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The cost of implementing UK guidelines for the management of chronic kidney disease

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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 $\geq 5\,ml/min/1.73\,m^2$/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) $<60\,ml/min/1.73\,m^2$ [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

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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 1990–2003. Risk factors associated with CKD, comorbidity 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 1. Recommendations specified by the UK CKD Guidelines

Stage of CKD (GFR)	Referral recommendation
Stage 5 (<15 ml/min/1.73 m^2)	Immediate referral
Stage 4 (15–29 ml/min/1.73 m^2)	Urgent referral (routine if known to be stable)
Stage 3 (30–59 ml/min/1.73 m^2)	Routine referral if: • Progressive fall in GFR/increase in serum creatinine • Microscopic haematuria present • Urinary protein–creatinine ratio >100 mg/mmol • Unexplained anaemia (Hb < 11 g/dl), abnormal potassium, calcium or phosphate • Suspected systemic illness, e.g. systemic lupus erythematosus • Uncontrolled BP (>150/90 mmHg despite complementary therapy with three classes of antihypertensive agents)
Stage 1–2 (60–89 ml/min/1.73 m^2)	Referral not required unless other problems
Stage 1–2 (>60 ml/min/1.73m^2)	Immediate referral for: • Malignant hypertension • Hyperkalaemia (potassium >7.0 mmol/l) Urgent referral for • Nephrotic syndrome Routine referral for: • Dipstick proteinuria present and urine protein/creatinine ratio >100 mg/mmol • Dipstick proteinuria and microscopic haematuria present • Macroscopic haematuria but urological tests negative
Follow-up blood tests	
Stage 3 CKD	Annual potassium, creatinine and estimated GFR check, provided renal function is stable. PTH concentration when stage 3 CKD is first diagnosed, and if raised, test 25-hydroxy vitamin D.
Stage 4/5 CKD	Three monthly check: FBC, renal function. PTH as above
Renal ultrasound	
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 m^2) of 5554 per million population: 84.8% 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 unreferred 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 m^2/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 m^2 within the 1-year study entry period. Those with any 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 m^2/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.

$$\text{Total cost} = \text{Cost of initial investigations} + \text{referral cost} + \text{follow-up cost}$$

Where,

$$\text{Initial investigation costs} = \text{Initial laboratory cost} + \text{ultrasound cost}$$

$$\text{Referral costs} = \text{Initial nephrology referral cost} + \text{follow-up nephrology visit costs over 12 months}$$

$$\text{Follow-up cost} = \text{Follow-up laboratory investigation cost over 12 months}$$

(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.

(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. Similarly, ultrasonography would be performed on all patients with uncontrolled hypertension and unacceptably declining renal function prior to referral.
(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.

Results

In the 1-year time period, 13 862 adult patients with an SCr were identified by the Java simulation (Figure 1). Of these, 1227 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 eGFR ≥60 ml/min/1.73 m^2, leaving 2391 patients highlighted to have CKD (eGFR <60 ml/min/1.73 m^2). This equates to 147.5 patients per 10 000 population.

Of the 147.5 per 10 000 with eGFR < 60ml/min/1.73 m^2 identified in the first year, 3.34 and 0.31 per 10 000 would have stage 4 and 5 CKD, respectively and 143.85 patients per 10 000 would have stage 3 CKD. A small proportion of stage 3 patients would require referral to nephrology: 1.11 per 10 000 with Hb <11 g/dl, 1.67 per 10 000 with uncontrolled hypertension and 14.8 per 10 000 with unacceptably declining renal function. The remainder (126.27 per 10 000) would have stable stage 3 CKD and not require referral; instead, they would need to undergo 'catch up' laboratory investigations to comply with the guidelines. All stages 4 and 5 CKD patients would require referral.

Table 4 shows the combinations of initial 'catch up' laboratory investigations that would be required on stage 3 CKD individuals. These tests were based upon missing investigations encountered by the Java simulation i.e. tests not already performed by primary care. The majority of the additional initial tests required for people with stage 3 CKD would be an additional SCr measurement to confirm the diagnosis, in addition to renal bone disease investigations amounting to a total of € 3145 per practice. Included in this cost is an initial test for PTH concentration, recommended by the guidelines on all stage 3 CKD patients. Adding the confirmatory test for eGFR in CKD stage 3 patients with declining renal function and those with a single eGFR showing stage 4 CKD, the total initial blood test investigation cost would be € 3197 per practice. Renal ultrasound costs were € 2914 (Table 3). Approximately, half of the ultrasound cost was for patients with declining renal function (€ 1421), most of the remainder was for investigation of LUTS (€ 1333) and € 160 was for individuals with uncontrolled hypertension.

The total referral cost was € 7836 per 10 000 (Table 3); € 6008 for the first visit and € 1828 for follow-up visits. A large proportion of this cost (€ 4188) was for referral of the 14 patients with declining renal function. The initial out-patient referral cost of the two to three new cases with stage 4 CKD amounted to a cost of € 784 + 158, while a new stage 5 CKD out-patient referral would cost € 88 per 10 000 per year. Assuming that all new cases of stage 4 and 5 CKD remained under long-term nephrology follow-up and were seen three times in the next 12 months, primary care would incur a cost of € 1828 just to support out-patient follow-up.

Table 5 shows the breakdown of follow-up laboratory investigations required in the next 12 months. Practices would be required to monitor the 126.27 patients per 10 000 with stable stage 3 CKD with an annual eGFR, electrolytes and full blood count investigation. Patients at higher risk (uncontrolled hypertension, Hb <11 g/dl and unacceptably declining renal function) would require at least two monitoring tests in the next year. The total cost of follow-up blood tests was € 3186 per practice. Given that testing for PTH and 25-hydroxy vitamin D is expensive, that would account for two-thirds of the cost (€ 2056 per practice).

The final cost estimation per practice in the first year was:

$$\begin{aligned}\text{Total cost} &= \text{Cost of initial investigations} \\ &\quad + \text{total referral cost} + \text{follow-up cost} \\ &= €\,6111 + €\,7836 + €\,3186 \\ &= €\,17\,133 \text{ per practice of} \\ &\quad 10\,000 \text{ patients}\end{aligned}$$

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

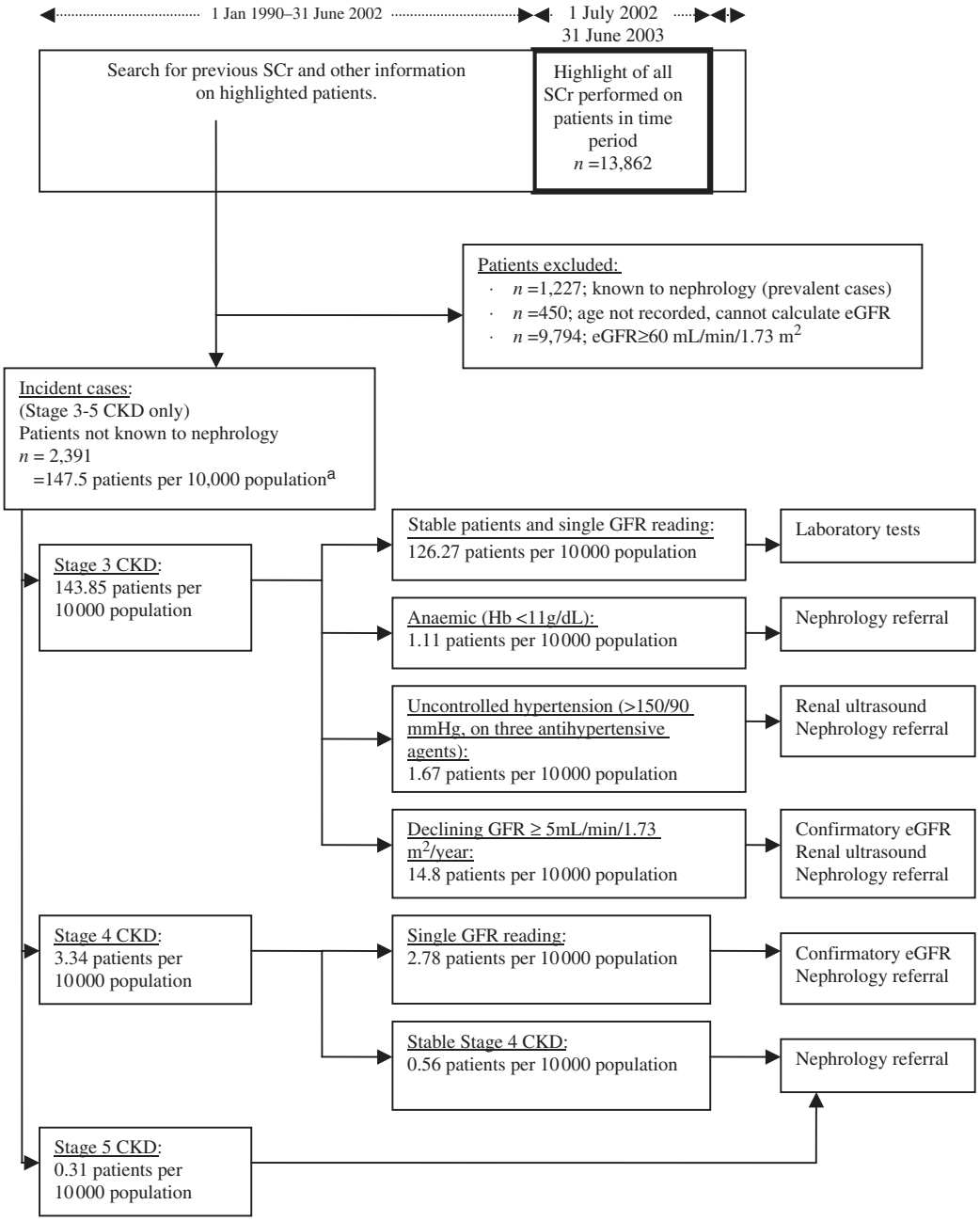

Fig. 1. Patients grouped by the Java simulation. [a]Patients per 10 000 = (10 000 × 2391)/162 113.

Table 2. The Department of Health reference for unit cost (2004)

	National average unit cost (EUR)
Chemical pathology	3
Parathyroid hormone[a]	22
1,25-hydroxy vitamin D[a]	22
Haematology, excluding anti-coagulation	4
Ultrasound renal tract	96
Nephrology out-patient (first visit)	283
Nephrology out-patient (follow-up)	167

[a]Kent and Medway reference cost.
Figures rounded to nearest EUR; for conversion from EUR to USD, multiply by 1.45; for EUR to GBP multiply by 0.67.

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]

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

Newly identified cases (Patients per 10 000 population)			Initial investigations		Follow-up laboratory investigations—next 12 months (Table 5)	Referral	
			Laboratory investigations (Table 4)	Ultrasound renal tract		Nephrology referral—initial	Nephrology follow-up—next 12 months[b]
Stage 3	Stable stage 3 (includes single GFR reading)	126.27	3145	1333[a]	3145	–	–
	Anaemic (Hb < 11 g/dl)	1.11	–	–	16	314	–
	Uncontrolled hypertension	1.67	–	160	23	473	–
	Declining GFR ≥ 5 ml/min/1.73 m^2/year	14.8	44	1421	207	4188	–
Stage 4	Single GFR reading	2.78	8	–	–	787	1392
	Stable Stage 4 CKD	0.56	–	–	–	158	281
Stage 5		0.31	–	–	–	88	155
Subtotal			3197	2914	3186	6008	1828
			6111 €		3186 €	7836 €	
Total cost per 10 000 population			**17 133** €				

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 or referral (Table 2).
[a]Assumption 4.
[b]Assumption 6.

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

Newly identified cases	Combinations of new tests required	Patients per 10 000 population	Cost (per 10 000 population)
Stable stage 3 CKD (126.27 patients per 10 000 population)	Calcium, phosphate PTH	27.15	679
	Creatinine, estimated GFR, potassium PTH	11.78	295
	Creatinine, estimated GFR, potassium, calcium, phosphate PTH	83.89	2097
	PTH only	3.35	74 (Subtotal 3145 €)
Stage 3 CKD, declining GFR ≥ 5 ml/min/1.73 m^2/year	Repeat GFR	14.8	44
Stage 4 CKD, single GFR reading	Repeat GFR	2.78	8
Total cost			**3197** €

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).

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

Table 5. The cost of follow-up laboratory investigations in next 12 months

Newly identified cases (Patients per 10 000)		Blood test	Cost (per 10 000 population)
Stable CKD stage 3	126.27	Potassium, creatinine, estimated GFR; Full blood count checked once	884
		25-hydroxy vitamin D + PTH checked once	2056[a]
Anaemia (Hb < 11 g/dl)	1.11	Potassium, creatinine,	16
Uncontrolled hypertension	1.67	estimated GFR; Full blood count checked twice	23
Declining GFR ≥ 5 ml/min/1.73 m^2/year	14.8		207
Total cost			**3186** €

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).
[a]Assumption 5.

Table 6. Sensitivity analysis

Cost breakdown	Current calculation	Analysis1	Analysis 2	Analysis 3	Analysis 4
Initial blood tests	3197	5593	5666	5043	5043
Ultrasound	2914	5100	4167	4598	6320
Initial referral	6008	10 307	10 441	9292	9292
Follow-up blood tests	3186	5575	5674	5026	5026
Follow-up referral	1828	2833	2869	2554	2554
Total per 10 000 patients	**17 133** €	**29 408** €	**29 790** €	**26 513** €	**28 235** €

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%.

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 quality improvement in this field [33,34]. This has been achieved through audit as well as more recently through financially incentivised quality improvement [17,35].

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

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.

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