Does higher quality of care in general practice reduce emergency hospital admissions? Evidence from diabetes management in the Quality and Outcomes Framework.

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Abstract

Background. The Quality and Outcomes Framework (QOF), introduced in 2004, linked substantial financial rewards to GPs to a range of quality indicators. The purpose of the QOF scheme is to improve outcomes for patients with chronic conditions, including reducing admissions to secondary care.

Objective. To investigate the association between practice emergency admissions to secondary care for short term complications of diabetes and indicators of practice quality of care for diabetes.

Setting. Longitudinal study of over 8000 English general practices over the period 2002/3 to 2005/6.

Methods. Panel data multiple regressions (linear fixed effects, linear random effects, and count data models) of practice yearly emergency admission rates for short term diabetic complications on the proportions of practice diabetic patients with good, moderate, and poor control of diabetes (HbA1c levels), the proportion of monitored diabetic patients, diabetes prevalence, baseline 2003/4 practice admission rates, plus attributed practice level socio-economic, demographic, and geographic characteristics.

Results. Emergency admission rates for all short term diabetic complications were significantly lower in practices with higher proportions of patients with good and moderate glycaemic control. The negative effects were strongest for specific hyperglycaemic emergency admissions. There was no significant effect of tighter control on hypoglycaemic complications.

Discussion. The results suggest that improvements in practice quality of diabetes care lead to reductions in emergency admission rates for short term complications of diabetes. Hence if the QOF improved quality of care, calculations of its cost-effectiveness need to take account of reduced costs of secondary care.

1 Introduction

The Quality and Outcomes Framework (QOF), introduced in 2004, links large financial rewards to the quality of care provided by general practices in the UK [Roland 2004]. The purpose of the QOF scheme is to improve outcomes for patients with chronic conditions, including reducing the need for admission to secondary care. Quality is measured by a set of clinical activity indicators relating to aspects of care for several common diseases. Practices are awarded points – which generate payments – according to the proportion of eligible patients for whom they achieve each target. The scheme includes 18 diabetes-related indicators (**Table 1**), which include both process measures for secondary prevention (for example screening for retinopathy) and intermediate outcome measures (for example controlling blood pressure).

Practice performance against the quality targets has generally been high [Doran 2006, IC 2007], but evidence for improved outcomes is lacking, with at most weak associations noted between practices' scores on QOF indicators and admission rates to secondary care [Downing 2007, Bottle 2008i, Bottle 2008ii]. The apparent lack of an association may be attributable to characteristics of the QOF scheme. In order to protect patients from inappropriate care practices are permitted to exclude ('exception report') patients they deem inappropriate from specific indicators, for reasons including extreme frailty, intolerance of a particular medication and declining treatment [DH 2004]. The quality indicators also have maximum achievement thresholds of between 50% and 90% (**Table 1**), hence it is possible for practices to score the maximum number of points without necessarily achieving the targets for all patients. For these reasons, it is more appropriate to examine the proportion of patients for whom practices achieve the QOF targets, rather than the number of points practices score under the incentive scheme.

Even then, the relationships between practices' achievement on the QOF indicators and patient outcomes are likely to be complex. In the case of diabetes, improved monitoring and tighter control of glycated haemoglobin levels might lead to fewer emergency admissions for hyperglycaemia, but could also result in more admissions for hypoglycaemia. Improved monitoring of peripheral pulses and neuropathy might have little impact on emergency admissions, but could lead to increased elective admissions over the short to medium term, as more complications are detected and treated, before leading to fewer admissions over the longer term. It is therefore necessary to measure the admission types most closely related to each of the incentivised activities, and to monitor any associations over time.

We aimed to examine the association between practice achievement of monitoring and control of glycated haemoglobin levels – measured as the proportion of all diabetic patients for whom the relevant QOF targets were met - and emergency admissions to secondary care for (i) all complications due to poor short term glycaemic control, (ii) acute hyperglycaemia (ketoacidosis and coma), and (iii) hypoglycaemia in the first three years of the scheme.

2 Data

Hospital admissions data were obtained from Hospital Episode Statistics for the financial years 1997/8 – 2006/7. We extracted all emergency, first finished consultant episodes for individuals with a primary diagnosis of diabetes as indicated from the primary ICD-10 diagnostic field in HES. We also extracted the patient's health resource group code to assist with the classification of patients into hyperglycaemic and hypoglycaemic categories. The HES data was cleaned of duplicate records, and transfers out to another hospital were dropped before extracting the data to avoid double counting of admissions. The HES data contained a GP practice field which indicates the registered GP of the patient, and it was used to aggregate admissions up to practice level.

GP practice quality indicators were obtained from Information Commission websites on the Quality and Outcomes Framework for the years 2004/5 to 2006/7 (IC 2008)

Other GP practice characteristics including practice list size, number of WTE GPs, age, gender and country of qualification and practice demographic characteristics were obtained from the GMS data set maintained by the Department of Health.

The practice list is measured at 1 April each year and so is a potentially inaccurate measure of the number of patients at risk of admission over the year. We attempt to allow for this measurement error in two ways. We use a three year moving average of the practice list to estimate the practice list when calculating admissions rates for a year. We also include this estimated variable as one of the covariates in the regression model. Practices with a list size of fewer than 1000 patients were dropped from the analysis as outliers whose population data and admission rates were likely to be unreliable.

The Low Income Scheme Index measures the proportion of prescriptions for patients in each practice which were dispensed without charge on the grounds of low income [Lloyd 1995]. It was calculated for each practice for the years 2004 – 2006

We used the Attribution Data Set for the years 2004 to 2006 which contain information on the number of patients in each practice resident in each Lower Super Output Area to attribute area characteristics to practices. The characteristics included measures of area morbidity, mortality, health behaviour, economic deprivation, and geographic characteristics from the Office of National Statistics Neighbourhood Statistics archive (ONS, 2008). The data is derived from ONS, the Census 2001, the Indices of Multiple Deprivation, and social security benefits payment records from the Department of Work and Pensions.

The covariates are summarised in **Table 2.** Most of the socio-economic covariates are time invariant, though practice population demographics and GP characteristics are observed in each year.

We had 8544 GP practices with complete hospital admissions data and diabetes registers for at least one year between 2004/5 and 2006/7. Practices were excluded from the study if: they had fewer than 1000 patients in any one year (56 practices); a

further 141 practices were dropped due to missing baseline admission rates (2001/2 – 2003/4); and a further 69 practices did not have complete socio-economic or GMS data.Our main results are drawn from an unbalanced panel of 8288 practices.

3 Methods

3.1 Admissions for short term diabetic complications

Hospital admissions data were obtained from Hospital Episode Statistics for the financial years 1997/8 – 2006/7. We extracted all emergency, first finished consultant episodes for individuals with a primary diagnosis of diabetes as indicated by the primary ICD-10 diagnostic field in HES. We also extracted the patient's health resource group code (HRG) to assist with the classification of admitted patients into poor short term glycaemic control categories. The HES data was cleaned of duplicate records, and transfers out to another hospital were dropped before extracting the data to avoid double counting of admissions. HES contains a GP practice field which indicates the registered GP of the patient, and it was used to aggregate admissions to practice level.

We look at three categories of short term diabetic complications:
(i) All short term poor glycaemic control emergency diabetic complications
(ii) Acute hyperglycaemic emergency admissions (ketoacidosis and coma)
(iii) Hypoglycaemic emergency admissions

Table 3 provides the full set of ICD-10 and HRG codes used to generate the three categories. The classification was based on the preventive quality indicators guide published by the US Agency of Health Care Quality and Research (AHRQ, 2007). All short term complications include acute hyperglycaemia, hypoglycaemia as well as less acute hyperglycaemic and diabetic disorders defined using a combination of ICD-10 and HRG codes, where the the HRG diabetic code is never used with an ICD-10 code that indicates a specific long term complication.

3.2 Practice quality measures

The Quality and Outcomes Framework rewards general practices for their performance on 146 quality indicators relating to care for specified chronic diseases, organisation of care and aspects of patient experience. Practices are awarded points, to a maximum of 1050, on the basis of the proportion of eligible patients for whom they achieve each target. There are minimum and maximum achievement thresholds that vary according to the indicator (**Table 1**). In Year 1 (2004-05) each point earned the practice £76, adjusted for the relative prevalence of the disease and the size of the practice population. This was increased to £126 for Years 2 and 3 (2005-06, 2006-07). In Year 1 the 18 diabetes indicators accounted for a total of 99 points (9.4% of the total), and the 3 indicators relating to the monitoring and control of glycated haemoglobin levels (DM5, DM6 and DM7 – **Table 1**) accounted for 30 points (2.9% of the total). The QOF was modified in Year 3, with changes to minimum and maximum thresholds, points allocations and some indicator specifications (**Table 1**).

Data on practice performance on the diabetes indicators were derived from the

Quality Management and Analysis System operated by the National Health Service Information Centre. This system automatically extracts data from practices' clinical computing systems, including the reported number of patients registered as having diabetes (R_0); the number deemed appropriate for each indicator, i.e. who were in the disease domain specified by the indicator and were not exception reported by the practice (D_i); and the number for whom the indicator was met (N_i). Practices report R_0 on February 14 each year, and N_i and D_i on March 31. Practices can continue to add patients to their disease registers between these dates; hence the denominator for an indicator (D_i) can be greater than the reported number of patients registered for the disease (R_0). We therefore estimated the number of patients registered with the disease on March 31 (R_1) by using the largest available denominator for the diabetes indicators or R_0, whichever was greater. Since Year 2, extracted data has also included the number of patients exception reported by the practice (E_i). For Year 1, we imputed rates of exception reporting for each indicator as $R_1 - D_i$, following the method of Doran et al [Doran 2006].

For the practice quality variables we used three measures relating to control of glycated haemoglobin levels – the proportion of all registered diabetic patients for whom:

- HbA1c was well controlled (HbA1c $\leq$ 7.4 in Years 1 and 2, $\leq$ 7.5 in Year 3) – calculated as N_{DM6}/R_1
- HbA1c was moderately well controlled (7.4% (7.5 in Year 3) < HbA1c $\leq$ 10) – calculated as $(N_{DM7} - N_{DM6})/R_1$
- HbA1c levels were measured – calculated as N_{DM5}/R_1

We also include the proportion of registered diabetic patients who were

- Exception reported for HbA1c measurement – calculated as (E_{DM5}/R_1)

Our main interest is in the effect of better HbA1c control on admissions. Since we include the number of practice patients registered with diabetes (R_1) in the regression models we expect that a higher proportion of diabetic patients with good or moderate control of HbA1c (the first two measures) should lead to reduced admissions for acute hyperglycaemic complications. The effect of a higher proportion of diabetic patients with good or moderate control on admissions for hypoglycaemic is potentially ambiguous: better monitoring and control may also prevent HbA1c levels from becoming too low, or the financial incentive to reduce HbA1c may lead to too low levels of HbA1c. We investigate the overall effect of good HbA1c control on short term emergency complications by combining all hyper and hypoglycemic admissions.

The effect on admissions of an increase in the proportion of diabetic patients who are exception reported for measurement of HbA1c depends on the grounds for exception reporting. If the proportion is higher because a practice has more diabetic patients with terminal conditions then admissions for diabetic complications will be lower. On the other hand if the higher proportion arises because more patients have refused to attend diabetic clinics for HbA1c measurement admissions are likely to be higher. Unfortunately the data collection process for the QOF only required information on the total number of exceptions and did not distinguish the reasons for exceptions.

When the number of diabetic patients, and the proportions with good or moderate control or exception reported are held constant, an increase in the proportion of

diabetic patients whose HbA1c levels are measured implies that the proportion of diabetic patients with measured HbA1c but with poor control (HbA1c > 10%) has increased. This suggests that the ceteris paribus effect of an increase in the proportion with measured HbA1c is to increase admissions.

4 Estimation

Practice admission rate equations were estimated separately for each of the three categories of short term emergency diabetes complications. We estimated both linear and non-linear panel data regression models on an unbalanced panel of GP practices.

Linear random effects generalised least squares (GLS) estimation, and OLS fixed effects estimation were used to model admission rates (per 10,000 practice population) in levels. The GLS random-effects estimator allowed for practice specific unobserved heterogeneity in admission rates by including a random intercept term in the model. The GLS estimator also has the advantage of not assuming normality of the panel specific and idiosyncratic error components. The OLS fixed effects or within-groups estimator uses only the within practice variation (changes in practice quality and admission rates over time) to identify the effect of quality and is an unbiased estimate of the effect of quality provided the change over time in unobserved practice characteristics is uncorrelated with admission rates and quality. The GLS estimator assumes that the within practice correlation (intra cluster correlation coefficient) is constant over time. Both the GLS and OLS models cluster the error term by GP practice to allow for autocorrelation.

The GEE negative binomial regression model for count data can be applied to admission rates by including the log of the practice population (the number of individuals at risk of admission) as an exposure term with a coefficient constrained to unity. GEE models are an extension of generalised linear models (GLM) to handle dependence within clusters (panels) induced by panel data. The model parameterises only the marginal distribution in the population, and does not condition the estimates on a panel specific effect. Hence the marginal effects are interpreted as an averaged marginal effect across all practices. The negative binomial model assumes that the count dependent variable follows a Poisson-like process with expectation μ_{it} and variance $\mu_{it} = \mu_{it} + \alpha\mu_{it}^2$ where α is the overdispersion parameter. The GEE models estimates an unstructured working correlation matrix in that allows for autocorrelation within panels over time by allowing the within panel correlation to vary over time.

All models were estimated using Stata version 10.1 and used robust (Huber/White) sandwich estimates of variance to allow for heteroskedasticity in the error term.

The GEE model estimation equation was

$$\ln(Y_{it}) = \ln(P_{it}) + \beta_0 + \sum_{t'} \beta_{1t'} T_{t'} + \beta_2 \left(\frac{R_{it}}{P_{it}}\right) + \sum_j \beta_{3j} \left(\frac{N_{jit}}{R_{it}}\right) + \beta_4 \left(\frac{E_{it}}{R_{it}}\right) + \beta_5 \left(\frac{Y_{it0}}{P_{it0}}\right) + \sum_k \beta_{6k} G_{kit} + \sum_s \beta_{7s} X_{sit} + \upsilon_i + \varepsilon_{it}$$

Y_{it} is the number of emergency short term diabetic admissions for practice *i* in year *t (t*

= 2004/5, 2005/6 and 2006/7*)*; P_{it} is the practice list size; T_t is the year t dummy; R_{it} is the number of patients on the diabetes register; N_{jit} is the number of diabetic patients for whom the quality indicator j was achieved; E_{it} is the number of patients exception reported from glycaemic monitoring. Y_{it0} is the total number of short term diabetic admissions over the years 2001/2 – 2003/4; P_{it0} is the total number of patients registered with the practice over the years 2001/2 and 2003/4; G_{kit} are GP practice characteristics; X_{sit} are patient demographic, morbidity, mortality, socio-economic, geographic and health care supply variables; υ_i is a practice specific random intercept term and ε_{it} is an idiosyncratic practice and year specific error term.

The GLS and OLS models have the same specification but are estimated in levels with the dependent variable being the admission rate $\left(Y_{it}/P_{it}\right)$ and the coefficient on P_{it} being unconstrained. υ_i is estimated as a set of practice coefficients in the fixed effects model

The random effects and GEE models included the baseline pre QOF (2001/2 – 2003/04) admission rates to allow for unobservable time invariant practice characteristics associated with admissions. It is not intended to control for state dependence (the effect of previous period admission rates on current period admission rates. We controlled for potential confounding factors likely to have a direct effect on hospital admission rates, but beyond the control of the primary care practice, including the demographic and socio-economic factors, morbidity and mortality. GP practice characteristics that could have a direct effect on admission rates conditional on quality of care were included. Year dummies were included to allow for secular trends in admissions over time, PCT fixed effects to control for unobserved environmental and geographical factors that influence admissions across areas. Geographic access measures (distance to nearest five hospitals and distance to nearest GP practice), hospital provider effects (proportion of patients admitted from each practice to each hospital), and rurality indicators were also included. We included the identical set of covariates for each diabetic admission category, but dropped time invariant covariates in the fixed effects models.

5 Results

Figure 1 and **Table 4** show the change over time in admission rates. **Figure 1** plots time series of the means of the three types of emergency diabetes admission rates. All show a steady long term increase in admission rates from 1997/8 to 2003/4. The rate of growth of hyperglycaemic admission rates appears to have increased since 2003/4 whereas the growth in all admissions and hypoglycaemic admissions seems to have slowed..

Figure 2 shows the distribution of practice diabetic emergency admission rates per 10000 person years for three admission types. They are all characterised by noticeable right skewness and a mass of practices at the lower end of the distribution with the majority of practices having fewer than 7 admissions per 10,000 person years. The hypoglycaemic admission rate is much smaller than the hyperglycaemic and overall rates and over 50% of practices have no admissions in a year.

Table 5 summarises the diabetic clinical quality indicators. Quality of diabetic care improved markedly between 2004/5 and 2006/7. The percentage of registered diabetic patients achieving good HbA1c control increased from 51% in 2004/05 to nearly 59% in 2006/07. There was a reduction in the percentage with moderate control but the overall percentage of those with good or moderate control increased from 83% to 87%. The percentage with monitored HbA1c but poor control fell from 8% to 6%. Monitoring of diabetic patients was already high in the first year of QOF with on average 91% of patients being monitored. There was however considerable variation and a left skewed distribution (see Figure 2). Average monitoring increased to 94% by 2006/07 with the extent of variation across practices declining: the coefficient of variation declined from 0.09 to 0.05 between 2004/5 and 2006/07. There was a 9% increase in recorded diabetic prevalence between 2004/5 and 2006/7.

Table 6 reports the full sets of results from the GEE negative binomial count data models. The coefficients for continuous variables show the proportionate effects of a one standard deviation increases in the variable and are incident rate ratios: a coefficient of less than 1 means that the variable is associated with fewer admissions and a coefficient of more than 1 that it is associated with more admissions. Thus the coefficient of 1.023 on the Low Income Scheme Index in the general admissions model shows that a one standard deviation increase in the LISI increases admissions by 2.3%. The coefficients for dummy binary variables show the effect of changing the variable from 0 to 1. Thus the coefficient on the 2006/7 year dummy in the hyperglycaemic model of 1.094 means that admissions were 9.4% higher in 2006/7 than in 2004/5.

The covariates have generally plausible effects. In particular, measures of morbidity, whether reported diabetes prevalence or attributed health measures such as potential life years lost or heart disease prevalence have positive effects on admissions, as do risk factors such as smoking, binge drinking, and obesity. The negative effect of total practice population is a partial effect, holding constant diabetic patients per 1000 and patients per GP. Thus it reflects the combined effect of a higher number of diabetic patients (which should increase admissions) and a higher number of GPs which should reduce them. The variable also measures true exposure with error and this will also tend to produce a negative effect of practice population on list size.

The baseline admission rate (averaged over 2001/2 to 2003/4) is highly significant in the hyperglycaemic model and shows that there are persistent unobservable practice level factors affecting admissions. The positive coefficients on the 2005/6 and 2006/7 year dummies show the underlying general trend increase in emergency general and specific hyperglycaemic admissions.

Increases in the proportion of diabetic patients with good or moderate control of HbA1c are significantly associated with lower admission rates for general and hyperglycaemic emergency admissions. Increases in the proportion of diabetic patients whose HbA1c levels were measured are associated with higher general and specific hyperglycaemic admissions. Since the regression holds constant the proportions with good and moderate control and the proportion exception reported, the coefficients on proportion monitored are picking up the effect of having a higher proportion of patients with poor control and a smaller proportion who the practice failed to monitor.

Intuitively, we find that an increase in good control is associated with a larger reduction in admission rates than an increase in moderate control.

There is no sign that the financial incentive to reduce HbA1c levels led to overly tight control: the proportions of diabetic patients with good and moderate control (id low HbA1c) are not significantly association with hypoglycaemic admissions.

Tables 7 and 8 report the results from the GLS random effects and OLS fixed effects models. The results are similar to those from the GEE model so we report only a subset of coefficients. The continuous variables are again measured in standand deviation units. The dependent variables are the practice admission rate divided by the mean admission rate over all practices. The coefficient on a continuous variables is the proportionate effect on admissions of one standard deviation increase in the variable. Again higher proportions with good and moderate control are associated with lower general and hyperglycaemic admissions, though the fixed effects results are generally not statistically significant. The RE models yield larger effects than the GEE models, which in turn are larger than the FE estimated effects.

6 Discussion

There was an overall trend increase in admissions between 1997/8 and 2006/7. It has been suggested that the QOF may have led to a lowering of thresholds for referring GPs to specialist clinics (Srirangalingam et 2006) for diabetic patients. The time series in Figure 1 show no obvious signs of a faster increase in admissions after the QOF was introduced.

If the QOF stimulated an increase in quality then we would expect a reduction in the rate of increase of admissions post QOF. Inspection of the series for overall short term emergency admissions (Figure 1) seems to provide some weak support for this hypothesis but the evidence is not strong.

We found increases in prevalence of diabetes by general practices between 2004/5 and 2006/7. This is attributable to both genuine changes in disease prevalence and changes in diagnosis, treatment and recording. Our findings broadly reflect the trends monitored in the Health Survey for England, which found that the prevalence of diagnosed diabetes increased by over 75% between 1994 and 2003, and continued to rise at a similar rate after the introduction of the QOF – to 5.6% for men and 4.2% for women in 2006 [HSE 2006]. However, a study of the effect of the QOF on recording of prevalence in 2005/6 suggests that some of the differences between practice prevalence reports may be due to the different effects of higher reported prevalence on practices above and below indicator upper thresholds (Gravelle, Sutton and Ma, 2008).

Our regression models do however suggest that improved quality in the form of a higher proportion of practice patients with good or moderate control of HbA1c does reduce practice admission rates for overall emergency admissions and for specific

hyperglycaemic admissions. Moreover, increasing the proportion with good control has a greater effect on admissions than increasing the proportion with only moderate control. The effect of a one standard deviation increase in the proportion of diabetic patients with good control is to reduce all admissions for short term diabetes admissions by between 6% and 11%.

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Figure 1: Time series graph of mean emergency diabetes admission rates 1997/98 to 2006/7

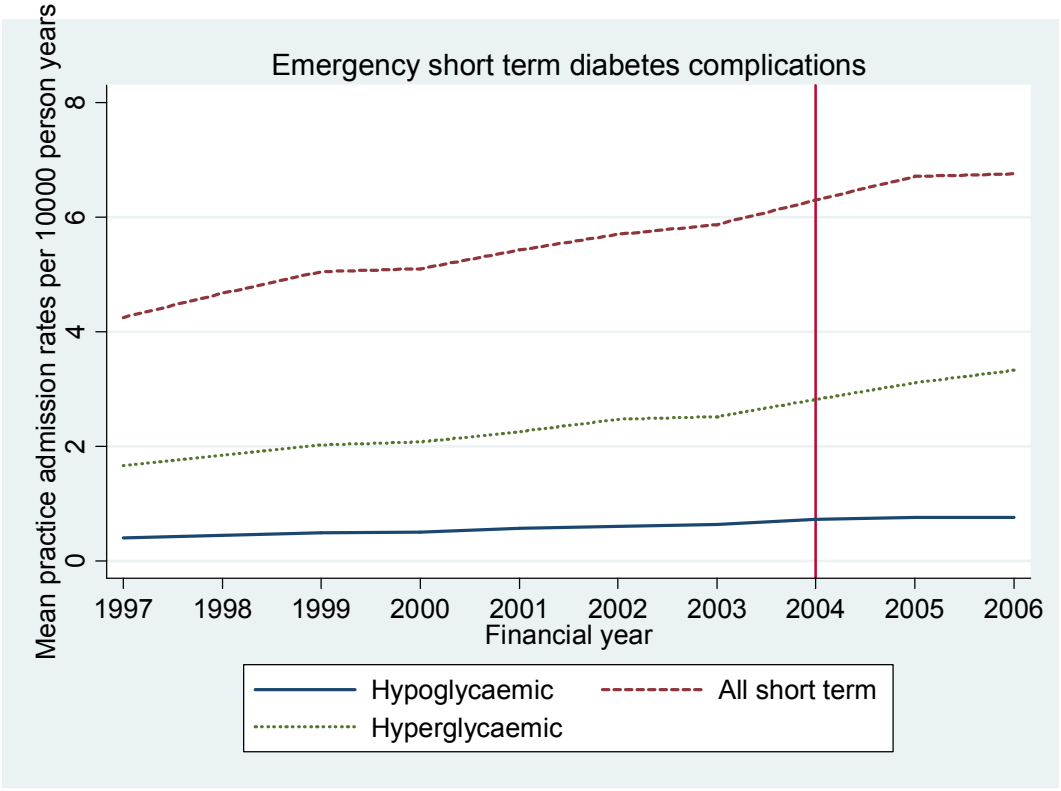

Figure 2: Distribution of short term emergency diabetes practice admission rates 2004/5-2006/7

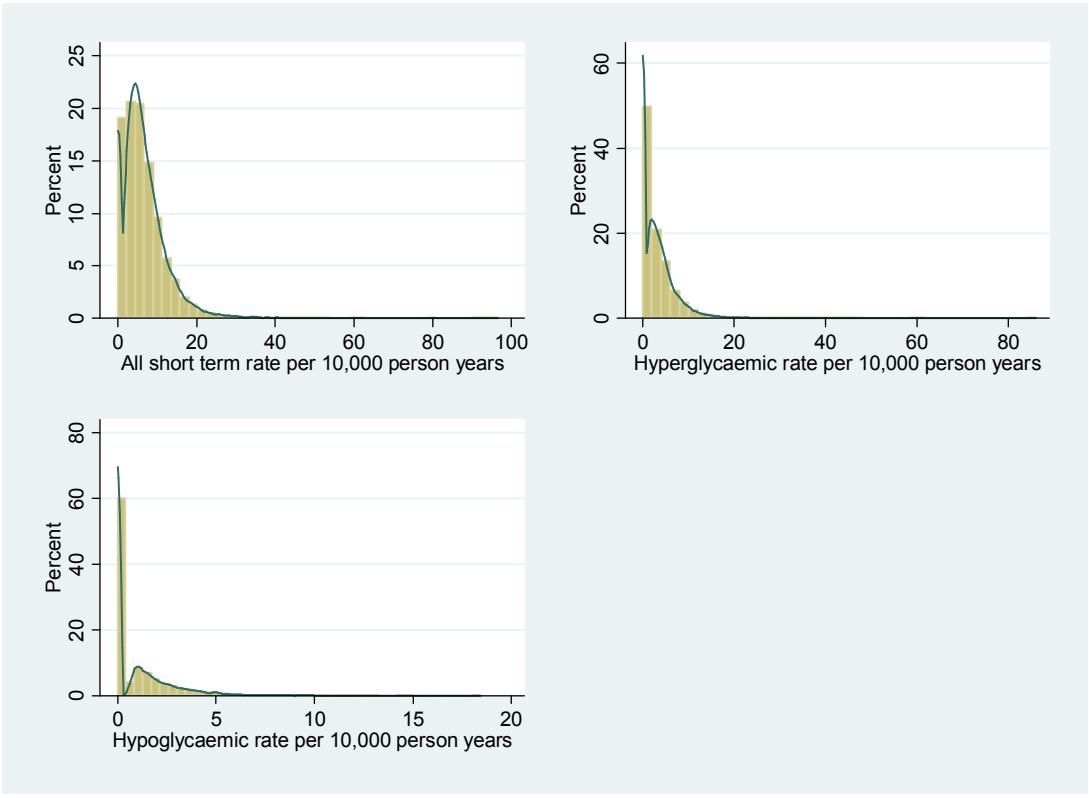

Table 1: Diabetes clinical indicators from the Quality and Outcomes Framework

Indicator	Points	Payment range 2004/05, 2005/06‡	Payment range 2006/07
DM 1 (19): The practice can produce a register of all patients[ʃ] with diabetes mellitus	**6**		
DM 2: The percentage of patients whose notes record Body Mass Index in the previous 15 months	**3**	25-90%	40-90%
DM 3: The percentage of patients in whom there is a record of smoking status in the previous 15 months except those who have never smoked where smoking status should be recorded once	**3***	25-90%	40-90%
DM 4: The percentage of patients who smoke and whose notes contain a record that smoking cessation advice has been offered in the last 15 months	**5***	25-90%	40-90%
DM 5: The percentage of patients who have a record of HbA1c or equivalent in the previous 15 months	**3**	25-90%	40-90%
DM 6 (20): The percentage of patients in whom the last HbA1C is 7.4 or less[†] (or equivalent test / reference range depending on local laboratory) in last 15 months	**16**[¶]	25-50%	40-50%
DM 7: The percentage of patients in whom the last HbA1C is 10 or less (or equivalent test / reference range depending on local laboratory) in last 15 months	**11**	25-85%	40-90%
DM 8: The percentage of patients who have a record of retinal screening in the previous 15 months	**5**	25-90%	40-90%
DM 9: The percentage of patients with a record of presence or absence of peripheral pulses in the previous 15 months	**3**	25-90%	40-90%
DM 10: The percentage of patients with a record of neuropathy testing in the previous 15 months	**3**	25-90%	40-90%
DM 11: The percentage of patients who have a record of the blood pressure in the past 15 months	**3**	25-90%	40-90%
DM 12: The percentage of patients in whom the last blood pressure is 145/85 or less	**17**	25-55%	40-60%
DM 13: The percentage of patients who have a record of micro-albuminuria testing in the previous 15 months (exception reporting for patients with proteinuria)	**3**	25-90%	40-90%
DM 14: The percentage of patients who have a record of serum creatinine testing in the previous 15 months	**3**	25-90%	40-90%
DM 15: The percentage of patients with proteinuria or micro-albuminuria who are treated with ACE inhibitors (or A2 antagonists)	**3**	25-70%	40-80%
DM 16:The percentage of patients who have a record of total cholesterol in the previous 15 months	**3**	25-90%	40-90%
DM 17: The percentage of patients whose last measured total cholesterol within previous 15 months is 5 or less	**6**	25-60%	40-70%
DM 18: The percentage of patients who have had influenza immunisation in the preceding 1 September to 31 March	**3**	25-85%	40-85%

‡ Points are awarded on a sliding scale within the stated range – e.g. for DM5 in 2004-05 and 2005-06, the practice must have recorded HBA1c levels for at least 25% of diabetic patients to earn any points, and must have recorded levels for 90% or more to have earned the maximum 3 points.

[ʃ] Patients aged 17 and over from 2006-07. The indicator code was changed to DM19 to reflect this change.

[†] 7.5 or less from 2006-07. The indicator code was changed to DM20 to reflect this change.

[*] Indicators amalgamated into combined smoking indicators in 2006-07.

[¶] Points increased to 17 in 2006-07

Table 2. Descriptive statistics for all other explanatory variables used in the panel data regression over all three years 2004/5 – 2006/7.

Variable name	Source	Obs.	Mean	Std. Dev.	Min	Max
Practice population	GMS	24213	6391.82	3842.48	1002	36636
Population per WTE GP	GMS	24213	1906.14	707.06	91	14033.33
PMS practice	GMS	24213	0.35	0.48	0	1
Average GP age	GMS	24213	48.10	7.80	28	206.6
Female GPs proportion	GMS	24213	0.36	0.28	0	1
UK qualified GPs proportion	GMS	24213	0.68	0.39	0	1
Non-principle GPs proportion	GMS	24213	0.13	0.19	0	1
Training practice	GMS	24213	0.28	0.45	0	1
Males 0 to 4	GMS	24213	0.03	0.01	0	0.11
Males 5 to14	GMS	24213	0.06	0.01	0	0.13
Males 15 to44	GMS	24213	0.22	0.05	0.09	0.69
Males 45 to 64	GMS	24213	0.12	0.02	0.00	0.27
Males 65 to 74	GMS	24213	0.04	0.01	0	0.10
Males 75 to 84	GMS	24213	0.02	0.01	0	0.08
Males 85 and over	GMS	24213	0.01	0.00	0	0.03
Females 0 to 4	GMS	24213	0.03	0.01	0	0.11
Females 5 to14	GMS	24213	0.06	0.01	0.00	0.14
Females 15to44	GMS	24213	0.21	0.04	0.09	0.59
Females 45 to 64	GMS	24213	0.12	0.03	0.00	0.19
Females 65 to 74	GMS	24213	0.04	0.01	0	0.11
Females 75 to 84	GMS	24213	0.03	0.01	0	0.11
Females 85 and over	GMS	24213	0.01	0.01	0	0.07
Non-white	Census	24213	11.45	15.93	0.04	81.05
Incapacity benefit	ONS	24213	0.08	0.03	0.01	0.24
Potential years of life lost	IMD	24213	65.69	12.05	32.50	116.87
IMD education	IMD	24213	22.97	14.28	1.09	83.30
Mental health prevalence	QOF	24213	0.01	0.00	0	0.13
Heart disease prevalence	QOF	24213	0.04	0.01	0	0.13
Smoking	ONS model	24213	24.61	6.10	10.27	49.83
Binge drinking	ONS model	24213	17.70	4.89	6.80	45.12
Obesity	ONS model	24213	23.37	4.05	8.46	33.50
Communal residents	ONS	24213	0.02	0.03	0.00	0.62
Low income scheme index	PPA	24213	12.45	8.09	0.04	89
Town and Fringe	ONS	24213	0.08	0.19	0	1
Town and Fringe Sparse	ONS	24213	0.00	0.05	0	0.88
Urban	ONS	24213	0.82	0.33	0	1
Urban sparse	ONS	24213	0.00	0.03	0	0.93
Village/Hamlet	ONS	24213	0.08	0.18	0	1
Village/Hamlet Sparse	ONS	24213	0.01	0.07	0	1
Distance to nearest GP (ln)	IMD	24213	0.19	0.55	-1.20	2.27
Distance to nearest 5 hospitals (ln)	AREA	24213	4.47	1.31	-1.14	9.19

Table 3. Classification of Definition of emergency short term diabetes admission

Emergency diabetes complication*	ICD-10 and HRG codes	Definitions of ICD-10 codes
All short term	E100; E101; E110; E111; E120; E121; E130"; E131; E140; E141; E162; R730; [(E107, E108, E109, E117, E118, E119, E127, E128, E129, E137, E138, E139, E147, E148, E149)& hrg(K11, K12, K13, K14, K15, K16, K98, K99, P11, P29)]	**ICD-10 codes:** E10: Insulin-dependent diabetes mellitus; E11: Non-insulin-dependent diabetes mellitus; E13: Other specified diabetes mellitus; E14: Unspecified diabetes mellitus. **Extension**: 0 With coma; 1 With ketoacidosis; 7 With multiple complications; 8 With unspecified complications; 9 Without complications E162: Hypoglycaemia, unspecified **HRG 3.5** K11:Diabetes with Hypoglycaemic Emergency >69 or w cc K12:Diabetes with Hypoglycaemic Emergency <70 w/o cc K13:Diabetes with Hyperglycaemic Emergency >69 or w cc K14:Diabetes with Hyperglycaemic Emergency <70 w/o cc K15:Diabetes and Other Hyperglycaemic Disorder >69 or w cc K16:Diabetes and Other Hyperglycaemic Disorder <70 w/o cc K98:Chemotherapy with an Endocrine or Metabolic System Primary Diagnosis P11/P29:Endocrine Disorders(including Diabetes)
Hyperglycaemic	E100, E101, E110, E111, E120, E121, E130, E131, E140, E141	
Hypoglycaemic	E162, K11, K12	

*Emergency admissions classified in HES as admission method (admimeth) equal to 21, 22, 23 and 28. Primary diagnostic field (diag_1) and HRG version 3.5 (hrglate35) fields used as well.

Table 4. Descriptive statistics for short term diabetes admission rates

Variable	Year	Obs.	Mean	Std. Dev.	Min	Max
All short term baserate	2001/3	8225	5.857	4.071	0	71.251
Hyperglycaemic baserate	2001/3	8225	2.461	2.553	0	38.864
Hypoglycaemic baserate	2001/3	8225	0.699	0.840	0	9.242
All short term	2004	8225	6.407	5.462	0	96.694
Hyperglycaemic		8225	2.824	3.725	0	60.779
Hypoglycaemic		8225	0.865	1.430	0	19.225
All short term	2005	7979	6.791	5.809	0	80.823
Hyperglycaemic		7979	3.093	4.020	0	58.780
Hypoglycaemic		7979	0.911	1.493	0	19.017
All short term	2006	8009	6.809	5.668	0	91.070
Hyperglycaemic		8009	3.305	4.156	0	86.011
Hypoglycaemic		8009	0.901	1.439	0	14.220

Table 5. Descriptive statistics for diabetic quality indicators

Variable	Year	Obs.	Mean	Std. Dev.	Min	Max
Diabetes prevalence	2004	8225	3.494	1.028	0.212	16.564
HbA1c < 7.4		8225	51.324	10.900	0.000	97.778
7.4 < HbA1c < 10		8225	31.881	7.288	0.000	66.667
HbA1c measured		8225	91.071	8.109	0.000	100.000
Excepted for HbA1c		8225	3.088	4.017	0.000	100.000
Diabetes prevalence	2005	7979	3.688	1.034	0.198	14.513
HbA1c < 7.4		7979	53.932	9.740	0.000	99.034
7.4 < HbA1c < 10		7979	31.466	6.722	0.000	56.667
HbA1c measured		7979	93.134	5.367	20.525	100.000
Excepted for HbA1c		7979	3.296	2.733	0.000	42.857
Diabetes prevalence	2006	8009	3.769	1.067	0.132	10.640
HbA1c < 7.4		8009	59.241	9.504	0.000	94.406
7.4 < HbA1c < 10		8009	27.431	6.507	0.000	83.333
HbA1c measured		8009	93.900	4.566	0.000	100.000
Excepted for HbA1c		8009	3.060	2.546	0.000	24.576

Table 6: GEE population averaged negative binomial estimates for all short term, hyperglycaemic, and hypoglycaemic emergency admissions.*

	All short term	Hyperglycaemic	Hypoglycaemic+
2005	1.054	1.067	1.010
	[5.71]***	[4.94]***	[0.63]
2006	1.056	1.094	0.979
	[4.60]***	[5.43]***	[1.19]
Diabetes prevalence	1.065	1.063	1.002
	[7.59]***	[5.26]***	[0.18]
HbA1c < 7.4	0.885	0.859	0.970
	[7.42]***	[6.10]***	[1.26]
7.4 < HbA1c < 10	0.924	0.888	0.981
	[5.99]***	[5.94]***	[0.95]
HbA1c monitored	1.060	1.083	1.016
	[5.01]***	[4.47]***	[0.90]
HbA1c excluded	1.003	1.012	0.994
	[0.58]	[1.60]	[0.61]
Baseline admission rate	1.123	1.124	1.022
	[13.80]***	[15.66]***	[2.78]***
Practice population	0.945	0.880	0.592
	[9.59]***	[14.28]***	[45.48]***
Population per WTE GP	0.989	0.992	0.982
	[1.90]*	[1.06]	[2.34]**
PMS practice	1.005	1.010	1.005
	[1.02]	[1.43]	[0.66]
Average GP age	1.003	1.021	1.057
	[0.42]	[2.09]**	[5.41]***
Female GPs	0.989	0.991	0.998
	[1.78]*	[1.02]	[0.28]
UK qualified GPs	0.991	0.988	0.989
	[1.22]	[1.22]	[1.07]
Non-principle GPs	0.986	0.987	1.005
	[2.65]***	[1.74]*	[0.59]
Training practice	1.012	1.018	0.989
	[2.25]**	[2.34]**	[1.50]
Males 0 to 4	0.995	1.005	0.993
	[0.41]	[0.28]	[0.43]
Males 5 to14	1.007	0.977	1.011
	[0.53]	[1.15]	[0.62]
Males 45 to 64	1.028	1.040	1.004
	[1.76]*	[1.82]*	[0.17]
Males 65 to 74	0.994	0.996	1.027
	[0.37]	[0.19]	[1.22]
Males 75 to 84	1.003	0.996	0.997
	[0.17]	[0.15]	[0.14]
Males 85 and over	1.009	1.013	0.983
	[0.76]	[0.83]	[1.15]
Females 0 to 4	1.018	1.024	0.957
	[1.43]	[1.35]	[2.54]**
Females 5 to14	1.019	1.029	0.993
	[1.38]	[1.36]	[0.39]
Females 15to44_std	1.035	1.028	0.964
	[1.85]*	[1.01]	[1.43]
Females 45 to 64	0.974	0.965	0.925

	[1.68]*	[1.61]	[3.96]***
Females 65 to 74	1.024	1.005	0.955
	[1.36]	[0.20]	[1.87]*
Females 75 to 84	1.036	1.027	0.970
	[1.99]**	[1.05]	[1.29]
Females 85 and over	1.032	1.034	1.026
	[2.85]***	[2.19]**	[1.66]*
Non-white	0.990	0.953	0.942
	[0.50]	[1.72]*	[2.31]**
Incapacity benefit	1.031	1.007	0.976
	[1.49]	[0.26]	[0.91]
Potential years of life lost	1.063	1.093	1.025
	[2.74]***	[2.98]***	[0.90]
Mental health prevalence	1.025	1.018	1.001
	[4.94]***	[2.54]**	[0.09]
Hearth disease prevalence	0.988	0.997	0.995
	[1.01]	[0.16]	[0.35]
Smoking	1.052	1.004	0.986
	[2.12]**	[0.13]	[0.46]
Binge drinking	1.011	1.044	0.919
	[0.40]	[1.18]	[2.40]**
Obesity	1.046	1.037	1.016
	[3.08]***	[1.82]*	[0.82]
Communal residents	0.981	0.982	1.002
	[2.50]**	[1.91]*	[0.14]
Low income scheme index	1.023	1.008	0.994
	[2.05]**	[0.50]	[0.35]
IMD education	0.990	1.027	0.992
	[0.49]	[0.97]	[0.29]
Town and Fringe	1.000	1.001	0.993
	[0.05]	[0.15]	[0.86]
Town and Fringe Sparse	1.000	1.004	0.979
	[0.03]	[0.49]	[3.46]***
Urban sparse	0.992	0.996	0.997
	[2.25]**	[0.79]	[0.54]
Village/Hamlet	0.965	0.975	0.985
	[3.73]***	[1.79]*	[1.25]
Village/Hamlet Sparse	0.987	0.986	1.017
	[1.67]*	[1.29]	[2.08]**
Distance to nearest GP	1.041	1.022	0.984
	[2.63]***	[0.98]	[0.81]
Distance to nearest 5 hospitals	0.997	0.990	1.030
	[0.18]	[0.39]	[1.18]
Observations	24213	24213	24213
Number of practices	8288	8288	8288

*Coefficients reported as incident rate ratios (Average factor change in practice admission rates given a 1 SD increase in explanatory variable). +Estimated as a Poisson model since negative binomial could not reject overdispersion parameter $\alpha = 0$. All models also include PCT dummies and the proportions of the practice admissions at each hospital Trust.

Table 7. GLS random effects estimates for all short term, hyperglycaemic, and hypoglycaemic emergency admissions*

Variable name	All short term+	Hyperglycaemic+	Hypoglycaemic+
Year: 2005	0.050	0.051	0.007
	[4.92]***	[3.62]**	[0.35]
Year: 2006	0.053	0.079	-0.029
	[5.29]***	[4.33]**	[-1.32]
Diabetes prevalence	0.055	0.053	-0.010
	[-3.88]***	[3.71]**	[-0.63]
HbA1c < 7.4	-0.102	-0.115	-0.044
	[4.10]***	[-4.46]**	[-1.45]
7.4 < HbA1c < 10	-0.058	-0.078	-0.023
	[-5.44]***	[-3.90]**	[-0.92]
HbA1c monitored	0.048	0.056	0.021
	[3.58]***	[3.05]**	[0.89]
HbA1c excluded	0.004	0.010	-0.009
	[0.73]	[1.19]	[3.89]**
Baseline admission rate	0.143	0.163	0.046
	[9.16]***	[10.28]***	
Observations	24213	24213	24213
Number of practices	8288	8288	8288
Intra practice correlation coef.	0.24	0.21	0.09
R2 overall	0.35	0.43	0.5
R2 within practice	0.21	0.33	0.49
R2 between practice	0.44	0.52	0.52

Robust z statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

+ Coefficients are the proportionate change in outcome variable for a 1SD change in explanatory variable. All models include the same explanatory variables as the GEE model, including PCT dummies and the proportions of the practice admissions at each hospital Trust.

Table 8. OLS fixed effects estimates for all short term, hyperglycaemic, and hypoglycaemic emergency admissions.

	All short term	Hyperglycaemic	Hypoglycaemic
2005	0.053	0.062	0.008
	[3.55]***	[3.00]***	[0.33]
2006	0.056	0.099	-0.035
	[2.35]**	[3.02]***	[-0.99]
Diabetes prevalence	0.048	0.010	-0.018
	[1.88]*	[0.280]	[-0.42]
HbA1c < 7.4	-0.057	-0.067	-0.037
	[-1.81]*	[-1.550]	[-0.880]
7.4 < HbA1c < 10	-0.034	-0.039	-0.024
	[-1.44]	[-1.26]	[-0.76]
HbA1c monitored	0.044	0.032	0.018
	[2.06]**	[1.09]	[0.65]
HbA1c excluded	0.010	0.011	-0.002
	[1.00]	[0.72]	[-0.15]
Observations	24213	24213	24213
Number of practices	8288	8288	8288
Adjusted R^2	0.49	0.54	0.69

* significant at 10%; ** significant at 5%; *** significant at 1%.

Coefficients on continuous variables are the proportionate change in admission rate per 10, 000 person years for a 1 SD change in the explanatory variable. All models also include the time varying explanatories in the GEE model, including the proportions of the practice admissions at each Trust.