Citation for published version


DOI

https://doi.org/10.1093/ndt/gfm248

Link to record in KAR

http://kar.kent.ac.uk/2844/

Document Version

UNSPECIFIED

Copyright & reuse
Content in the Kent Academic Repository is made available for research purposes. Unless otherwise stated all content is protected by copyright and in the absence of an open licence (eg Creative Commons), permissions for further reuse of content should be sought from the publisher, author or other copyright holder.

Versions of research
The version in the Kent Academic Repository may differ from the final published version. Users are advised to check http://kar.kent.ac.uk for the status of the paper. Users should always cite the published version of record.

Enquiries
For any further enquiries regarding the licence status of this document, please contact: researchsupport@kent.ac.uk
If you believe this document infringes copyright then please contact the KAR admin team with the take-down information provided at http://kar.kent.ac.uk/contact.html
The cost of implementing UK guidelines for the management of chronic kidney disease

Bernhard Klebe¹, Jean Irving², Paul E. Stevens¹, Donal J. O'Donoghue³, Simon de Lusignan⁴, Roger Cooley², Helen Hobbs¹, Edmund J. Lamb⁵, Ian John¹, Rachel Middleton³, John New⁶ and Christopher K.T. Farmer¹

¹Department of Renal Medicine, Kent and Canterbury Hospital, East Kent Hospitals NHS Trust, Ethelbert Road, ²Computing Laboratory, University of Kent, Canterbury, Kent CT2 7NF, ³Department of Renal Medicine, Hope Hospital, Stott Lane, Salford, Greater Manchester, M6 8HD, UK, ⁴Primary Care Informatics, Division of Community Health Sciences, Hunter Wing, St George’s—University of London, London SW17 0RE, ⁵Department of Clinical Biochemistry, Kent and Canterbury Hospital, East Kent Hospitals NHS Trust, Ethelbert Road, Canterbury, Kent CT1 3NG and ⁶Department of Diabetes, Hope Hospital, Stott Lane, Salford, Greater Manchester, M6 8HD, UK

Abstract

Background. Chronic kidney disease (CKD) is a major public health problem. In the UK, guidelines have been developed to facilitate case identification and management. Our aim was to estimate the annualized cost of implementation of the guidelines on newly identified CKD cases.

Methods. We interrogated the New Opportunities for Early Renal Intervention by Computerised Assessment (NEOERICA) database using a Java program created to recompile the CKD guidelines into rule-based decision trees. This categorized all patients with a serum creatinine recorded over a 1-year period into those requiring more tests or referral. A 12-month cost analysis for following the guidelines was performed.

Results. In the first year, a practice of 10 000 would identify 147.5 patients with stages 3–5 CKD over and above those already known. All stages 4–5 CKD cases would require nephrology referral. Of those with stage 3 CKD (143.85), 126.27 stable patients would require more tests. The following would require referral: 14.8 with estimated glomerular filtration rate decline ≥5 ml/min/1.73 m²/year, 1.11 with haemoglobin <11 g/dl and 1.67 with blood pressure >150/90 on three anti-hypertensives. The projected cost per practice of investigating stable stage 3 CKD was €6111; and €7836 for nephrology referral. Total costs of €17 133 in the first year were increased to €29 790 through the effect of creatinine calibration.

Conclusions. CKD guideline implementation results in significant increases in nephrology referral and additional investigation. These costs could be recouped by delaying dialysis requirement by 1 year in one individual per 10 000 patients managed according to guidelines.

Keywords: cardiovascular risk; chronic kidney disease; cost analysis; glomerular filtration rate; guidelines; referral

Introduction

Chronic kidney disease (CKD) is a major public health problem with significant health service costs, compounded by the late referral to nephrology of people with advanced renal disease. Current estimates suggest that 5–11% of the total population have CKD, defined as glomerular filtration rate (GFR) <60 ml/min/1.73 m² [1–5]. Not only are CKD patients at increased risk of requiring renal replacement therapy (RRT) but also have a significantly increased cardiovascular morbidity and mortality [6]. Renal services currently consume 2% of the National Health Service (NHS) budget in the UK [7] and this is set to rise with increasing numbers requiring RRT. Tariff-based hospital haemodialysis is expensive, costing €34 000 per patient annually in the UK [8]. Late referral of patients from both primary and secondary care to nephrology services [9–11] results in increased hospitalization, cost and mortality [12–15]. Late specialist referral of people with advanced CKD is undesirable. Both the UK Renal National Service Framework [16] and the inclusion of CKD in
the financially incentivized quality-based contract for
general practice in England [17] reflects the increased
recognition of CKD within the NHS. More recently,
the Royal College of Physicians and Renal Association
have developed UK guidelines for the identification,
management and referral of people with CKD
(Table 1) [18,19]. These include comprehensive
guidance on the identification of CKD, appropriate
investigation, who should be monitored in the
community and who should be referred. We carried
out this study to determine the annualized cost of
implementing these guidelines on incident CKD cases.

Subjects and methods

Study population

The NEOERICA (New Opportunities for Early Renal
Intervention by Computerised Assessment) study is a large
community-based study of the comorbidity and medicines
management of a cohort of patients registered in primary
care in the UK. The study cohort comprised 162,113
participants of all ages and from 17 primary care practices
recruited from three regions: Kent, Surrey and Greater
Manchester. Data was extracted using Morbidity
Information Query and Export Syntax (MIQUEST) [20], a
Department of Health sponsored computer program, to
obtain read-coded data on these patients in the time period
obtain and prescribed medication were obtained in addition to
demographic and biochemical results. Detailed descriptions of
the NEOERICA study design and objectives have been
published elsewhere [2]. The NEOERICA study, showed that
it is possible to identify CKD from routinely collected
general practice computers and also that these primary care
data are reliable [21].

Of the 162,113 participants, all adult patients (aged >18
years) who had a serum creatinine (SCr) measured over the
course of 1 year in the time period (1 July 2002 and 31 June
2003) were included for the purposes of the study. Estimated
GFR (eGFR) was calculated using the four-variable
Modification of Diet in Renal Disease (MDRD) study
formula [17]. Persons with no age recorded on the database
were excluded due to inability to calculate eGFR. Patients
already under the care of nephrology were excluded. In order
to ascertain the additional cost to be incurred in primary care
through implementing the CKD guidance, the remaining
patients were analysed further. For these patients, the
NEOERICA database was interrogated to determine existing
investigation results, comorbidity and prescription data.
Details of the data items used are listed in the description
of the computer simulation. This approach, therefore, only
identified new, incident CKD cases not already known to
nephrology during a 1-year period. Incident cases were
expressed as patients per 10,000 population.

Other epidemiological data used

Follow-up data [23] from the East Kent Longitudinal Study
of Unreferred CKD [24] were used to estimate the proportion
of patients with increased parathyroid hormone (PTH)

<table>
<thead>
<tr>
<th>Stage of CKD (GFR)</th>
<th>Referral recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 5 (&lt;15 ml/min/1.73 m²)</td>
<td>Immediate referral</td>
</tr>
<tr>
<td>Stage 4 (15–29 ml/min/1.73 m²)</td>
<td>Urgent referral (routine if known to be stable)</td>
</tr>
<tr>
<td>Stage 3 (30–59 ml/min/1.73 m²)</td>
<td>Routine referral if:</td>
</tr>
<tr>
<td></td>
<td>• Progressive fall in GFR/increase in serum creatinine</td>
</tr>
<tr>
<td></td>
<td>• Microscopic haematuria present</td>
</tr>
<tr>
<td></td>
<td>• Urinary protein-creatinine ratio &gt;100 mg/mmol</td>
</tr>
<tr>
<td></td>
<td>• Unexplained anaemia (Hb &lt;11 g/dl), abnormal potassium, calcium or phosphate</td>
</tr>
<tr>
<td></td>
<td>• Suspected systemic illness, e.g. systemic lupus erythematosus</td>
</tr>
<tr>
<td></td>
<td>• Uncontrolled BP (&gt;150/90 mmHg despite complementary therapy with three classes of antihypertensive agents)</td>
</tr>
<tr>
<td>Stage 1–2 (60–89 ml/min/1.73 m²)</td>
<td>Referral not required unless other problems</td>
</tr>
<tr>
<td>Stage 1–2 (&gt;60 ml/min/1.73 m²)</td>
<td>Immediate referral for:</td>
</tr>
<tr>
<td></td>
<td>• Malignant hypertension</td>
</tr>
<tr>
<td></td>
<td>• Hyperkalaemia (potassium &gt;7.0 mmol/l)</td>
</tr>
<tr>
<td></td>
<td>Urgent referral for:</td>
</tr>
<tr>
<td></td>
<td>• Nephrotic syndrome</td>
</tr>
<tr>
<td></td>
<td>Routine referral for:</td>
</tr>
<tr>
<td></td>
<td>• Dipstick proteinuria present and urine protein/creatinine ratio &gt;100 mg/mmol</td>
</tr>
<tr>
<td></td>
<td>• Dipstick proteinuria and microscopic haematuria present</td>
</tr>
<tr>
<td></td>
<td>• Macroscopic haematuria but urological tests negative</td>
</tr>
</tbody>
</table>

Follow-up blood tests

| Stage 3 CKD | Annual potassium, creatinine and estimated GFR check, provided renal function is stable. |
| Stage 4/5 CKD | PTH concentration when stage 3 CKD is first diagnosed, and if raised, test 25-hydroxy vitamin D. |
| Renal ultrasound | Three monthly check: FBC, renal function. PTH as above |
| Any CKD stage | Patients with lower urinary tract symptoms |
| | Uncontrolled hypertension |
| | Family history of hereditary renal disease |
| | Unexplained fall in GFR |

CKD, Chronic kidney disease; GFR, Glomerular filtration rate; Hb, haemoglobin; PTH, parathyroid hormone; FBC, full blood count.
concentration. In this study, CKD patients were defined using the National Institute of Health referral criteria (SCr > 80 µmol/l in males and > 135 µmol/l in females) yielding a prevalence of CKD (median eGFR 28.5 ml/min/1.73 m²) of 5554 per million population: 64.8% of patients were unknown to the renal service. During a median follow-up of 31 months, 38% had died due to cardiovascular disease with renal failure accounting for only 5% of the deaths. A subset of unrecorded patients was studied prospectively to examine the potential benefit of specialist investigation and management. The majority of patients had stable CKD, only 2.8% had an eGFR declining by ≥ 5 ml/min/1.73 m²/year. More than one-third (37%) of CKD patients had increased PTH concentrations (≥ 90 ng/l).

**Computer simulation**

A computer program was written using Java® (Sun Microsystems) to simulate implementing the CKD guidelines. This program contained 30 pages of Java source code and recompiled the guidelines in the form of rule-based decision trees. The program parsed the NEOERICA data carrying out the following steps:

(i) All adults with a SCr result in the study entry period were identified, i.e. the SCr must lie between 1 July 2002 and 31 June 2003.
(ii) Previous SCr values prior to the study entry period on the new cases identified in step (i) were highlighted.
(iii) GFR for all SCr results were calculated using the four-variable MDRD formula.
(iv) Where more than one SCr recording was present, rate of change in eGFR was ascertained.
(v) New (incident) cases of CKD were defined as those with a newly identified eGFR < 60 ml/min/1.73 m² within the 1-year study entry period. Those with a history of a renal diagnosis, procedure or referral to a nephrologist were presumed to be existing (prevalent) cases and were excluded.
(vi) The incident cases were further divided into those with abnormal results or rate of decline requiring nephrology referral and those with stable renal disease requiring further blood tests that had not been done previously.
(vii) The following factors were identified by the program to enable it to model whether further investigation or referral of incident cases might be indicated: systolic blood pressure (BP), diastolic BP, prescription of anti-hypertensive medication, in addition to laboratory investigations (SCr, haemoglobin (Hb), potassium, calcium, phosphate, 25-hydroxy vitamin D and PTH).
(viii) Uncontrolled hypertension was defined as an incident patient with a BP > 150/90 mmHg while on three complementary groups of anti-hypertensive agents.
(ix) Unacceptably declining renal function was defined as a rate of decline of eGFR ≥ 5 ml/min/1.73 m²/year.

**Calculation of cost**

(i) For cost calculation, items recommended in the UK CKD guidelines were priced using the 2004 national schedule of reference costs [8]. (ii) All costs were calculated for the following year on identified incident cases using a pragmatic cost model.

Total cost = Cost of initial investigations + referral cost + follow-up cost

Where,

Initial investigation costs = Initial laboratory cost + ultrasound cost

Referral costs = Initial nephrology referral cost + follow-up nephrology visit costs over 12 months

Follow-up cost = Follow-up laboratory investigation cost over 12 months

(iii) Only costs of any additional investigations required to complete the list dictated in the guidelines were added. Other tests were not repeated, except where the guidelines required confirmatory tests prior to possible referral; e.g. repeat SCr when eGFR is rapidly declining or where there was only a single SCr recorded.

(iv) Costs were converted from British pounds (GBP) to EUR using a currency conversion rate of 1.48. Given that the average population of a primary care practice in the UK is 10,000 patients, costs were expressed per 10,000 patients.

(v) A sensitivity analysis was conducted to systematically examine the influence of variation in the variables used for the cost calculation.

**Sensitivity analysis**

First, the change in prevalence engendered by creatinine calibration was modelled into the sensitivity analysis. We have shown that SCr calibration to the method used by the MDRD laboratory in the NEOERICA database increased the proportion of stage 3 CKD by a factor of 1.75 and stage 4 CKD by a factor of 1.6, while stage 5 CKD remained unaffected [25]. This increase in detected prevalence would increase the cost.

Second, data was used from a manual search of 500 records [21]; and examining the change in prevalence of CKD recording in the same practice, e.g. a higher detection of incident CKD would result in higher cost prediction.

Third, the cost-lowering effect if a higher proportion of patients were already known to nephrology was also assessed. Lastly, other population studies [26–29] show higher prevalence rates for lower urinary tract symptoms (LUTS); and this too was factored into the sensitivity analysis when taking into account renal ultrasound costs.

**Assumptions made**

The following assumptions were made in the calculation of the cost model:

(i) All patients with a specific nephrology read-code diagnosis were assumed to be already under nephrology follow-up.
Results

In the 1-year time period, 13,862 adult patients with an SCr were identified by the Java simulation (Figure 1). Of these, 1,227 patients were already under the care of nephrology and 450 patients had no age recorded for eGFR calculation. 9794 of the remaining 12,185 had an nephrology and 450 patients had no age recorded for eGFR. Of these, 1,227 patients were already under the care of nephrology and 450 patients had no age recorded for eGFR (Table 1). In the 1-year time period, 13,862 adult patients with an SCr were identified by the Java simulation (Figure 1). Similarly, ultrasonography would be performed on all patients with uncontrolled hypertension and unacceptably declining renal function prior to referral. For PTH-related cost, it was assumed that 37% of persons with CKD would have increased PTH (≥90 ng/l) using data from the follow-up study [23] to the East Kent Longitudinal study [24].

All stage 4 and 5 CKD were suitable for nephrology assessment and would be followed up by nephrology.

Patients requiring nephrology follow-up would be seen three times in the next 12 months.

(ii) All patients with unacceptably declining renal function were assumed to require referral to nephrology services.
(iii) All at-risk stage 3 CKD persons (unacceptably declining renal function, Hb <11 g/dl and uncontrolled hypertension) would be referred to nephrology, thereafter followed up in primary care.
(iv) A renal tract ultrasound would be performed on all 11% of the stage 3 CKD population with LUTS.
(v) For PTH-related cost, it was assumed that 37% of persons with CKD would have increased PTH (≥90 ng/l) using data from the follow-up study [23] to the East Kent Longitudinal study [24].
(vi) All stage 4 and 5 CKD were suitable for nephrology assessment and would be followed up by nephrology.
(vii) Patients requiring nephrology follow-up would be seen three times in the next 12 months.

Sensitivity analysis

The impact of the sensitivity analysis is described in detail in Table 6. The effect of calibration of creatinine was to lower eGFR and this effect was greatest at lower creatinine levels. The proportion of those with stage 5 CKD remained unchanged, whilst the proportion of those with stage 4 CKD increased by a factor of 1.6, and by a factor of 1.75 in people with stage 3 CKD. The impact of including creatinine calibration into the sensitivity analysis significantly increased cost.

Based upon a detailed review of primary care practices, the annual audits of CKD revealed that the proportion of the patient population who have had a SCr measured has risen from 2522 (23%) in 2004; to 3013 (27%) in 2005; and to 3565 (32%) in data collected for 2006. The prevalence of identified CKD has risen to 6.4% (709/1140) in 2006 compared with
There has been little change in BP. Between 2004 and 2005, mean systolic BP fell from 143.4 to 140.7 mmHg ($P < 0.001$) and then increased to 141 mmHg in 2006. Diastolic BP steadily reduced from 80.7 to 79.9, and then to 79.2 mmHg across the 3 years of the audit. A systematic review of one of the practices used in the NEOERICA study that showed that the computer search underestimated the number of patients known to renal services by 11% (4/36) compared with the manual search.

Variations in the prevalence rates for LUTS exist: three other large population studies showed different prevalence rates of 16% [26], 18.5% [27] and 24% [28] the 5.1% in 2004. There has been little change in BP. Between 2004 and 2005, mean systolic BP fell from 143.4 to 140.7 mmHg ($P < 0.001$); and then increased to 141 mmHg in 2006. Diastolic BP steadily reduced from 80.7 to 79.9, and then to 79.2 mmHg across the 3 years of the audit.

A systematic review of one of the practices used in the NEOERICA study that showed that the computer search underestimated the number of patients known to renal services by 11% (4/36) compared with the manual search.

Variations in the prevalence rates for LUTS exist: three other large population studies showed different prevalence rates of 16% [26], 18.5% [27] and 24% [28]
The cost of implementing UK guidelines for the management of CKD

Table 3. Likely incurred cost in primary care for the first 12 months on all newly identified cases in the study time period

<table>
<thead>
<tr>
<th>Newly identified cases (Patients per 10000 population)</th>
<th>Initial investigations</th>
<th>Follow-up laboratory investigations—next 12 months (Table 5)</th>
<th>Referral</th>
<th>Nephrology follow-up—next 12 monthsb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Laboratory investigations (Table 4)</td>
<td>Ultrasound renal tract</td>
<td>Nephrology referral—initial</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stable stage 3 (includes single GFR reading)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anaemic (Hb &lt;11 g/dl)</td>
<td>1.11</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Uncontrolled hypertension</td>
<td>1.67</td>
<td>160</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Declining GFR ≥ 5 ml/min/1.73 m²/year</td>
<td>14.8</td>
<td>44</td>
<td>1421</td>
</tr>
<tr>
<td></td>
<td>Stage 4 Single GFR reading Stable Stage 4 CKD</td>
<td>2.78</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Stable stage 3 CKD (126.27 patients per 10000 population)</td>
<td>0.56</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Stage 5</td>
<td>0.31</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Subtotal</td>
<td>3197</td>
<td>2914</td>
<td>3186</td>
<td>6008</td>
</tr>
<tr>
<td>Total cost per 10 000 population</td>
<td>6111 €</td>
<td>3186 €</td>
<td>7836 €</td>
<td></td>
</tr>
</tbody>
</table>

Figures rounded to nearest EUR, for conversion from EUR to USD, multiply by 1.45; for EUR to GBP multiply by 0.67. Cost per cell: multiplying corresponding amount of patients by unit cost for investigation or referral (Table 2).

Table 4. The cost of initial laboratory investigations required on newly identified CKD cases

<table>
<thead>
<tr>
<th>Newly identified cases</th>
<th>Combinations of new tests required</th>
<th>Patients per 10 000 population</th>
<th>Cost (per 10000 population)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable stage 3 CKD</td>
<td>Calcium, phosphate PTH</td>
<td>27.15</td>
<td>679</td>
</tr>
<tr>
<td>(126.27 patients per 10000 population)</td>
<td>Creatinine, estimated GFR, potassium PTH</td>
<td>11.78</td>
<td>295</td>
</tr>
<tr>
<td></td>
<td>Creatinine, estimated GFR, potassium, calcium, phosphate PTH PTH only</td>
<td>83.89</td>
<td>2097</td>
</tr>
<tr>
<td>Stage 3 CKD, declining GFR ≥ 5 ml/min/1.73 m²/year</td>
<td>Repeat GFR</td>
<td>3.35</td>
<td>74 (Subtotal 3145 €)</td>
</tr>
<tr>
<td>Stage 4 CKD, single GFR reading</td>
<td>Repeat GFR</td>
<td>2.78</td>
<td>8</td>
</tr>
<tr>
<td>Total cost</td>
<td></td>
<td></td>
<td>3197 €</td>
</tr>
</tbody>
</table>

Figures rounded to nearest EUR, for conversion from EUR to USD, multiply by 1.45; for EUR to GBP multiply by 0.67. Cost per cell: multiplying corresponding amount of patients by unit cost for investigation (Table 2).

for LUTS in men older than 40–45 years of age and a study by Terai et al. [29], shows prevalence rates for LUTS to be similar in both genders. The prevalence of LUTS at 11% in NEOERICA may, therefore, have been an underestimation; rather, a mean of the above population studies (20%) would probably be a more realistic estimation.

Re-running the model on the basis of creatinine calibration, an 11% increase in the proportion of patients known to renal services, the growth in SCr concentration recording (and indirectly the CKD prevalence by 1.3%), little change in systolic BP control and increased prevalence of LUTS (20%), the model produced a maximum estimate of € 29 270 per practice.

Discussion

This study provides an estimate of workload and cost in the first 12 months of implementing the new UK guidelines for the management of newly identified CKD cases over a 1-year period. In interpreting the results, it is important to realize that the study concentrates on ‘incident’ stages 3–5 CKD, not ‘prevalent’ CKD. The cost of implementation of
these guidelines has three components: First, there is a cost of referral to secondary care. Second, a cost of ‘catch-up’ investigations; and lastly, the cost of ongoing monitoring of stable CKD patients.

The guidelines, designed to reduce late referral of stages 4 and 5 CKD and high-risk cases, will in the short-term accelerate the number of patients being referred to secondary care. Although this will result in an increased workload for nephrology, patients may benefit through earlier reduction of cardiovascular risk, treatment of anaemia and patient education.

The costs of implementation of the guidelines may be offset in the long-term by the reduction in number of people progressing to require RRT, and by a reduction in late referral for dialysis. These benefits, however, cannot currently be incorporated in a cost-savings model because, as yet, there are no outcome data on early referral and reduction of development of end-stage renal disease (ESRD). This also holds true for the increased expenditure required on ‘catch-up’ investigations and ongoing monitoring of stable CKD patients. The majority of extra investigations were found to be tests related to renal bone disease parameters (calcium, phosphate and PTH). Currently due to the lack of outcome data on the monitoring of renal bone disease, the benefits of testing for these parameters are debateable. The UK CKD guidelines acknowledge the high costs associated with this strategy and that currently there is only limited outcome data demonstrating benefit as a result of this increased testing [30]. However, it is also acknowledged that the recommendations are far less extensive in this respect than those in other comparable international guidelines [31,32]. Commissioners of NHS services will have to carefully appraise the cost–benefit of carrying out these tests.

The volume of work the guidelines will create in general practice will not be dissimilar to volume of work in other areas of chronic disease management with a similar prevalence; for example cholesterol management in cardiovascular disease. General practice has shown itself to be equal to the challenge of this field [33,34].

The study clearly has limitations. Firstly, figures are based upon the detection of newly identified cases in one calendar year and the numbers of incident CKD cases are, therefore, dependant on the amount of persons tested for SCr in the study period. More specific screening approaches [36], where restriction of

<table>
<thead>
<tr>
<th>Table 5. The cost of follow-up laboratory investigations in next 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Newly identified cases (Patients per 10 000)</strong></td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Stable CKD stage 3</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Anaemia (Hb &lt; 11 g/dl)</td>
</tr>
<tr>
<td>Uncontrolled hypertension</td>
</tr>
<tr>
<td>Declining GFR ≥ 5 ml/min/1.73 m²/year</td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
</tr>
</tbody>
</table>

Figures rounded to nearest EUR, for conversion from EUR to USD, multiply by 1.45, for EUR to GBP multiply by 0.67.

Cost per cell: multiply corresponding amount of patients by unit cost for investigation (Table 2).

<table>
<thead>
<tr>
<th>Table 6. Sensitivity analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost breakdown</strong></td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Initial blood tests</td>
</tr>
<tr>
<td>Ultrasound</td>
</tr>
<tr>
<td>Initial referral</td>
</tr>
<tr>
<td>Follow-up blood tests</td>
</tr>
<tr>
<td>Follow-up referral</td>
</tr>
<tr>
<td>Total per 10 000 patients</td>
</tr>
</tbody>
</table>

All figures rounded to nearest EUR, for conversion from EUR to USD, multiply by 1.45, for EUR to GBP multiply by 0.67.

Analysis 1: Increase in stage 4 CKD by a factor of 1.6 and stage 3 CKD by a factor of 1.75 due to calibration of SCr.

Analysis 2: Analysis 1 plus increase in CKD incidence by 1.3% due to increased testing for SCr.

Analysis 3: Analysis 2 plus an increase in known-to-nephrology (prevalent) cases by 11%.

Analysis 4: Analysis 3 plus an increase in LUTS prevalence to 20%. 

Figures rounded to nearest EUR, for conversion from EUR to USD, multiply by 1.45, for EUR to GBP multiply by 0.67.

Assumption 5.
screening to those with hypertension, diabetes or aged older than 55 years would, according to Hallan et al., [36] potentially identify more people with CKD and carry a significantly greater cost. Nevertheless, the NEOERICA data was representative of the diversity of comorbidity. In all people registered in primary care and a substantial sample of day-to-day CKD management in primary care practice was available. Recorded data in high-risk patients was high, thus enabling a reasonable cost estimation for primary care. A recorded sCr was available in 27% of the NEOERICA population and 46.3% had two or more sCr values greater than three months apart. We found that recording of sCr in patients with diabetes mellitus was 83.6%, suggesting that targeted testing for CKD is already occurring in primary care in the UK. Therefore, our projected costs produced by the model are likely to be reasonably accurate.

The NEOERICA data was collected before the inception of the new primary care general practitioner contract [17,35]. This contract provides financial incentives for the creation of registers for certain chronic diseases (hypertension, diabetes and CKD since 2006) and is bound to have had a positive effect on increased testing for renal disease in such high risk populations. The effect of increased detection of incident cases of CKD through increased testing for SCr has been included in the sensitivity analysis. This gives some indication of the possible accuracy of the cost estimate, and costs may change as more research is carried out in this domain. Also, within the sensitivity analysis, we have modelled for the impact of SCr calibration on stage of CKD. This significantly increased the total cost from €17,133 to €29,408 per 10,000 patients.

We have not modelled for the mortality from CKD. Keith et al. [37] found 5-year mortality rates in CKD as high as 24.3% in stage 3 CKD patients. For the costs model, we included patients who were more likely to be alive i.e. had had a blood test for SCr in the latter one year of the database. Moreover, to further minimize the effect of mortality, only costs for the initial 12 months of following the guidelines were modelled.

We did not include the cost of any of the additional therapy that might be generated from the investigation of the patients highlighted for referral. Likewise, we have made no estimate of the costs of tertiary referral in secondary care for the management of any comorbidities or underlying diagnoses identified. We have not included the costs of treatment of any renal anaemia detected.

We also acknowledge that some stages 4 and 5 CKD cases may have been unsuitable for nephrology referral due to excessive comorbidity. Conversely, had proteinuria data been present we could have included it in the model. Proteinuria is often recorded in free text in primary care so the decision tree(s) were therefore unable to provide categorization information on patients with overt proteinuria due to the poor data quality in this area in general practice computer systems.

Conclusion

CKD has been largely unrecognized in UK primary care. The combination of the UK Renal National Service Framework, the inclusion of CKD in the quality-based primary care general practitioner contract, implementation of eGFR reporting and the UK guidelines have raised awareness of CKD. The new CKD guidelines represent the creation of a more specific platform of care for patients with CKD. Undoubtedly, they would result in increased referral of stages 4 and 5 and high-risk stage 3 CKD, and this has potential to reduce morbidity and mortality in these patients. In order to comply with the guidelines, much more routine testing of CKD parameters, particularly those of renal bone disease would be required. It is evident that there will be an increased financial resource required to deliver an effective CKD management programme: the cost of initial management of newly identified CKD in one year for a practice of 10,000 being between €17,113 and €29,790. In terms of the actual budget of a primary care practice, this may seem an acceptable cost considering the high prevalence of CKD. As yet it is uncertain whether following the guidelines will have a significant effect on hard outcomes of CKD, such as rate of progression and reduction of cardiovascular disease and a reduction in ESRD. The benefit alone of reduction of late referral may not justify the estimated cost of €17,133–€29,790. However, this strategy only has to delay ESRD by a single year on one patient to save €34,000. Will the increased cost be offset by a reduction of ESRD or cardiovascular comorbidity? This will have to be the focus of future research.

Conflict of interest statement. D.J.O'D. is the co-chair of the Renal Advisory Group for the implementation of the UK National Service Framework for Renal Services. P.E.S. and E.J.L. were members of the UK CKD Guidelines Group. S. de L. is the National Expert Advisor for the Chronic Kidney Disease element of the Quality Outcomes Framework. Primary Care Informatics, St George's University of London and was funded by Roche Products Ltd to process the data used in the NEOERICA study. B.K., R.M., D.J.O'D., P.E.S and C.K.T.F have received honoraria from Roche Products Ltd, Amgen, Ortho-Biotech and Pfizer to attend conferences.

References
