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ORIGINAL ARTICLE

Influence of doctors' perception on the diagnostic status of chronic kidney disease: results from 976 409 individuals with electronic health records in China

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ABSTRACT

Background. The diagnostic status of chronic kidney disease (CKD) and its underlying reasons provide evidence that can improve CKD management. However, the situation in developing countries remains under-investigated.

Methods. Adults with electronic health records (EHRs; 2008–19) in Yinzhou, China were included. The gold standard for CKD was defined as having persistently reduced estimated glomerular filtration rate (eGFR), albuminuria/proteinuria, haematuria or a history of CKD. CKD stages (G1–G5) were defined by eGFR. Clinical diagnosis of CKD in the real world setting was evaluated using International Classification of Diseases (ICD)-10 codes related to primary cause or stages of CKD. The specialty of doctors who administered the serum creatinine (SCr) tests and who made the primary-cause/CKD-staging diagnoses was analysed. The accuracy of CKD-staging codes was assessed.

Results. Altogether, 85 519 CKD patients were identified from 976 409 individuals with EHRs. Of them, 10 287 (12.0%) having persistent urinary abnormalities or labelled with CKD-related ICD codes did not receive SCr tests within 12 months before or after the urine tests. Among 75 147 patients who received SCr tests, 46 150 (61.4%) missed any CKD-related codes, 6857 (35.7%) were merely labelled with primary-cause codes, and only 2140 (2.9%) were labelled with CKD-staging codes. The majority of CKD patients (51.6–91.1%) received SCr tests from non-nephrologists, whereas CKD-staging diagnoses were mainly from nephrologists (52.3–64.8%). Only 3 of 42 general hospitals had nephrologists. The CKD-staging codes had high specificity (>99.0%) but low sensitivity (G3–G4: <10.0%).

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Conclusions. Under-perception of CKD among doctors, rather than unsatisfactory health-seeking behaviour or low detection rates, was the main cause of under-diagnosis of CKD in China. Intensification of CKD education among doctors with different specialties might bring about immediate effective improvement in the diagnosis and awareness of CKD.

Keywords: chronic kidney disease, diagnostic status, doctors' perception, electronic health record, ICD-10 code

INTRODUCTION

Chronic kidney disease (CKD) is a global public health burden because of its high prevalence, low awareness, multiple comorbidities and substantial economic burdens [1–3]. The Global Burden of Diseases study [4] estimated that CKD would be the fifth cause of mortality in 2040. Timely and accurate diagnosis improves not only the awareness of CKD but also the initiation of the long-term integrated management resulting in a better outcome of CKD [5–7]. However, previous studies reported the under-diagnosis of CKD in developed countries [8–11]. The low detection rate of CKD-related tests and a shortage of medical resources were considered as the main causes of under-diagnosis of CKD [2, 10, 12]. Regarding the utilization of healthcare services, the asymptomatic nature of early stages of CKD hinders patients' motivation to seek healthcare services and the limited health literacy of patients is associated with less efficient use of the service, which together aggravate the low rates of detection and diagnosis of CKD [13–15]. Hence, population-based screening of CKD, patient education and an increase in financial support were recommended to improve the early diagnosis of CKD [2, 3, 16]. However, the feasibility and effectiveness of these strategies in developing countries might be influenced by the disparity of socioeconomic and medical development [3]. Therefore, individualized solutions, which could be modified according to the current diagnostic status and underlying reasons in the less developed regions, were needed. However, the diagnostic status of CKD in developing countries, such as China, which is facing great challenges because of its large population, ageing society and unique socioeconomic status [17], remains unclear.

As to the diagnosis of CKD, the US-based Kidney Disease Outcomes Quality Initiative group proposed the CKD staging system in 2002, which classifies CKD into five stages (G1–G5) from normal to kidney failure according to the levels of estimated glomerular filtration rate (eGFR) [18]. CKD is the cause and consequence of multiple diseases [5, 18, 19]. Hence, the Kidney Disease: Improving Global Outcomes (KDIGO) clinical guidelines for CKD (2012) further developed the staging system into cause, GFR and albuminuria to stress the integrated management of CKD, including primary-cause treatment, kidney function preservation and prognosis prediction [5]. This generated a unique insight into CKD diagnosis, extended the traditional cause- or classification-based diagnosis of kidney disease and emphasized the importance of CKD diagnosis as an independent clinical manifestation.

The International Classification of Diseases-10 (ICD-10) had coded CKD G1–G5 as N18.1 to N18.5, respectively [20]—a notable action to promote the concept of CKD and the staging system into clinical diagnosis [20]. In China, ICD-10 codes have been widely used in healthcare systems. The utilization of primary-cause and CKD-staging-related ICD codes in the real world setting could, respectively, represent the traditional cause-based diagnosis of kidney disease and the specific diagnosis of CKD in daily clinical practice. Based on the laboratory results extracted from electronic health records (EHRs), gold standard for CKD in accordance with the KDIGO-CKD clinical guidelines could be adopted to recognize the patient with CKD. Therefore, this study investigated the diagnostic status of CKD and its underlying reasons in China by evaluating the utilization of CKD-related ICD codes based on 976 409 individuals with EHRs, which span across 758 health and medical institutes during a time period of 11 years in Yinzhou, Zhejiang, China.

MATERIALS AND METHODS

Data source and pre-processing

The process of this study is summarized in Figure 1. This study was conducted based on the Regional Health Information System (RHIS) in Yinzhou. Yinzhou is a district of Ningbo City, Zhejiang Province in China, located 230 km south of Shanghai. By the end of 2019, Yinzhou had a population of 1.42 million, 98% of which has been registered in the RHIS. An EHR in RHIS is the personal health profile including data from the population census and registered health insurance database, health checks database, disease surveillance and management database, outpatients/inpatient electronic medical records (EMRs) database, and charge and claims database. An EMR is the personal medical profile including medical records, laboratory results, imaging results and costs data in clinical institutes [21]. Detailed description of the RHIS has been published elsewhere [21, 22].

Individuals aged ≥18 years and having EMRs in any medical institute from 1 May 2008 to 31 December 2019 were included as candidates in this study. To select eligible candidates, a unique code for each individual was generated according to the person's ID number, name, gender and date of birth. Using the unique code, data de-duplication and linkage were performed to integrate the EHRs and EMRs of each individual together. After de-duplication, 1 028 254 individuals with EHRs and 10 981 723 individuals with EMRs were extracted, respectively. After data linkage, 976 409 individuals aged ≥18 years with intersecting EHRs were included as candidates in the following analyses (Figure 1).

Focussing on the target population of 976 409 candidates, the following data were extracted from their intersecting EHRs: (i) general demographic data; (ii) medical records containing diagnoses and specialty of doctors; and (iii) urine tests and serum creatinine (SCr) tests. Patients identified as having CKD (described below) but missing diagnosis records or ICD codes within 12 months before or after the CKD-related tests were ultimately excluded (Figure 1).

This study has been approved by the ethics committee of Peking University First Hospital.

Criteria for CKD and staging

Patients with CKD were identified from the population of 976 409 candidates. In accordance with the KDIGO-CKD clinical guidelines (2012) [5], the criteria for CKD were defined as one or more of the following manifestations persisting for 3 months or longer: (i) eGFR <60 mL/min/1.73 m^2; (ii) albuminuria: urine albumin-to-creatinine ratio ≥30 mg/g or urine albumin excretion

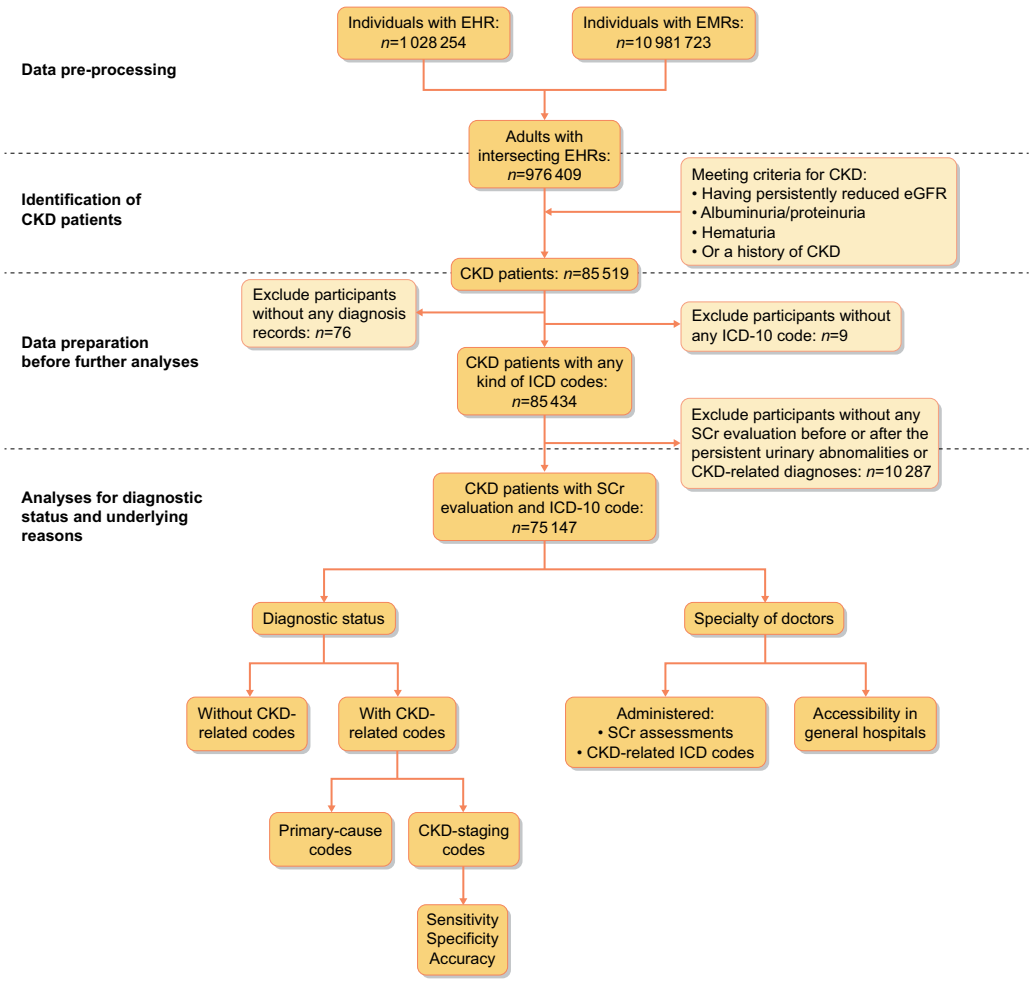

FIGURE 1: Flow chart of this study.

≥30 mg/24 h; (iii) proteinuria: urine protein-to-creatinine ratio ≥150 mg/g, or 24-h proteinuria ≥150 mg/24 h or urinalysis protein ≥+1; (iv) haematuria: urine red blood cell ≥3 cells/high-power field or urine occult blood +2 or more; (v) history of CKD: primary or secondary kidney disease, congenital kidney disease, maintenance dialysis or being recipient or donor of kidney transplantation. The eGFR was calculated using the CKD Epidemiology Collaboration equation [23]. Patients showed solely persistent haematuria (without albuminuria/proteinuria, declined levels of eGFR or CKD-related diagnoses) and had diagnoses of infection, stones, tumour or injury of ureter, bladder or urethra within 2 months before or after the results of haematuria were excluded.

CKD staging was defined as the levels of eGFR in accordance with the KDIGO-CKD clinical guidelines [5]: G1, eGFR ≥90 mL/min/1.73 m^2; G2, 60 ≤ eGFR < 90 mL/min/1.73 m^2; G3, 30 ≤ eGFR < 60 mL/min/1.73 m^2; G4, 15 ≤ eGFR < 30 mL/min/1.73 m^2; G5, eGFR <15 mL/min/1.73 m^2.

Criteria for CKD-related ICD-10 codes

The Chinese edition of ICD-10 was used in this study. In this edition, the ICD-10 codes were extended from four to six digits to localize and adapt the Chinese healthcare system. The diagnostic status of CKD was evaluated by analysing the utilization rates of different CKD-related ICD-10 codes.

Primary-cause codes, which indicate the diagnosis of primary cause of CKD, include primary, secondary or congenital kidney disease, maintenance dialysis and being a recipient or donor of kidney transplantation. Because of the inexact causality between some common primary causes of kidney injury (such as Wegener granulomatosis, Sjögren's syndrome, etc.) and CKD, primary-cause codes were only used to evaluate the quality of CKD diagnosis, instead of the identification of CKD patients. The detailed primary-cause codes and the correspondence between the English and Chinese editions are presented in Supplementary data, Table S1.

CKD-staging codes, which indicate the CKD diagnosis with staging, include: N18.801 CKD, Stage 1 (corresponding to N18.1 in the English edition); N18.802 CKD, Stage 2 (corresponding to N18.2 in the English edition); N18.803 CKD, Stage 3 (corresponding to N18.3 in the English edition); N18.804 CKD, Stage 4 (corresponding to N18.4 in the English edition); and N18.001 CKD, Stage 5 (corresponding to N18.5 in the English edition).

Statistical analysis

Age [mean (standard deviation, SD)], gender (*n*, %), inpatient/outpatient category (*n*, %) and proportions of patients receiving SCr tests before and after the publication of KDIGO-CKD clinical guidelines (*n*, %) were described by each CKD stage. The

utilization rates of primary-cause codes and CKD-staging codes before and after the publication of KDIGO-CKD clinical guidelines were analysed. The specialty of doctors who administered the SCr tests and who made the CKD diagnoses with primary-cause or CKD-staging codes were analysed. Nephrology-related resources in general hospitals, characterized as the accessibility of nephrologists, were analysed. The identification performance of each CKD-staging codes was evaluated in terms of sensitivity, specificity and accuracy using the following formula:

$$\text{Sensitivity} = \frac{\text{True positive}}{\text{True positive} + \text{False negative}} \times 100\%$$

$$\text{Specificity} = \frac{\text{True negative}}{\text{True negative} + \text{False positive}} \times 100\%$$

$$\text{Accuracy} = \frac{\text{True positive} + \text{True negative}}{\text{True positive} + \text{False positive} + \text{True negative} + \text{False negative}} \times 100\%$$

The present computation in the RHIS was based on the Hadoop framework. The computing engine was Spark and the data warehouse was Hive as the support for SQL (The Apache Software Foundation, Wakefield, UK). The accuracy of CKD-staging codes was analysed using MedCalc version 15.8 (MedCalc Software Ltd, Ostend, Belgium).

RESULTS

Characteristics of patients with CKD

Altogether, 85 519 patients with CKD were identified from 976 409 candidates. The prevalence of CKD in Yinzhou was 8.8%. After excluding the patients missing diagnosis records or any ICD codes, 85 434 patients with CKD were ultimately included. Among them, 10 287 (12.0%) patients having persistent proteinuria or haematuria or labelled with CKD-related codes had no SCr tests within 12 months before or after the abnormal urine tests.

Of 75 147 patients who received SCr tests, 85.0% were in early stages (G1 and G2). The age of CKD patients peaked in G3 (G1: 49.0 years; G3: 74.2 years; G5: 62.3 years). Fewer males were observed in this study compared with females (males versus females: 39.6% versus 60.4%). Altogether, 28 967 (38.5%) patients with CKD and showed albuminuria/proteinuria and 32 364 (43.1%) patients showed haematuria. The percentage of patients with albuminuria/proteinuria increased with stages and showed the highest proportion in G5 (545, 68.5%). More outpatients were observed (overall: 47 422; 63.1%) except for patients in G5 (359; 45.2%). The majority of patients with CKD received SCr tests after the publication of KDIGO-CKD clinical guidelines (62 469; 83.1%) (Table 1).

Utilization of CKD-related ICD codes

The utilization rates of CKD-related ICD codes were low, especially the CKD-staging codes. Altogether, 46 150 (61.4%) patients who received SCr tests were not labelled with any CKD-related codes. Patients with CKD in early stages were more likely to miss CKD-related codes (G1 versus G5: 66.9% versus 18.1%) (Table 1).

Among the patients labelled with CKD-related ICD codes, 26 857 (35.7%) patients were merely labelled with primary-cause codes, without CKD-staging codes. This indicates that a number of doctors had the capacity to diagnose the kidney disease, however they were lacking the perception of CKD as an independent manifestation. Only 2140 (2.9%) patients were labelled with CKD-staging codes and 75.0% (1606) of them were also labelled with primary-cause codes. Of the patients in G1, 32.4% had primary-cause codes and 0.8% had CKD-staging codes. Of the patients in G5, 60.0% had primary-cause codes and 21.9% had CKD-staging codes. Altogether, 2125 (99.3%) patients with CKD were labelled with CKD-staging codes after the publication of KDIGO-CKD guidelines (Table 1).

Specialty of doctors who administered SCr tests to patients with CKD

The majority of patients with CKD visited non-nephrologists and received SCr tests from them. Only 8.9% of the patients with CKD in G1 and 11.8% in G2 received SCr tests from nephrologists. Meanwhile, only 11.7% of the patients in G3 and 21.7% in G4, who have an increased risk of adverse outcomes of CKD [5], received SCr tests from nephrologists. More than 50% of the patients in G5 received SCr tests from non-nephrologists (Table 2).

Specialty of doctors who labelled CKD patients with CKD-related ICD codes

Diagnoses labelled with CKD-staging codes were mainly made by nephrologists (52.3–64.8%). Among patients in G1–G4, the diagnoses merely labelled with primary-cause codes were largely made by general internists (46.2–52.3%). This indicates that a number of non-nephrologists had the capacity to diagnose the kidney disease while lacking perception of CKD as an independent manifestation. In addition, 19.9–23.7% of patients in G1–G4 merely labelled with primary-cause codes were diagnosed by nephrologists, indicating the necessity to further intensify CKD education among nephrologists (Table 3).

For patients with CKD in G5 (the end-stage of kidney disease), the primary-cause codes provided by nephrologists were mainly the codes related to uraemia, maintenance dialysis or failed transplantation (131, 68.9%), whereas the primary-cause codes provided by general internists were largely related to primary or secondary cause of CKD (107, 60.4%) (Supplementary data, Table S2).

Nephology-related medical resources

The EHRs of patients with CKD in this study were extracted from 42 general hospitals and 257 community healthcare centres. Among the 42 general hospitals, 40 hospitals had general internists, 37 had obstetricians and gynaecologists, 30 had general surgeons and only 3 hospitals had nephrologists (Figure 2).

Performance of CKD-staging codes

The performance of each CKD-staging codes in identifying patients with CKD was evaluated in terms of sensitivity, specificity and accuracy. All CKD-staging codes had high specificity (>99.0%) but low sensitivity. The codes of CKD G1 (N18.001, corresponding to N18.1 in the English edition) and G2 (N18.002, corresponding to N18.2 in the English edition) had sensitivities of 0.3 and 1.6%, respectively. Although an increasing trend was observed in codes of advanced stages, the sensitivity was still <10.0% even in the progressed stages of G3 and G4 (Table 4).

DISCUSSION

Using EHRs of 976 409 individuals, this study reported the under-diagnosis of CKD in China, illustrated the significant

Table 1. Demographic characteristics of CKD patients and the diagnostic rates using different types of CKD-related ICD codes

Items	Overall	G1	G2	G3	G4	G5
Demographic characteristics						
In total, *n*	75 147	46 287	17 596	9217	1253	794
Age, mean ± SD, years	56.7 ± 17.7	49.0 ± 14.0	66.2 ± 13.6	74.2 ± 12.8	73.8 ± 14.6	62.3 ± 17.7
Gender, *n* (%)						
Male	29 758 (39.6)	15 275 (33.0)	8692 (49.4)	4719 (51.2)	652 (52.0)	426 (53.7)
Female	45 389 (60.4)	31 012 (67.0)	8904 (50.6)	4498 (48.8)	601 (48.0)	368 (46.3)
Populations, *n* (%)						
Outpatient	47 422 (63.1)	30 322 (65.5)	10 560 (60.0)	5468 (59.3)	713 (56.9)	359 (45.2)
Inpatient	27 282 (36.3)	15 592 (33.7)	6975 (39.6)	3470 (37.7)	540 (43.1)	435 (54.8)
Albuminuria/proteinuria, *n* (%)[a]	28 967 (38.5)	17 146 (37.0)	7136 (40.6)	3421 (37.1)	719 (57.4)	545 (68.6)
Haematuria, *n* (%)[b]	32 364 (43.1)	21 851 (47.2)	7456 (42.4)	2324 (25.2)	422 (33.7)	311 (39.2)
Date of SCr test, *n* (%)						
Before KDIGO-CKD (2012) guidelines	12 678 (16.9)	7652 (16.5)	2920 (16.6)	1512 (16.4)	312 (24.9)	282 (35.8)
After KDIGO-CKD (2012) guidelines	62 469 (83.1)	38 635 (83.5)	14 676 (83.4)	7705 (83.6)	941 (75.1)	512 (64.5)
Diagnostic rates						
Labelled with CKD-staging code, *n* (%)[c]	2140 (2.9)	352 (0.8)	599 (3.4)	767 (8.3)	248 (19.8)	174 (21.9)
Date of diagnosis						
Before KDIGO-CKD (2012) guidelines	15 (0.7)	0 (0.0)	4 (0.7)	4 (0.5)	4 (1.6)	3 (1.8)
After KDIGO-CKD (2012) guidelines	2125 (99.3)	352 (100.0)	595 (99.3)	763 (99.5)	244 (98.4)	171 (98.3)
Labelled with primary-cause code, *n* (%)[d]	26 857 (35.7)	14 994 (32.4)	7502 (42.6)	3230 (35.0)	655 (52.3)	476 (60.0)
Date of diagnosis						
Before KDIGO-CKD (2012) guidelines	6300 (23.5)	3379 (22.5)	1664 (22.2)	774 (24.0)	237 (36.2)	246 (51.7)
After KDIGO-CKD (2012) guidelines	20 557 (76.5)	11 615 (77.5)	5838 (77.8)	2456 (76.0)	418 (63.8)	230 (48.3)
No CKD-related code, *n* (%)	46 150 (61.4)	30 941 (66.9)	9495 (54.0)	5220 (56.6)	350 (27.9)	144 (18.1)
Date of diagnosis						
Before KDIGO-CKD (2012) guidelines	6363 (13.8)	4273 (9.3)	1252 (13.2)	734 (14.1)	71 (20.3)	33 (22.9)
After KDIGO-CKD (2012) guidelines	39 787 (86.2)	26 668 (57.8)	8243 (86.8)	4486 (85.9)	279 (79.7)	111 (77.1)

[a]Albuminuria: urine albumin-to-creatinine ratio ≥30 mg/g or urine albumin excretion ≥30 mg/24 h. Proteinuria: urine protein-to-creatinine ratio ≥150 mg/g, or 24-h proteinuria ≥150 mg/24 h or urinalysis protein ≥+1.
[b]Haematuria: urine red blood cell ≥3 cells/high-power field or urine occult blood ≥+2.
[c]CKD-staging code: ICD code of CKD in each stage.
[d]Primary-cause code: ICD code of primary cause of CKD.

influence of doctors' perception on the diagnosis of CKD, and stressed the importance of the CKD education among doctors with different specialties. To our knowledge, it is the first research to report the diagnostic status of CKD and its underlying reasons in China. With the striking development, the allocation of medical resources and people's health-seeking behaviour, the quality of healthcare in China cannot be solely evaluated by the standard of less developed regions as in the past decades. The present results were from the developed area of China and showed the intermediate state of the development of the healthcare system, which was manifested in the imbalance between relatively sufficient medical resources and yet relatively lagging expertise of primary medical staff. As to CKD, urine and kidney function had been widely detected in China, whereas the abnormal results were frequently overlooked. Taking into consideration the high prevalence of CKD and the frequent interaction between non-nephrologists and CKD patients, intensification of education on CKD among doctors, especially among the non-nephrologists, would be promising to bring about immediate effectiveness on improving the awareness and early management of CKD in developing countries such as China.

Shortage of medical resources and limited healthcare-seeking behaviour are generally considered as the major reasons for low awareness and diagnostic rates of CKD, especially in developing countries [1–3, 12]. The studied region, Yinzhou District, Zhejiang Province, is one of the developed areas in China providing annual physical examination for free to residents aged ≥60 years, primary and middle school students, and farmers [24–26]. Shortage of medical resources was not the main cause of under-diagnosis of CKD in the present region. In addition, laboratory results extracted as the criteria for CKD in this study were those administered by the doctors to the patients who visited the clinics and were willing to receive the tests. Therefore, neither patient's healthcare-seeking behaviour nor low detection rates were the causes of under-diagnosis of CKD in this study. According to the current results, 12% of patients having persistent proteinuria or haematuria did not undergo assessment of kidney function within 1 year before or after the abnormal urine tests. Although some patients might be unwilling to receive blood tests, it is hard to explain such a high percentage of absence of SCr tests by patient compliance. Whether doctors overlooked the abnormal urine tests, or they were under-perceptive of the linkage between urine problems and kidney injury, these patients were very likely to miss the early intervention for CKD. Stevens *et al.* [10] and Minutolo *et al.* [9] reported that low detection rates of SCr were correlated to unsatisfactory CKD diagnosis in the USA and Italy. However, the present results found that 60% of patients who received SCr tests had no diagnosis related to CKD. Doctors who administered the SCr tests failed to recognize the abnormal results, resulting in the high misdiagnosis rate of CKD and low sensitivity of CKD-staging codes. The relatively high utilization rates of primary-cause codes indicated that a number of Chinese doctors had the capacity to diagnose kidney disease, while the low usage of CKD-staging codes further demonstrated the lack of

Table 2. Specialty of doctors who administered SCr tests to CKD patients

	G1		G2		G3		G4		G5	
Rank	Specialty	Patients receiving tests, *n* (%)	Specialty	Patients receiving tests, *n* (%)	Specialty	Patients receiving tests, *n* (%)	Specialty	Patients receiving tests, *n* (%)	Specialty	Patients receiving tests, *n* (%)
1	General internist	10 195 (22.0)	General internist	4128 (23.5)	General internist	2147 (23.3)	Nephrologist	272 (21.7)	Nephrologist	384 (48.4)
2	Obstetrician & gynaecologist	6770 (14.6)	Nephrologist	2072 (11.8)	Emergency medicine specialist	1097 (11.9)	General internist	241 (19.2)	General internist	97 (12.2)
3	Nephrologist	4129 (8.9)	Urologist	1964 (11.2)	Nephrologist	1075 (11.7)	Emergency medicine specialist	198 (15.8)	Emergency medicine specialist	67 (8.4)
4	Urologist	3611 (7.8)	Emergency medicine specialist	1297 (7.4)	Urologist	605 (6.6)	Urologist	77 (6.1)	Urologist	55 (6.9)
5	Emergency medicine specialist	3179 (6.9)	General surgeon	661 (3.8)	Cardiologist	550 (6.0)	Cardiologist	64 (5.1)	Endocrinologist	50 (6.3)
Others	Other specialists	18 403 (39.8)	Other specialists	7474 (42.5)	Other specialists	3743 (40.6)	Other specialists	401 (32.0)	Other specialists	141 (17.8)

perception of CKD as a distinguishing manifestation among the doctors.

According to the current results, a large proportion of patients with CKD were cared for by non-nephrologists. Baldwin [27] reported the positive effects of early nephrology referral on the outcome of CKD and emphasized the better expertise of nephrologists on the management of CKD compared with non-nephrologists. van Dipten *et al.* [28] reported that CKD was perceived by general practitioners as an abstraction rather than a detailed clinical manifestation. In this study, the majority of CKD patients, even those in advanced stages such as G3 and G4, visited non-nephrologists, whereas the CKD diagnoses were mainly made by nephrologists. Thus, whether patients with CKD received proper management from non-nephrologists was raised as an issue. Compared with massive nephrology referral, especially among patients in early stages of CKD, intensification of CKD education for non-nephrologists was more likely to be time- and cost-efficient. In addition, it should be noted that only 3 of 42 general hospitals involved in this study had nephrologists, while the nephrologists from these 3 hospitals made the majority of CKD diagnoses in the whole region. The heavy burden of nephrologists remains to be solved. Although the deficiency of the nephrology workforce has been shown to be common in low- to middle-income areas [3], this study found that the cultivation of a nephrology-related workforce in a region with a well-built primary healthcare system and a high-quality health information system was still lagging. Policy makers should expend more efforts on improving CKD education and enhancing the nephrology workforce .

This study has advantages. Clinical data from a population of a million from the real world were analysed. Additionally, this study explored the detailed types of CKD diagnosis, the specialty of doctors who interacted with CKD patients, the accessibility of nephrology-related medical resources and the application of KDIGO-CKD clinical guidelines in China. In summary, this study provides detailed and comprehensive clues for policy-makers and doctors to individually improve the strategy of CKD management in China. It also has significance for other developing countries.

This study has several limitations. First, the CKD diagnoses labelled with ICD codes were made within 12 months before or after the SCr tests. The accuracy of CKD-staging codes might be underestimated. Second, the field survey of detailed CKD perception was not completed because of the observational feature. Third, the prognosis of patients in different diagnostic statuses could not be evaluated in this study because of the lack of follow-up information. This is worth investigating in the future.

CONCLUSION

The under-diagnosis of CKD is substantial in China and the main cause was under-perception of CKD among doctors with different specialties. Policy-makers should pay more attention to CKD. In addition to the financial investment and population-based screening of CKD, strengthening of CKD education among the doctors might be a quickly cost-efficient solution for improving the diagnostic status and awareness of CKD.

SUPPLEMENTARY DATA

Supplementary data are available at ckj online.

Table 3. Specialty of doctors who labelled CKD patients with CKD-staging/primary-cause codes

	G1		G2		G3		G4		G5	
Rank	Specialty	Labelled patients, *n* (%)	Specialty	Labelled patients, *n* (%)	Specialty	Labelled patients, *n* (%)	Specialty	Labelled patients, *n* (%)	Specialty	Labelled patients, *n* (%)
CKD-staging code										
1	**Nephrologist**	**134 (52.3)**	**Nephrologist**	**303 (58.8)**	**Nephrologist**	**458 (63.5)**	**Nephrologist**	**142 (64.8)**	**Nephrologist**	**95 (62.5)**
2	General internist	82 (32.0)	General internist	166 (32.2)	General internist	189 (26.2)	General internist	59 (26.9)	General internist	38 (25.0)
3	Urologist	7 (2.7)	Cardiologist	10 (1.9)	Cardiologist	29 (4.0)	Cardiologist	5 (2.3)	Urologist	7 (4.6)
4	Cardiology	6 (2.3)	Urologist	6 (1.2)	Urologist	6 (0.8)	Urologist	3 (1.4)	General surgeon	2 (1.3)
5	Neurologist	4 (1.6)	Endocrinologist	5 (1.0)	Emergency medicine specialist	4 (0.6)	Haematologist	2 (0.9)	–	–
Others	Other specialists	23 (9.0)	Other specialists	25 (4.9)	Other specialists	35 (4.9)	Other specialists	8 (3.7)	Other specialists	10 (6.6)
Missing	–	96 (23.7)	–	84 (14.0)	–	46 (6.0)	–	29 (11.7)	–	22 (12.6)
Primary-cause code										
1	General internist	7331 (50.9)	General internist	3706 (52.3)	General internist	1410 (46.2)	General internist	287 (46.7)	**Nephrologist**	**190 (42.0)**
2	**Nephrologist**	**2863 (19.9)**	**Nephrologist**	**1393 (19.7)**	**Nephrologist**	**724 (23.7)**	**Nephrologist**	**145 (23.6)**	General internist	177 (39.2)
3	General surgeon	1350 (9.4)	General Surgeon	572 (8.1)	General surgeon	186 (6.1)	General surgeon	30 (4.9)	Emergency medicine specialist	16 (3.5)
4	Urologist	614 (4.3)	Urologist	340 (4.8)	Emergency medicine specialist	113 (3.7)	Emergency medicine specialist	30 (4.9)	Urologist	12 (2.7)
5	Endocrinologist	505 (3.5)	Endocrinologist	180 (2.5)	Urologist	107 (3.5)	Urologist	26 (4.2)	General surgeon	9 (2.0)
Others	Other specialists	1752 (12.2)	Other specialists	894 (12.6)	Other specialists	509 (16.7)	Other specialists	96 (15.6)	Other specialists	48 (10.6)
Missing	–	579 (3.9)	–	417 (5.6)	–	181 (5.6)	–	41 (6.3)	–	24 (5.0)

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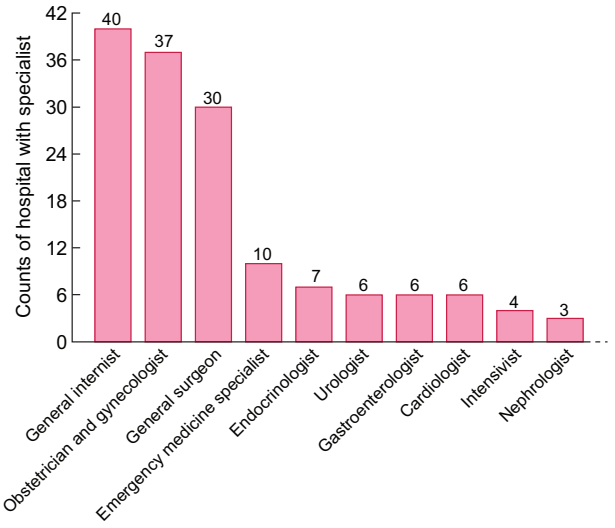

FIGURE 2: Counts of hospitals with the specialists interacting with CKD patients.

CONFLICT OF INTEREST STATEMENT

L.Z. reports grants from AstraZeneca, independent from this study. The remaining authors have no competing financial interests to declare.

DATA AVAILABILITY STATEMENT

The data underlying this article cannot be shared publicly due to privacy protection.

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Table 4. Identification performance of CKD-staging codes

ICD-10 code[a]	N18.801	N18.802	N18.803	N18.804	N18.001
CKD stage	G1	G2	G3	G4	G5
In total, *n*	46 287	17 596	9217	1253	794
Percentage among CKD, %	61.60	23.42	12.27	1.67	1.06
True positive, *n*[b]	120	277	492	106	114
True negative, *n*[c]	232	322	275	142	60
False positive, *n*[d]	28 628	57 229	65 655	73 752	74 293
False negative, *n*[e]	46 167	17 319	8725	1147	680
Sensitivity, %	0.26	1.57	5.34	8.46	14.36
95% CI	0.21–0.31	1.40–1.77	4.89–5.82	6.98–10.14	11.99–16.99
Specificity, %	99.20	99.44	99.58	99.81	99.92
95% CI	99.09–99.30	99.38–99.50	99.53–99.63	99.77–99.84	99.90–99.94
Accuracy, %	38.26	76.52	88.02	98.28	99.02

[a]Correspondence between CKD and stage codes in the Chinese and in the English edition: N18.801 = N18.1; N18.802 = N18.2; N18.803 = N18.3; N18.804 = N18.4; N18.001 = N18.5.
[b]True positive was defined if the patients having the levels of eGFR of each stage of CKD were labelled with the correctly correspondent CKD-stage codes.
[c]True negative was defined if the patients iin whom the levels of eGFR were not in one of stages of CKD were not labelled with the correspondent CKD-stage codes.
[d]False positive was defined if the patients who were labelled with one CKD-stage code showed levels of eGFR of other stages of CKD.
[e]False negative was defined if the patients having the levels of eGFR of a stage of CKD were not labelled with the correctly correspondent CKD-stage codes.

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