Quality achievement and disease prevalence in primary care predicts regional variation in renal replacement therapy (RRT) incidence: an ecological study

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Abstract

Background. Diabetes Mellitus (DM) and hypertension (HT) are important causes of end-stage renal disease (ESRD) and renal replacement therapy (RRT) is the standard active treatment. Financially, incentivized quality initiatives for primary care include pay-for-performance (P4P) in DM and HT. Our aim was to examine any effect of disease prevalence and P4P on RRT incidence and regional variation.

Method. The incidence of RRT, sex and ethnicity data and P4P disease register and achievement data were obtained for each NHS locality. We calculated correlation coefficients for P4P indicators since 2004/05 and socio-demographic data for these 152 localities. We then developed a regression model and regression coefficient ($R^2$) to assess to what extent these variables might predict RRT incidence.

Results. Many of the P4P indicators were weakly but highly significantly correlated with RRT incidence. The strongest correlation was 2004/05 for DM prevalence and 2006/07 for HT quality. DM prevalence and the percentage with blood pressure control in HT target (HT quality) were the most predictive in our regression model ($R^2 = 0.096$ and $R^2 = 0.085$, respectively ($P < 0.001$). Combined they predicted a fifth of RRT incidence ($R^2 = 0.2$, $P < 0.001$) while ethnicity and deprivation a quarter ($R^2 = 0.25$, $P < 0.001$). Our final model contained proportion of population >75 years, DM prevalence, HT quality, ethnicity and deprivation index and predicted 40% of variation ($R^2 = 0.4$, $P < 0.001$).

Conclusions. Our findings add prevalence of DM and quality of HT management to the known predictors of variation in RRT, ethnicity and deprivation. They raise the possibility that interventions in primary care might influence later events in specialist care.

Keywords: blood pressure; chronic kidney disease; diabetes mellitus; incentive; renal replacement therapy

Introduction

Diabetes Mellitus (DM) and hypertension (HT) are the commonest causes of end-stage renal disease (ESRD), and investment in improved management of these conditions in primary care may slow progression and postpone the need for renal replacement therapy (RRT). RRT, dialysis and transplantation are the best active treatment options for people with ESRD. RRT is expensive and can have a negative effect on the quality and quantity of life for patients with ESRD [1, 2]. In 1999, it was estimated that ~0.001% of the UK population is on RRT and it is estimated that 1–2% of the total health care budget is spent on RRT [3], this high level of expenditure was confirmed in the 2004 Wanless report [4]. Diabetic nephropathy is the commonest single cause of ESRD and accounts for 24% of incident diagnoses of patients starting RRT in the UK [5]. Variations in RRT incidence may reflect the quality of chronic disease management in DM and HT [6, 7].

In the UK, the incidence of RRT has levelled off in recent years. This is a trend that has been seen in many other European countries and consistent with trends in the USA, New Zealand and Canada [8–12]. Understanding the reasons for these national trends and also regional variations in RRT incidence has significant patient welfare and financial implications. Previous research has shown that ethnicity and deprivation indices correlate strongly with the variation in standardized incidence of RRT. However, to date, no link has been made between the introduction of pay-for-performance (P4P) quality indicators in UK primary care and incidence of RRT [13].

UK primary care is highly computerized and aggregated routine data used to monitor achievement of quality targets are in the public domain. Computers are used at the point
of care with data entry largely completed by clinicians [14]. A national system of registration allows patients to register with a single practice; electronic prescribing, electronic communication of pathology results and the introduction of P4P based on data collected for usual clinical care have all led to an improvement in data quality and the validity of the P4P data [15].

We carried out this study to examine whether regional variations of RRT incidence in England could be explained by the prevalence of chronic disease and the achievement of quality targets in primary care.

Materials and methods

We obtained data about the incidence of RRT from the UK Renal Registry (RR). The RR receives quality electronic data extracts from subscriber renal centres throughout England [16]. The RR provided the number of new cases of RRT and calculated the incidence of RRT per million population (p.p.m.) by geographical area for the years 2003–08. Each of these geographical areas contain local health organizations currently called Primary Care Trusts. Although these had changed their boundaries in 2006, the new authorities were all coterminous with the smaller organizations that had been brought together at that time.

We downloaded detailed socio-demographic population data for all the localities in England from publicly available datasets. We obtained age, sex and ethnicity data from the 2001 census and indices of deprivation for 2007 from the Office for National Statistics [17]. The deprivation index combines a number of indicators, chosen to cover a range of economic, social and housing issues, into a single deprivation score for each small area in England [18]. The age and sex demographics were available in 5-year age bands. We calculated the percentage of people aged >75 years in each locality’s population to investigate how a larger elderly population may affect the incidence of RRT.

P4P for chronic disease management, the ‘Quality and Outcomes Framework’, has been in place since April 2004 [19]. P4P has two components: the first is the creation of disease registers for key chronic diseases, including DM and HT; the second are quality achievement targets using the disease register population as a denominator. Practices have the option of exception reporting patients on a disease register from quality targets if they frequently do not attend consultations or standard treatments are contraindicated. These patients are removed from the target denominator and apparent disease prevalence. These data are publicly available and of acceptable quality for research [20]. Disease registers investigated in this paper are complete for all localities.

We measured the correlation coefficient between the disease prevalence based on P4P disease registers, quality targets and socio-demographic data to test for any relationship between them. We made the assumption that we were comparing independent variables and that each of the 152 geographical areas could be given equal weighting. We measured the correlation coefficient and its probability for each year for which we have RRT and P4P data available. Where a variable is not normally distributed we use the Spearman rank correlation.

We developed a regression model to compare how the variables we explored might predict the incidence of RRT. We initially separately tested the effect of the possible predictor or independent variables on our chosen outcome or dependent variable—incidence of RRT 2008 (the last year of complete RR data). In this first stage, we explored known predictor variables: percentage with non-white ethnicity, the percentage aged >75 years and deprivation index. We also explored the following: DM and HT prevalence; percentage of people with HT not at blood pressure (BP) target (>140 systolic, >90 diastolic). We then repeated this including people ‘exception reported’ as ineligible for the P4P target; we then repeated this for people with DM not at BP target (>135 systolic, >85 diastolic). We investigated the DM and HT indicators because of their association with progression to ESRD in people with chronic kidney disease (CKD) [21–23]. DM and HT have been part of the P4P targets since their launch in 2004. Other clinically relevant indicators such as CKD prevalence and HbA1c quality (<6.5%, Diabetes Control and Complications Trial (DCCT)/ <48mmol/mol International Federation of Clinical Chemists (IFCC)) were initially investigated but were found to have very weak association with RRT and were not investigated further; some like the CKD targets were only implemented in 2006. These were rejected on the basis of no correlation or introduced too late to have impact.

We report our regression model using the unstandardized coefficient (B) for all the variables mentioned above. B predicts the effect of a unit change in predictor on the outcome variable; in this study, incidence of RRT 2008. Second, we quote 95% confidence intervals for B and the probability that this difference occurred by chance. Thirdly, we quote the regression coefficient (R²) which indicates the weighting of their influence on incidence of RRT, i.e. the proportion of change which can be attributed to that variable and the probability (P) that this happened by chance.

We created three models to explore which variables best predicted our outcome variable, the incidence of RRT. Model 1 is constructed from the known predictor variables: ethnicity and deprivation score; Model 2 is constructed from the best P4P variables. Finally, Model 3 will be the best model (i.e. the largest value of R²) and draw on one or more components from Models 1 and 2.

We carried out several checks to test the reliability of our linear regression model. We tested for correlation between variables in the model and used the Durbin–Watson statistic to test the assumption that any errors were independent; a value between 1 and 3 is acceptable. We also looked at the collinearity statistics tolerance and variance inflation factor (VIF). We looked for a tolerance >0.2 and a VIF around 1.

We carried out our analysis using Statistical Package for the Social Sciences (SPSS) version 16 [24].

The UK RR has approval from the Secretary of State through the Patient Information Advisory Group (PIAG—now replaced by National Information Governance Board for Health and Social Care, NIGB) to collect identifiable patient data without individual patient consent. We carried out all analyses for this ecological study on publicly available data.

Results

Incidence of RRT and correlation with known predictors of RRT incidence

The incidence of RRT in England is relatively static though with considerable variation between localities. The incidence was just under 100 p.p.m. in 2003/04 (mean 97.6 p.p.m.; SD 26.7; range min = 35.0, max = 164.6) and was just >100 p.p.m. from 2006–08 (mean 110.5, 108.3 and 110.2 p.p.m.; range min = 56.4, max = 197.7; min = 21.7, max = 229.6; min = 36.2, max = 243.2 for 2006–08, respectively, Figure 1).

The proportion of the population who are >75 years, the deprivation score and proportion of non-white ethnicity are known to be associated with the incidence of RRT. The mean proportion of the population aged >75 years in 2008 was 7.6% (Table 1) and there was a weak negative correlation with the proportion of older people but this appeared to be variable year on year. The Pearson correlation coefficient was −0.345 (P < 0.0001) in 2007 and −0.15 (P = 0.65) in 2008 (Table 3).

The deprivation score showed a weak positive and consistently highly significant correlation with RRT incidence. For the 4-year follow-up period, Pearson correlation varied between 0.248 and 0.336. It reached the peak in 2005 and 2007, when the Pearson correlations were 0.336 (P < 0.0001), R² = 0.113 and 0.320 (P < 0.0001), R² = 0.102, respectively. The median proportion of the non-white population was 5.0% and the mean 10.7%. This variable significantly correlated with RRT incidence [Spearman rank correlations are 0.37 in 2006 and 0.36 in 2007 and 2008 (P < 0.0001)].

Correlation with P4P disease registers and quality indicators

Disease registers and P4P data are present for all localities; the DM prevalence data are normally distributed around a
The proportion of people not at BP target between 2005 and 2008 showed improvement and decreased from 29 to 22%, respectively. The proportion of people not at BP target was also normally distributed; the mean for 2008 was 22% (SD 6.8%, median 22%). The highest correlation was observed between the percentages of people with HT not at BP target in 2006 and RRT incidences in 2008 (Pearson correlation coefficient 0.292, $R^2 = 0.085$, $P < 0.001$, Figure 3 and Table 3).

### Initial regression analysis using single variables

We carried out an initial regression analysis separately testing each variable to explore any predictive effect on our outcome variable, incidence of RRT in 2008. The variables are ranked in their order of greatest to least unstandardized coefficient effect ($B$). This means that for every unit change of the predictor variable the outcome variable is affected by this amount. The deprivation score and ethnicity significantly correlated with RRT incidence. DM prevalence and proportion not at BP target have the biggest effect on the outcome variable (Table 4); e.g. if DM prevalence rose from 4 to 5% of the population, the incidence of RRT might be expected to rise by 25 cases per year. All the effects were statistically significant except HT prevalence and proportion of the population >75 years.

### Three combined regression models: (i) known factors, (ii) P4P and (iii) best combined model

We developed three final models that were most predictive of our outcome variable, 2008 RRT incidence. Model 1: previously known predictor variables, ethnicity and

![Figure 1. Incidence of RRT p.m.p. in England 2003–08 showing the variation between localities.](image-url)
deprivation score predict around a quarter of RRT incidence ($R^2 = 0.253$, $P < 0.001$; $B = 1.32$, Standard error of $B$ (SEB) = 0.21, 95% CIs higher = 1.74, lower = 0.90 and $B = 0.10$, SEB = 0.30, 95% CIs higher = 0.70, lower = $-0.50$ for % non-white population and deprivation score, respectively).

Model 2: the best prevalence and quality target predictor variables, DM prevalence and % HT not at BP target, considered alone predicted a fifth of RRT incidence ($R^2 = 0.20$, $P < 0.001$; $B = 2674.01$, SEB = 580.19, 95% CIs higher = 3820.47, lower = 1527.55 and $B = 6.43$, SEB = 1.46, 95% CIs higher = 9.33, lower = 3.54, for DM prevalence 2004/05 and % HT not at BP target 2006/07, respectively). Model 3: our best predictive model combined Models 1 and 2 and also added other variables which did not break our collinearity criteria. This final model contained the proportion of the population aged >75 years, diabetes prevalence, proportion of people with HT not at target and deprivation index. This model predicts 40% of the change in the outcome variable ($R^2 = 0.40$, $P < 0.001$) (Table 5).

**Discussion**

**Principal findings**

It appears that a combination of socio-deprivation and biomedical markers predict up to 40% of the incidence in RRT. These findings raise the possibility that the rate of RRT may be amenable to interventions elsewhere in the health care system, in this case primary care. The achievement of BP targets and DM prevalence should be added to the variables that are predictive of the incidence of RRT. Our model confirms that age [25], deprivation score and ethnicity influence rate of RRT, previously known predictor variables [26]. However, our combined model predicts a greater proportion of the outcome variable than previous models.

**Implications of the findings**

Our findings suggest that efforts to achieve targets for BP and to try to reduce the prevalence of DM may reduce the incidence of RRT. If our findings were to be confirmed in prospective studies, these findings have important implications for health policy. Potentially, interventions in primary care might have an impact later and reduce the incidence of RRT. It provides a further rationale for incentivizing quality targets and continuing the P4P scheme in primary care.

**Comparison with the literature**

This paper confirms previous reports of significant regional variation of RRT incidence and a strong association with ethnicity [27, 28]. However, it extends the interventions required and suggests that good biomedicine is required...
Fig. 2. Scatter plot of 2008 RRT incidence versus DM mellitus prevalence 2004/05 per geographical locality.

Fig. 3. Scatter plot of 2008 RRT incidence versus the percentage of people with HT not at BP target 2006/07 per locality.
alongside of addressing social deprivation and inequalities [29, 30].

In a large European study, the elderly population was found to be the only age group to have had an increase in RRT incidence. Yet in our analysis, we found a negative effect of an elderly population on RRT incidence. This may reflect a higher incidence of conservative management in the elderly compared to other age groups in England. Our paper also adds a previously unknown and frequently called for insight into the effect DM prevalence and BP targets have had on the incidence of RRT.

Limitations of the method

Our study has several limitations. Firstly, an ecological study comparing populations carries less weight than comparisons at the individual level. Secondly, our best model predicts only 40% of the outcome variable, there are other variables, such as proteinuria, we have not been able to adjust for, control or analyse; it is possible that once the CKD P4P indicator has been established for several years [31] and issues over CKD prevalence are resolved [32] that this or high-risk patients with proteinuria might be added to the model.

The RR data does not include the numbers of patients (usually the elderly with significant comorbidities) that have opted for conservative management over RRT and hence, its impact is not known. One observational study of a single-centre cohort in the UK investigating the quality and quantity of life for elderly patients who chose conservative management over RRT found 14% initially chose conservative management [33]. It has been reported that prevalence of CKD correlates strongly with referral rates from primary to secondary care [34], but not its effect on the incidence of RRT, though these findings have not been reproduced [35]. Our initial analyses included the prevalence of CKD but we chose to exclude it from our final analyses as it has only recently been introduced as a P4P target (April 2006). CKD prevalence may prove a better predictor variable of RRT incidence in the future. Other possible explanations for the regional variance shown could be local patterns of care and access to that care, physician attitudes and an inexact standard for when people should start RRT. P4P changes may also have had an impact. We noted that the Pearson correlation and $R^2$ for DM changes in 2006 when new rules were introduced changing the target from ‘DM’ to only Type 1 and Type 2 being collected in separate disease registers. This change has been associated with issues around coding and classification of DM [36].

HT recording may be subject to bias. While the trend in the numbers not at target is compatible with other studies

<table>
<thead>
<tr>
<th>Predictor variables</th>
<th>Unstandardized coefficients</th>
<th>$95%$ CI</th>
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<th>Standardized coefficients</th>
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</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>-104.66</td>
<td>38.57</td>
<td>-180.90</td>
<td>-28.43</td>
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<tr>
<td>% aged &gt;75 years</td>
<td>862.69</td>
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</tr>
<tr>
<td>DM prevalence 2004/05</td>
<td>584.97</td>
<td>649.68</td>
<td>-699.02</td>
<td>1868.97</td>
</tr>
<tr>
<td>HT % not at BP target 2006/07</td>
<td>4.70</td>
<td>1.35</td>
<td>2.04</td>
<td>7.37</td>
</tr>
<tr>
<td>% non-white population</td>
<td>1.95</td>
<td>0.29</td>
<td>1.38</td>
<td>2.51</td>
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<tr>
<td>Deprivation index score</td>
<td>0.13</td>
<td>0.31</td>
<td>-0.49</td>
<td>0.74</td>
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$a$Sig; statistical significance (P).

Table 5. Model 3 the final predictive model

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<tr>
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$a$R$^2$ for the model = 0.40; significance for the model = <0.001.
showing that BP in primary care is being reduced overtime [37], end-digit preference reduces the precision of BP recording [38]. Additionally, there may be bias around P4P indicator values, though this appears not to persist [39]. There are also issues in primary care around accuracy of coding of a diagnosis of DM [40].

Our model has shown that the incidence of RRT is complex. Even though we have included previously known strong predictors and the prevalence of key chronic disease and the achievement of their management targets, we have only explained ~40% of the regional variance in England. Furthering our data analyses, we found that dividing the country into North England and South England causes the correlations of DM prevalence and the % HT not at BP target to be stronger (data not shown in this paper). This suggests a more local analysis may target with RRT incidence to be stronger (data not shown in this paper). Further research is needed to fully explain the regional variance seen. This knowledge will have significant patient welfare and financial implications.

Conclusions

The strengths of our paper lie in the data used for analysis. The RR data and the P4P data have been routinely collected for years and have been shown to be of a high quality. We would not expect policy to be changed based on ecological studies and our model only suggests an association which explains ~40% of the regional variance of the incidence of RRT seen in England. Further research is needed to assess the effect of DM prevalence and BP targets (and proteinuria) on the incidence of RRT.

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Contributions: N.D. was a former research assistant at SGUL, now a medical student. He planned this research a year prior to his elective, and spent 3 weeks acquiring the datasets 2 months prior to starting the analysis and write up. N.D. wrote the first draft of the paper as his elective report. S.L. conceived the idea for the paper and set out a framework with P.S. and D.O’.D.—and created a brief discussion paper based on this at the RCGP annual conference 2010. S.L. supervised N.D. elective wrote the second draft of the paper and final amendments. O.D. statistical analysis and O.D. worked with S.L. to develop the idea and the RCGP conference submission, contributed to subsequent drafts. D.O’.D. worked with S.L. to develop the idea and the RCGP conference submission, contributed to subsequent drafts.

Conflict of interest statement. S.L. was the Expert Advisor developing QOF P4P CKD indicator. GP Advisor to NICE for CKD indicator. P.S. was clinical advisor to NICE for CG73 Identification and management of chronic kidney disease and has contributed to development of QOF P4P CKD indicators. D.O’.D. National Clinical Director for Kidney Care in January 2007 and has led the development of the Renal NSF since 2003 (National guidance for managing renal disease). D.O’.D. worked with S.L. and P.S. to develop QOF P4P in CKD. None of the other two authors have no conflict of interest.

References

High chronic nephropathy detection yield in CKD subjects identified by the combination of albuminuria and estimated GFR

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Abstract

Background and objectives. Epidemiological studies have shown that the burden of chronic kidney disease (CKD) is huge. CKD is a non-specific diagnosis, however, and it is hard to say which renal disorders comprise the body of CKD diagnosed on the strength of the combination of albuminuria and estimated glomerular filtration rate (eGFR). We have shown that the burden of chronic kidney disease (CKD) is huge. CKD is a non-specific diagnosis, however, and it is hard to say which renal disorders comprise the body of CKD diagnosed on the strength of the combination

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