



Hypertension and cardiovascular risk factor management in a multi-ethnic cohort of adults with CKD: a cross sectional study in general practice

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Abstract

Background Hypertension, especially if poorly controlled, is a key determinant of chronic kidney disease (CKD) development and progression to end stage renal disease (ESRD).

Aim To assess hypertension and risk factor management, and determinants of systolic blood pressure control in individuals with CKD and hypertension.

Design and setting Cross-sectional survey using primary care electronic health records from 47/49 general practice clinics in South London.

Methods Known effective interventions, management of hypertension and cardiovascular disease (CVD) risk in patients with CKD Stages 3–5 were investigated. Multivariable logistic regression analysis examined the association of demographic factors, comorbidities, deprivation, and CKD coding, with systolic blood pressure control status as outcome. Individuals with diabetes were excluded.

Results Adults with CKD Stages 3–5 and hypertension represented 4131/286,162 (1.4%) of the total population; 1984 (48%) of these individuals had undiagnosed CKD without a recorded CKD clinical code. Hypertension was undiagnosed in 25% of the total Lambeth population, and in patients with CKD without diagnosed hypertension, 23.0% had systolic blood pressure > 140 mmHg compared with 39.8% hypertensives, $p < 0.001$. Multivariable logistic regression revealed that factors associated with improved systolic blood pressure control in CKD included diastolic blood pressure control, serious mental illness, history of cardiovascular co-morbidities, CKD diagnostic coding, and age < 60 years. African ethnicity and obesity were associated with poorer systolic blood pressure control.

Conclusion We found both underdiagnosed CKD and underdiagnosed hypertension in patients with CKD. The poor systolic blood pressure control in older age groups ≥ 60 years and in Black African or obese individuals is clinically important as these groups are at increased risk of mortality for cardiovascular diseases.

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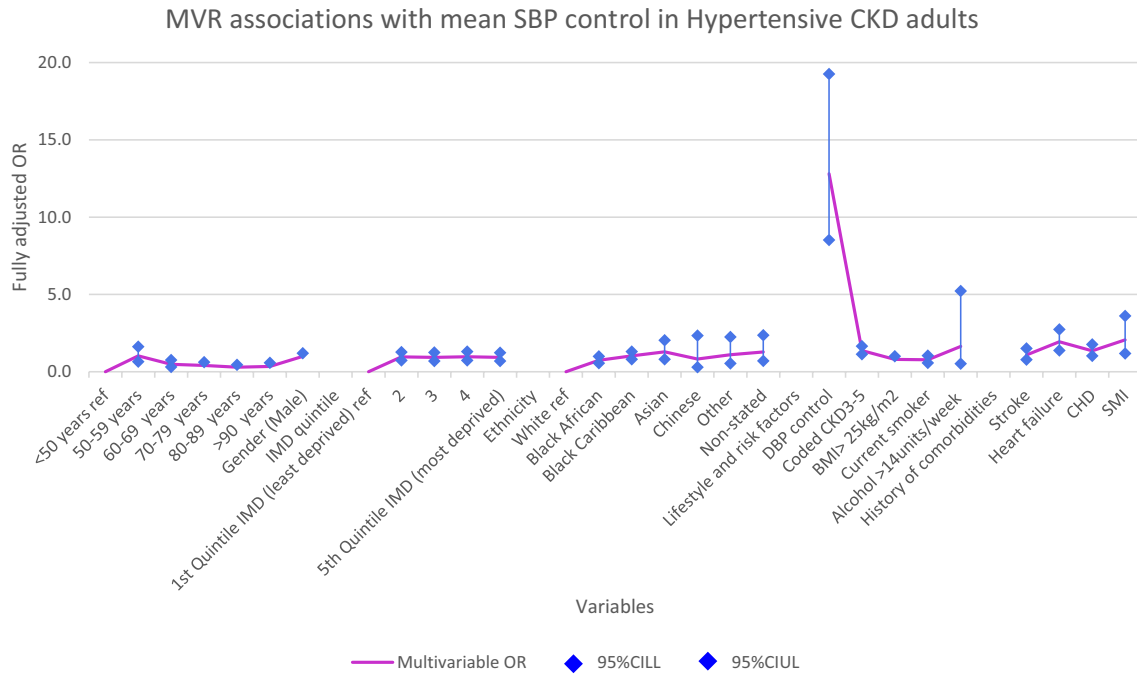
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Graphic abstract



Keywords CKD · Hypertension · Ethnicity · CVD · Undiagnosed · African

Abbreviations

ACEI	Angiotensin-converting-enzyme inhibitor drug
ACR	Albumin creatinine ratio
AOR	Adjusted odds ratio
ARB	Angiotensin-receptor blocker
BMI	Body mass index
BP	Blood pressure
CCB	Calcium channel blocker
CCG	Clinical Commissioning Group
CHD	Coronary heart disease
CKD	Chronic kidney disease
CVD	Cardiovascular disease
COXIB	A type of non-steroidal anti-inflammatory drug (NSAID) that directly targets cyclooxygenase-2 COX-2, an enzyme responsible for inflammation and pain
DBP	Diastolic blood pressure
(e)GFR	(Estimated) glomerular filtration rate
EHR	Electronic health record
ESRD	End-stage renal disease
GFR	Glomerular filtration rate
HF	Heart failure
HT	Hypertension
IMD	Index of multiple deprivation
KCL	King’s College London
KDIGO	Kidney Disease: Improving Global Outcomes

LDN	Lambeth DataNet
MDRD	Modification of Diet in Renal Disease
MPH	Master of Public Health
MVR	Multivariable logistic regression
NA-CKD	Normoalbuminuric chronic kidney disease
NCKDA	National CKD audit
NICE	National Institute for Health and Care Excellence
NSAIDS	Non-steroidal anti-inflammatory medication
QOF	Quality Outcome Framework
READ	A coded thesaurus of clinical terms. There are two versions: version 2 (v2) and version 3 (CTV3 or v3)
RRT	Renal replacement therapy
SBP	Systolic blood pressure
SMI	Serious mental illness
WHO	World Health Organization

Introduction

CKD and hypertension

The diagnosis of chronic kidney disease (CKD) is mainly based on estimated glomerular filtration rate (eGFR) < 60 ml/min/1.73m² for at least 3 months, even if

the broader definition includes all persistent alterations of renal morphology and of blood or urine composition [1]. Key risk factors for CKD include hypertension, cardiovascular disease (CVD), and diabetes [2], and CKD is associated with significant morbidity and mortality, in particular in these groups [2, 3].

CKD is common in England, an estimated 6.1% people aged $16 \geq$ years are living with CKD (defined as $eGFR < 60 \text{ ml/min/1.73m}^2$), and this is projected to include 3.2 million people in 2021 [4]. The treatment of CKD Stage 3–5 poses a considerable financial burden, and the lifetime the lost health-related quality of life is estimated as £7.18 billion in England [5]. This includes the high cost of renal replacement therapy (RRT) for survivors with end-stage renal disease and cardiovascular disease complications. In UK primary care, the Quality and Outcomes Framework (QOF) incentivises maintaining a CKD register with regular renal monitoring, which now includes classification of GFR categories “G3a to G5” (based on eGFR), although recommendations for BP targets $< 140/90$, and Albumin Creatinine Ratio (ACR) testing have been dropped [6]. However, persistent albuminuria prevalence (elevated urinary ACR with normal eGFR) in CKD stages 1 and 2 is estimated as high as 10% [7] and is associated with a doubling in mortality risk [8].

Data from the national CKD audit (NCKDA) report suggest that individuals with CKD and hypertension may not be well managed [9]. However, the NCKDA (gathering a largely White population) was unable to examine ethnic inequalities. The NCKDA audit suggests that 30% of CKD is undiagnosed (i.e. not formally coded), especially at younger ages, resulting in poorer quality of care [9]. The National Institute for Health and Care Excellence (NICE) Guidelines recommend regular renal function monitoring for individuals with hypertension, diabetes, and cardiovascular disease (CVD). In these groups, CKD is therefore more likely to be detected, as this is supported by QOF incentives for disease monitoring, including renal function.

Hypertension, especially if poorly controlled [10, 11] is a key determinant of CKD development and progression, and is present in the majority of people with diagnosed CKD (89%) in England [12, 13]. Antihypertensive medications, such as angiotensin receptor blockers (ARBs) and angiotensin-converting-enzyme inhibitors (ACEIs), are also currently recommended by the NICE (National Institute for Health and Care Excellence) guidelines as first line management for proteinuric CKD and for non proteinuric CKD in patients with hypertension [14], although recent findings suggest that these medications are under-prescribed [10, 15].

Known markers of CKD progression (measured by eGFR decline) include proteinuria [16–18], and blood pressure control has been shown to reduce proteinuria, and delay eGFR decline [19–21]. Blood pressure control has been

reported to be poor in patients with CKD Stage 3 [15], but little is known in later stages of CKD. Recognised risk factors for CKD include age, sex, ethnicity, hypertension, diabetes, cardiovascular disease, smoking, obesity and non-steroidal anti-inflammatory drug (NSAID) use [22, 23].

Patients with CKD and hypertension alone are managed and captured differently under Quality Outcome Framework, compared to those with CKD and diabetes. The NCKDA report has previously published differences in management by diabetes status. To our knowledge, there has been limited focus on the management of CKD in the UK by hypertension status. This study aimed to assess hypertension and risk factor management, and determinants of systolic blood pressure (SBP) control in individuals with CKD and hypertension HT.

Methods

Study design

Cross-sectional study of non-diabetic individuals with CKD.

Data sources

We used a dataset derived from general practice electronic health records (EHRs), Lambeth DataNet (LDN), south London, extracted from patient records from 1990 until October 2013. LDN contains clinical data, prescription data, laboratory data, and demographic information, such as age, sex, and ethnicity, based on categories of the UK 2001 census, CVD risk factors and co-morbidities. We investigated demographic factors, comorbidities, and other interventions considered as potentially effective, in a population identified as having CKD Stage 3–5, with and without hypertension.

Study population

Individuals with CKD Stage 3–5 (defined based on the criteria reported below). Patients with diabetes were excluded, as they have different profiles of proteinuria and cardiovascular risk [24]. The study was carried out using anonymised data from patients registered in 47/49 general practices, in an ethnically and socially diverse population of 286,162 adults (≥ 18 years), followed-up in Lambeth, south London.

Identification of CKD

Our CKD Stage 3–5 cohort comprised diagnosed and undiagnosed cases. Diagnosed CKD status was determined using QOF incentive scheme CKD descriptive codes, plus codes for dialysis or renal transplantation (Appendix Table S1).

Table 1 Prevalence of CVD risk factors and effective risk factor interventions characteristics in patients with CKD by hypertensive status

Variables	CKD and HT N (Col %)	CKD without acknowl- edged hypertension N (Col %)	<i>p</i> -value
CKD stage ≥ 3	4131 (16.5)	2657 (1.1)	**
Sex			
Female	2388 (57.8)	1556 (58.6)	$P > 0.05$
Male	1743 (42.2)	1101 (41.4)	
Age (years)			
< 50	346 (8.4)	720 (27.1)	**
50–59	568 (13.8)	642 (24.2)	
60–69	620 (15.0)	480 (18.1)	
70–79	1,127 (27.3)	406 (15.3)	
80–89	1,149 (27.8)	322 (12.1)	
> 90	321 (7.8)	87 (3.3)	
BMI (kg/m ²)			
Normal or below normal (below 25 kg/m ²)	1027 (24.9)	778 (31.9)	**
Overweight (25.0–29.9 kg/m ²)	1,452 (35.2)	796 (30.0)	
Obesity grade I (30.0–34.9 kg/m ²)	858 (20.8)	412 (15.5)	
Obesity grade II (35.0–39.9 kg/m ²)	333 (8.1)	147 (5.5)	
Obesity grade III (≥ 40 kg/m ²)	149 (3.6)	57 (2.1)	
Missing value	312 (7.6)	399 (15.0)	
Index of Multiple Deprivation 2015 (IMD)			
Quintile (% coded)			
1 (least deprived)	962 (23.3)	623 (23.5)	$P > 0.05$
2	915 (22.2)	528 (19.1)	
3	697 (16.9)	463 (17.4)	
4	767 (18.6)	524 (19.7)	
5	788 (19.1)	515 (19.4)	
Missing	2 (0.05)	4 (0.15)	
Ethnicity			
European	1,878 (45.5)	1,141 (42.9)	**
Black African	662 (16.0)	421 (15.8)	
Black Caribbean	879 (21.3)	522 (19.7)	
South Asian	174 (4.2)	109 (4.1)	
Chinese	29 (0.7)	9 (0.3)	
Other ethnicity	66 (1.6)	58 (2.2)	
Non-stated	94 (2.3)	69 (2.6)	
Missing	349 (8.5)	328 (12.3)	
History of comorbidities			
Previous stroke	342 (8.2)	61 (2.3)	**
Cancer	37 (0.9)	31 (1.2)	$P > 0.05$
Coronary Heart Disease, CHD	602 (14.6)	193 (7.3)	**
Serious mental illness, SMI	164 (4.0)	142 (5.3)	*
Heart failure	345 (8.3)	100 (3.7)	**
Mean SBP < 140 mmHg	1,522 (60.2)	472 (77.0)	**
Mean DBP < 90 mmHg	2,278 (90.1)	576 (94.0)	*
BMI (kg/m ²)			
BMI > 25 kg/m ²	2,792 (73.1)	1,412 (62.5)	**
Current or ex-smoker	465 (11.3)	464 (17.6)	**
Alcohol > 14 units/week	29 (0.70)	26 (1.0)	$P > 0.05$
Prescribed treatments			
NSAIDs	991 (24.0)	780 (29.4)	**

Table 1 (continued)

Variables	CKD and HT	CKD without acknowl- edged hypertension	<i>p</i> -value
	N (Col %)	N (Col %)	
COXIBs	16 (0.4)	12 (0.5)	<i>P</i> > 0.05
ACEIs/ARBs	2,945 (71.3)	335 (12.6)	**
Beta-blockers	1,562 (37.8)	319 (12.0)	**
Calcium channel blockers	2,682 (64.9)	167 (6.2)	**
Diuretics	2,191 (53.0)	145 (5.5)	**
Statins	2,266 (54.9)	618 (23.3)	**

CKD includes both diagnosed and undiagnosed CKD Stage 3–5. Patients with diabetes were excluded
HT hypertension, *CHD* coronary heart disease, *BP* blood pressure, *BMI* body mass index, *NSAIDs* non-steroidal anti-inflammatory drugs, *COXIBs* COX-2 inhibitors, *ACEIs* angiotensin-converting-enzyme inhibitors, *ARBs* angiotensin receptor blockers, *CCBs* calcium channel blockers, *IMD* index of multiple deprivation

**P* < 0.05

***P* < 0.001

Non-diagnosed CKD was defined, in the absence of the previous codes, based on the latest two readings ≥ 90 days apart of eGFR levels < 60 ml/min/1.73m² calculated from serum creatinine using the modified four-variable Modification of Diet in Renal Disease (MDRD) equation adjusted for sex and, when appropriate, Black African or Black-Caribbean ethnicity [4]. We excluded miscoded patients, who after use of the ethnic correction factor had an eGFR > 60 ml/min/1.73m². Hypertensive CKD is defined as individuals with CKD and hypertension.

Identification of hypertension

Individuals were defined as hypertensive if they were included in the hypertension Quality Outcome Framework (QOF) register.

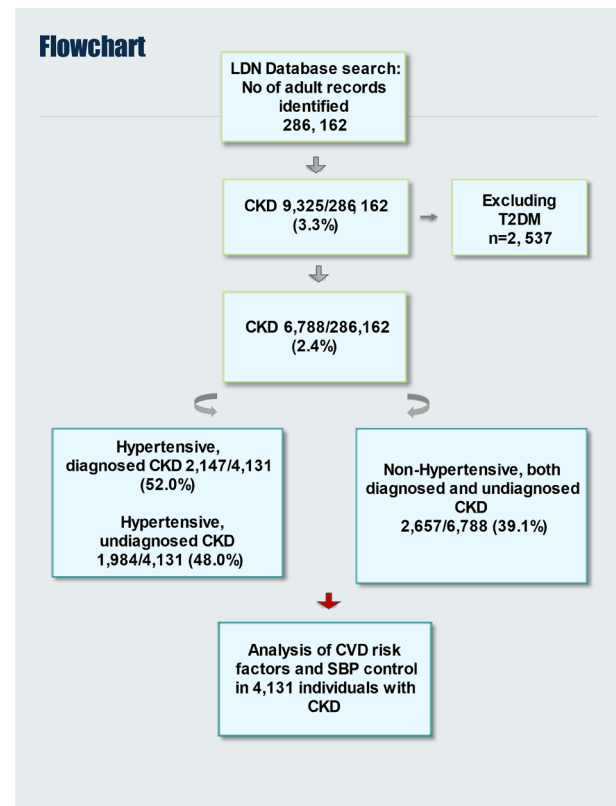
Risk factor management

Risk factor management and CKD prevalence by stage was investigated. Appropriate systolic blood pressure control was defined as below 140/90 based on the mean of the two latest readings, in individuals with CKD, according to NICE guidelines [14]. For patients with urinary albumin creatinine ratio > 70 mg/mmol, BP targets were more stringent, $< 130/80$ mmHg [25]. As we were interested in modifiable lifestyle risk factor management, current smoking status and BMI were included in the analysis.

Covariates

We examined the following factors: age, gender, ethnicity, deprivation (Index of Multiple Deprivation 2015), and selected comorbidities likely to influence SBP control including coronary heart disease (CHD), heart failure (HF),

stroke and serious mental illness, (SMI). Other measured factors were: diastolic blood pressure (DBP) control, prescribed ACEIs or ARBs, calcium channel blockers (CCBs), statins, NSAIDs and COX-2 inhibitors, (COXIBs) and lifestyle factors smoking and obesity. High alcohol intake was defined as > 14 units/week. BMI was determined according



Key *CKD= CKD Stage 3-5

Fig. 1 Patient data selection process

Table 2 Risk factor management in patients with hypertension and CKD (both diagnosed and undiagnosed), according to age

	CKD3 n (%)	CKD 4 n (%)	CKD 5 n (%)
Mean SBP control (< 140 mmHg)			
Age < 75 years	783 (51.4)	39 (49.4)	84 (90.3)
Age ≥ 75 years	739 (48.6)	40 (50.6)	9 (9.7)
	P > 0.05	P > 0.05	P > 0.05
Mean DBP control (< 90 mmHg)			
Age < 75 years	1,070 (47.0)	50 (45.0)	103 (86.6)
Age ≥ 75 years	1,208 (53.0)	61 (55.0)	16 (13.4)
	**	*	P > 0.05
Smoker (current)			
Age < 75 years	301 (64.7)	18 (66.7)	31 (96.9)
Age ≥ 75 years	164 (35.3)	9 (33.3)	1 (3.1)
	**	*	P > 0.05
Statin prescription			
Age < 75 years	986 (43.5)	43 (40.2)	115 (88.5)
Age ≥ 75 years	1,280 (56.5)	64 (59.8)	15 (11.5)
	**	*	P > 0.05
ACEI or ARB prescription			
Age < 75 years	1,456 (49.4)	70 (50.7)	135 (88.8)
Age ≥ 75 years	1,489 (50.6)	68 (49.3)	17 (11.2)
	P > 0.05	P > 0.05	P > 0.05
Calcium channel blocker pre- scription			
Age < 75 years	1,435 (53.5)	74 (52.1)	134 (86.4)
Age ≥ 75 years	1,247 (46.5)	68 (47.9)	21 (13.6)
	**	P > 0.05	P > 0.05
Overweight and obese (BMI ≥ 25 kg/m ²)			
Age < 75 years	1,543 (55.3)	54 (50.5)	103 (85.8)
Age ≥ 75 years	1,249 (44.7)	53 (49.5)	17 (14.2)
	**	P > 0.05	P > 0.05

P-values comparing age < 75 years and ≥ 75 years in each category (column totals by age-group), respectively

HT hypertension, CKD chronic kidney disease, SBP systolic blood pressure, DBP diastolic blood pressure, BMI body mass index, ACEI angiotensin-converting-enzyme inhibitor use, ARB angiotensin receptor blocker use, CCB calcium channel blocker use

*P < 0.05

**P < 0.001

to the World Health Organization (WHO) classification [26]. Ethnicity was self-reported and aggregated into 7 categories: White, African, Black Caribbean, South Asian, Chinese, Other, and Non-stated. Proteinuria measurements were incomplete and therefore were not included.

The primary outcome was systolic blood pressure control; the secondary outcome was CVD risk factor control in patients with CKD.

Analysis

A cross-sectional study design was used to describe demographic factors, comorbidities, and other interventions considered as being potentially effective (prescribing of statins, ACEI or ARBs) associated with hypertension status. Analysis was stratified by CKD Stage. Differences between categorical variables were assessed using Pearson's chi-squared test (χ^2) (Tables 1 and 2, Table S2, and Table S3). A two-sided p value < 0.05 was considered statistically significant.

Partially adjusted (adjusted for age-group and gender) and fully adjusted (adjusted for age-group, gender, and all other covariates are included in Table 3) logistic regression was conducted to examine the association between systolic blood pressure control in hypertensive CKD patients with demographic factors, selected comorbidities and treatments recommended by the NICE guidelines for cardiovascular risk management in CKD patients (Table 3 and Table S4). A two-sided p value < 0.05 was considered statistically significant.

We excluded anti-hypertensive pharmacotherapy from the logistic regression approach due to ethnicity-guided prescribing, as we had already adjusted for ethnicity. The analysis adjusted for demographic and life-style factors and comorbidities in the final model. All analyses were conducted using STATA 15.

Results

Descriptive characteristics of the study population

Figure 1 shows the flowchart of how patient were selected. The population consisted of 286,162 adults followed in 47/49 GP practices in Lambeth 4131 patients out of 286,162 individuals (1.4%) had CKD (both diagnosed and undiagnosed) and hypertension, nearly half of them (48%, $n = 1984$) had undiagnosed CKD, as defined by eGFR < 60 ml/min in at least two determinations, without a recorded CKD diagnosis. Figure S1 illustrates the prevalence of CKD in the different age groups in individuals with concurrent hypertension. Figure S2 shows the relationship between age and CKD and hypertension, whose prevalence is rising steeply after 60 years.

CVD risk factors and comorbidities (Tables 1, 2)

The majority of individuals with CKD were aged > 75 years. Achievement of systolic blood pressure targets was sub-optimal (60.2% vs. 77.0%), both in patients with hypertensive without acknowledged and coded hypertension.

Table S3 shows CKD Stage and measured eGFR according to demographic variables. The prevalence of hypertensive CKD in stage 3 was higher in females than males

Table 3 Multivariable regression (MVR) Associations with Mean SBP control in Hypertensive CKD (non-diabetic) adults

	Univariable OR ¹ , 95% CI	Multivariable OR ² , 95% CI
Age (years)		
< 50	Ref.	Ref.
50–59	1.31 (0.96–1.77)	1.03 (0.65–1.62)
60–69	1.25 (0.94–1.68)	0.48 (0.31–0.76)**
70–79	1.14 (0.88–1.50)	0.41 (0.26–0.62)**
80–89	0.96 (0.73–1.26)	0.29 (0.19–0.45) **
> 90	1.05 (0.74–1.51)	0.34 (0.20–0.58)**
Gender (male)	1.06 (0.94–1.21)	0.99 (0.82–1.20)
IMD quintile		
1.00 least deprived	Ref.	Ref.
2.00	0.93 (0.78–1.12)	0.96 (0.73–1.27)
3.00	1.00 (0.82–1.23)	0.93 (0.69–1.25)
4.00	0.99 (0.81–1.20)	0.97 (0.73–1.30)
5.00 most deprived	1.00 (0.82–1.21)	0.93 (0.69–1.23)
Ethnicity		
White	Ref.	Ref.
Black African	0.80 (0.65–0.97)	0.74 (0.55–0.99)*
Black Caribbean	0.82 (0.70–0.96)	1.03 (0.81–1.30)
Asian	1.04 (0.79–1.36)	1.29 (0.81–2.04)
Chinese	0.72 (0.36–1.44)	0.82 (0.29–2.34)
Other	1.78 (1.03–3.07)	1.10 (0.54–2.25)
Non-stated	1.06 (0.67–1.67)	1.28 (0.70–2.36)
Lifestyle and risk factors		
DBP control	12.45 (9.04–17.15)	12.81 (8.52–19.26)**
Coded CKD3-5	1.11 (0.97–1.26)	1.37 (1.13–1.65)**
BMI > 25 kg/m ²	0.81 (0.69–0.95)	0.80 (0.65–1.00)*
Current smoker	0.91 (0.74–1.12)	0.77 (0.57–1.04)
Alcohol > 14units/week	0.63 (0.30–1.32)	1.64 (0.52–5.22)
History of comorbidities		
Stroke	1.06 (0.86–1.32)	1.08 (0.78–1.51)
Heart failure	1.53 (1.23–1.89)	1.94 (1.38–2.74)**
CHD	1.33 (1.12–1.58)	1.35 (1.03–1.77)*
SMI	1.64 (1.15–2.32)	2.06 (1.18–3.61)*

CKD includes both diagnosed and undiagnosed CKD Stage 3–5

SMI serious mental illness, *CHD* coronary heart disease, *IMD* index of multiple deprivation, *BMI* body mass index, *CKD* chronic kidney disease, *DBP* diastolic blood pressure, *SBP* systolic blood pressure

*P < 0.05

**P < 0.001

¹Adjusted for age and gender

²Adjusted for all baseline covariates in the table

(16.1% vs 12.9%, $p < 0.001$), but prevalence of hypertensive CKD in stage 5 was higher in males than females (1.2% vs 0.6%, $p < 0.001$.)

BP control

The proportion of patients who achieved the SBP target was similar in patients younger or older than 75 years (61.3% versus 59.1%). Achievement of the systolic blood

pressure target (< 140 mmHg) was lower in CKD 3–5 in patients of Black African ethnicity compared with patients of White ethnicity (55.7% and 60.5%, respectively, $p = 0.02$), but was not different when compared with Black Caribbean patients (58.8%, $p = 0.5$) (Table S2).

Pharmacotherapy

Three hundred nine/4,131 (7.4%) individuals with diagnosed HT and CKD were not taking any of the anti-hypertensive medications considered in our study. Statins were under-prescribed, and this was more marked in hypertensive vs. non hypertensive CKD patients, receiving statins respectively in 54.9% vs 23.3% of the cases ($P < 0.001$) (Table 1), the gap was especially important for patients under 75 years (47.8 vs 62.0%, $p < 0.001$).

Logistic regression

Multivariable logistic regression analyses of factors associated with systolic blood pressure control are shown in Table 3. The multivariable logistic regression analyses revealed the following significant associations with SBP control: diastolic blood pressure control (adjusted odds ratio 12.81 (95% CI: 8.52–19.26)) and the following comorbidities: heart failure (OR 1.94), coronary heart disease (OR 1.35), serious mental illness (OR 2.06). Conversely, diagnostic CKD coding was associated with improved SBP control. Factors associated with poor systolic blood pressure control were age ≥ 60 years and Black African ethnicity.

Discussion

The first important finding in this large cohort of patients followed up in 47 GP practices in Lambeth SE London is the high prevalence of both underdiagnosed CKD (nearly 50%) and underdiagnosed hypertension (23%) in patients with CKD. Furthermore, systolic blood pressure control was below target in a relevant percentage of cases. Multivariable logistic regression revealed that factors associated with improved systolic blood pressure control in CKD included diastolic blood pressure control, and the presence of comorbidities that are probably associated with a more strict patient control; these include serious mental illness, history of cardiovascular co-morbidities, CKD diagnostic coding, and age < 60 years. African ethnicity and obesity were conversely associated with poorer systolic blood pressure control. The finding of a better blood pressure control in patients with serious mental illness is important as this group is at increased risk of cardiovascular mortality [27].

This is a study of a well characterized ethnically and socially diverse population in 47 GP practices in Lambeth SE London, with extensive recording of clinical data, medication, and patients' characteristics. Our large database allowed us to undertake a detailed exploration of risks in individuals with CKD and hypertension, sorting them by ethnicity, and adding important information on CKD

prevalence and management in Black African and Black Caribbean sub-groups.

The study has however several limitations and these limitations are mostly shared by observational real life studies; these include diagnostic misclassifications, lack of data on medication adherence and patients' choices, missing data (e.g., proteinuria) and unmeasured confounders. We tried to correct some misclassifications by revising CKD codes, using MDRD ethnicity-adjusted eGFR values. Furthermore, blood pressure readings were based on the mean of the last two recorded measurements after CKD diagnosis, and BP trajectories may provide better longer-term estimates of BP control in future studies. Currently, smoking cessation services are provided by an external provider, and are poorly coded in our database, and so this information was not included in this study.

Although prescriptions were well captured, we did not have estimates of adherence to the prescribed treatments, which may be modulated by ethnicity and CKD status. Lastly, we were also unable to look at longitudinal outcomes, including morbidity and mortality and start of renal replacement therapy.

We found that the overall prevalence of CKD ≥ 3 (both diagnosed and undiagnosed) amongst adults was 3.3%, which is lower than the national average of 4.3% [9]. As the Lambeth population is much younger; data from Lambeth DataNet suggests 45% of the Lambeth population are aged between 18 and 39 years old, differences in population demographics and/or CKD prevalence in different ethnic groups are likely to explain this variation [28]. However, we also noted CKD is underdiagnosed in general practice, similar to national findings in England [9]. Due to the high prevalence of hypertension-related kidney diseases, we would expect most individuals with CKD to have previously diagnosed hypertension. Our study found that in our non-diabetic CKD cohort 4131 individuals out of 6788 cases with CKD (61.9%) had been diagnosed with hypertension. Of 3142 cases with sufficient BP readings, 1994 (63.5%) reached their systolic blood pressure target (Table 1). However, we found that 23% of CKD patients not recorded as with hypertension had mean systolic blood pressure > 140 mmHg, and, importantly, the prevalence of diagnosed heart failure in this group was 3.7%, clinically relevant, even if lower than the prevalence of 8.3% found in CKD patients recorded as hypertensive ($P < 0.05$).

Obesity and poor blood pressure control are key risk factors for CKD development [22, 23]. However, differences in CKD prevalence by stage and progression cannot be attributed to BP control alone, and disease progression is likely to be multifactorial. Blood pressure remains one of the key determinants of progression, even if not the only one, and our study shows that current BP targets are not being met in a large proportion of the patients. This observation is of

clinical importance, considering also that large studies, like SPRINT [29] and ACCORD-BP [30] suggested that even lower BP targets should be adopted [31]. The STOP ACEI trial, which completed recruiting in 2019, will probably identify whether the use of ACEIs and ARBs is beneficial in Stage 4 and 5 CKD, allowing us modulating these treatments in our population [32]. The NICE guidelines recommend an extensive use of statins in CKD for the prevention of cardiovascular diseases and suggest seeking specialist advice before increasing statin doses in patients with eGFR at or lower than 30 mL/min/1.73 m² [14]. The latest KDIGO guideline does not recommend initiation of statins in CKD 5 patients on dialysis (following SHARP and 4-D trials) [33], although this may change in future. Even with these caveats, the use of statins was relatively low in our population, thus suggesting that there may be room for improvement in this regard.

Raising awareness of the importance of risk factor management in primary care includes more rigorous management of systolic blood pressure, together with a series of potentially beneficial actions on CKD progression, including smoking cessation, which however was not analysed in our study, and correction of overweight and obesity tailoring pharmacotherapy (statins, ACEI/ARB) is also an important tool to prevent CKD development and slow progression. Public health strategies, and education about CKD are important to minimise preventable morbidity and mortality [34]. Subsequently, improved coding linked to eGFR and proteinuria (no longer incentivised in QOF) may offer opportunities for improving data standards, overall supporting better care [35].

Conclusions

The main result of this study was to find a high prevalence of underdiagnosed CKD and underdiagnosed hypertension in patients with CKD. In CKD patients with hypertension, poorly controlled blood pressure may contribute to CKD progression and increase the risk of heart failure. Our study shows that there is an unmet need to improve CKD detection and management (relative underdiagnosis of CKD Stage 3) in high-risk groups (<75 years, Black African, Asian, and “Other” ethnic groups). In our study, management of modifiable risk factors was found to be sub-optimal, particularly in younger patients. This applies also to pharmacotherapy (anti-hypertensives, ACEIs/ARBs, statins), which was found to be under prescribed. Improving risk factor management and establishing public health educational strategies should be a priority, as these interventions may help prevent CKD diagnosis or delay disease progression.

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Author contributions MM and DN contributed to the idea generation and protocol development. EMC and SD prepared the data for analysis, EMC and MM performed the statistical analyses. EMC and MM interpreted study results, EMC and MM had primary responsibility in writing the manuscript. MA, DN, EA and CS also contributed to manuscript writing. All authors critically reviewed the manuscript.

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Declarations

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

Ethical statement Ethical approval for LDN was provided by The Lambeth DataNet Steering Group, a sub-group of Lambeth CCG. Information Governance (IG) was approved by the IG team at the Commissioning Support Unit and Lambeth CCG's Caldicott Guardian.

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References

1. Levey AS, Coresh J (2012) Chronic kidney disease. *The Lancet* 379:165–180. [https://doi.org/10.1016/S0140-6736\(11\)60178-5](https://doi.org/10.1016/S0140-6736(11)60178-5)
2. Webster AC, Nagler EV, Morton RL, Masson P (2017) Chronic Kidney Disease. *The Lancet* 389:1238–1252. [https://doi.org/10.1016/S0140-6736\(16\)32064-5](https://doi.org/10.1016/S0140-6736(16)32064-5)
3. Gansevoort RT (2019) Too much nephrology? The CKD epidemic is real and concerning. A PRO view. *Nephrol Dial Transplant* 34:577–580. <https://doi.org/10.1093/ndt/gfy330>
4. Public Health England (2014) Chronic Kidney Disease (CKD) prevalence model. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/612303/ChronicKidneyDiseaseCKDprevalencemodelbriefing.pdf
5. Nguyen NTQ, Cockwell P, Maxwell AP et al (2018) Chronic kidney disease, health-related quality of life and their associated economic burden among a nationally representative sample of

- community dwelling adults in England. *PLoS ONE* 13:e0207960. <https://doi.org/10.1371/journal.pone.0207960>
6. NHS (2021) NHS Digital Quality and Outcomes Framework (QOF), enhanced services and core contract extraction specifications (business rules). In: NHS Digit. <https://digital.nhs.uk/data-and-information/data-collections-and-data-sets/data-collections/quality-and-outcomes-framework-qof>. Accessed 23 Apr 2021
 7. Fat LN, Mindell J, Roderick P (2017) Health Survey for England 2016 Kidney and liver disease
 8. Nichols GA, Déruaz-Luyet A, Hauske SJ, Brodovicz KG (2018) The association between estimated glomerular filtration rate, albuminuria, and risk of cardiovascular hospitalizations and all-cause mortality among patients with type 2 diabetes. *J Diabetes Complications* 32:291–297. <https://doi.org/10.1016/j.jdiacomp.2017.12.003>
 9. Nitsch D, Caplin B, Hull S, Wheeler D (2017) National Chronic Kidney Disease Audit: National Report (Part 1)
 10. Hull S, Dreyer G, Badrick E et al (2011) The relationship of ethnicity to the prevalence and management of hypertension and associated chronic kidney disease. *BMC Nephrol* 12:41. <https://doi.org/10.1186/1471-2369-12-41>
 11. Martins D, Agodoa L, Norris KC (2012) Hypertensive chronic kidney disease in African Americans: strategies for improving care. *Cleve Clin J Med* 79:726–734. <https://doi.org/10.3949/ccjm.79a.11109>
 12. Hanratty R, Chonchol M, Miriam Dickinson L et al (2010) Incident chronic kidney disease and the rate of kidney function decline in individuals with hypertension. *Nephrol Dial Transplant* 25:801–807. <https://doi.org/10.1093/ndt/gfp534>
 13. Kawar B, Kossi ME, Patel R, et al (2009) Practical approaches to the diagnosis and management of common nephrological problems. In: El Nahas (ed) *Chronic Kidney Disease: A practical guide to understanding and management*. Oxford University Press
 14. NICE (2020) Chronic kidney disease. <https://cks.nice.org.uk/topics/chronic-kidney-disease/>. Accessed 23 Apr 2021
 15. Fraser SD, Roderick PJ, McIntyre NJ et al (2013) Suboptimal blood pressure control in chronic kidney disease stage 3: baseline data from a cohort study in primary care. *BMC Fam Pract* 14:88. <https://doi.org/10.1186/1471-2296-14-88>
 16. Hemmelgarn BR, Manns BJ, Lloyd A et al (2010) Relation between kidney function, proteinuria, and adverse outcomes. *JAMA* 303:423–429. <https://doi.org/10.1001/jama.2010.39>
 17. Hallan SI, Ritz E, Lydersen S et al (2009) Combining GFR and Albuminuria to Classify CKD Improves Prediction of ESRD. *J Am Soc Nephrol* 20:1069–1077. <https://doi.org/10.1681/ASN.2008070730>
 18. Lopez-Giacoman S, Madero M (2015) Biomarkers in chronic kidney disease, from kidney function to kidney damage. *World J Nephrol* 4:57–73. <https://doi.org/10.5527/wjn.v4.i1.57>
 19. Bell EK, Gao L, Judd S et al (2012) Blood Pressure Indexes and End-Stage Renal Disease Risk in Adults With Chronic Kidney Disease. *Am J Hypertens* 25:789–796. <https://doi.org/10.1038/ajh.2012.48>
 20. Klag MJ, Whelton PK, Randall BL et al (1996) Blood pressure and end-stage renal disease in men. *N Engl J Med* 334:13–18. <https://doi.org/10.1056/NEJM199601043340103>
 21. Young JH, Klag MJ, Muntner P et al (2002) Blood Pressure and Decline in Kidney Function: Findings from the Systolic Hypertension in the Elderly Program (SHEP). *J Am Soc Nephrol* 13:2776–2782. <https://doi.org/10.1097/01.ASN.0000031805.09178.37>
 22. Chang AR, Grams ME, Ballew SH et al (2019) Adiposity and risk of decline in glomerular filtration rate: meta-analysis of individual participant data in a global consortium. *BMJ*. <https://doi.org/10.1136/bmj.k5301>
 23. Tsai W-C, Wu H-Y, Peng Y-S et al (2016) Risk factors for development and progression of chronic kidney disease. *Medicine*. <https://doi.org/10.1097/MD.0000000000003013>
 24. Klimontov VV, Korbut AI (2019) Albuminuric and non-albuminuric patterns of chronic kidney disease in type 2 diabetes. *Diabetes Metab Syndr Clin Res Rev* 13:474–479. <https://doi.org/10.1016/j.dsx.2018.11.014>
 25. NICE (2015) Chronic kidney disease in adults: assessment and management. Clinical guidelines [CG182]. <https://www.nice.org.uk/guidance/cg182/chapter/1-Recommendations>. Accessed 23 Apr 2021
 26. WHO (2021) Body mass index—BMI. <https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi>. Accessed 23 Apr 2021
 27. Correll CU, Solmi M, Veronese N et al (2017) Prevalence, incidence and mortality from cardiovascular disease in patients with pooled and specific severe mental illness: a large-scale meta-analysis of 3,211,768 patients and 113,383,368 controls. *World Psychiatry* 16:163–180. <https://doi.org/10.1002/wps.20420>
 28. Kim LG, Cleary F, Wheeler DC et al (2018) How do primary care doctors in England and Wales code and manage people with chronic kidney disease? Results from the National Chronic Kidney Disease Audit. *Nephrol Dial Transplant* 33:1373–1379. <https://doi.org/10.1093/ndt/gfx280>
 29. Ambrosius WT, Sink KM, Foy CG et al (2014) The design and rationale of a multicenter clinical trial comparing two strategies for control of systolic blood pressure: the Systolic Blood Pressure Intervention Trial (SPRINT). *Clin Trials Lond Engl* 11:532–546. <https://doi.org/10.1177/1740774514537404>
 30. Papademetriou V, Zaheer M, Doumas M et al (2016) Cardiovascular outcomes in action to control cardiovascular risk in diabetes: impact of blood pressure level and presence of kidney disease. *Am J Nephrol* 43:271–280. <https://doi.org/10.1159/000446122>
 31. Collard D, Brouwer TF, Olde Engberink RHG et al (2020) Initial Estimated Glomerular Filtration Rate Decline and Long-Term Renal Function During Intensive Antihypertensive Therapy. *Hypertens Dallas Tex* 75:1205–1212. <https://doi.org/10.1161/HYPERTENSIONAHA.119.14659>
 32. Bhandari S, Ives N, Brettell EA et al (2016) Multicentre randomized controlled trial of angiotensin-converting enzyme inhibitor/angiotensin receptor blocker withdrawal in advanced renal disease: the STOP-ACEi trial. *Nephrol Dial Transplant* 31:255–261. <https://doi.org/10.1093/ndt/gfv346>
 33. KDIGO (2013) Lipids in CKD. <https://kdigo.org/guidelines/lipids-in-ckd/>. Accessed 23 Apr 2021
 34. Carrero JJ, Hecking M, Chesnaye NC, Jager KJ (2018) Sex and gender disparities in the epidemiology and outcomes of chronic kidney disease. *Nat Rev Nephrol* 14:151–164. <https://doi.org/10.1038/nrneph.2017.181>
 35. Hull SA, Rajabzadeh V, Thomas N et al (2019) Improving coding and primary care management for patients with chronic kidney disease: an observational controlled study in East London. *Br J Gen Pract* 69:e454–e461. <https://doi.org/10.3399/bjgp19X704105>

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