10**	*(0.04)*
Number of prior emergencies	1.17***	*(0.04)*	1.20***	*(0.03)*	1.20***	*(0.07)*	1.24***	*(0.06)*	1.04	*(0.03)*	1.05*	*(0.03)*

*** p<0.01, ** p<0.05, * p<0.1

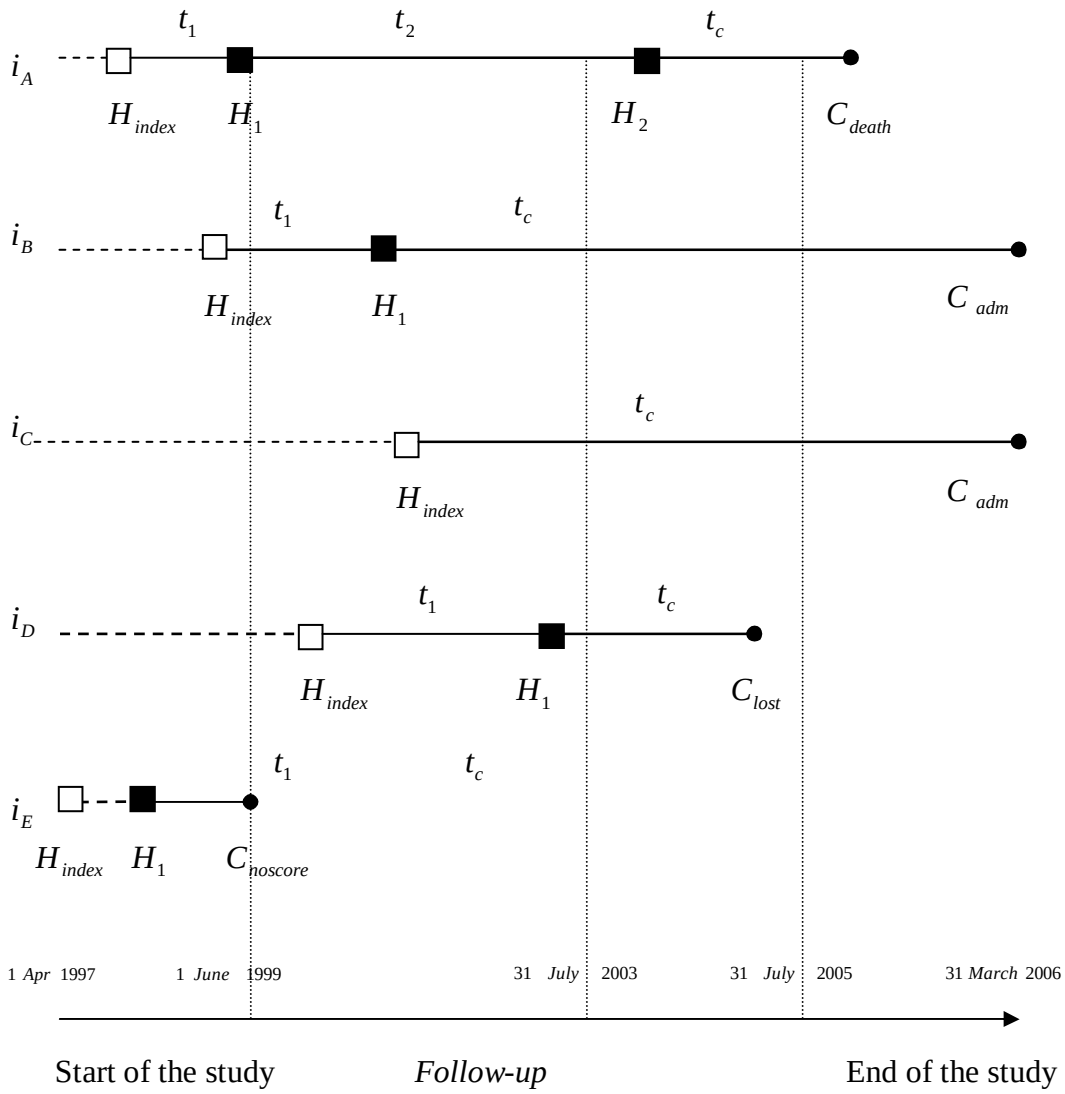
Robust standard errors in parentheses.

All models are stratified by calendar year and diagnosis of initial admission. PWP models are stratified by number of previous admissions.

[¶] Adjusted by Health Authority effects.

[§] Standardised variables (*var*-r(mean))/r(sd).

APPENDIX
Figure 1 The study design



Individual *A* had two readmissions and was censored by death.
Individual *B* had one readmission and was censored because of the end of the study.
Individual *C* had never experienced the event.
Individual *D* had one readmission and then was lost to follow-up because he moved to a different GP practice.
Individual *E* had one readmission and was censored at time 31Jul03 because of missing quality scores. GPs dropped out from the study.