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REVIEW

CKD Screening and Surveillance in Australia: Past, Present, and Future

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Chronic kidney disease (CKD) was largely a hidden health problem until the publication of an internationally agreed approach to its identification, monitoring, and treatment. The 2002 National Kidney Foundation CKD classification and the subsequent 2006 Kidney Disease Improving Global Outcomes (KDIGO) recommendations are powerful tools for translating thinking about CKD into clinical practice. These guidelines were strongly endorsed by the international community, including Australia, and were incorporated into CKD practice guidelines. In the past, CKD research studies in Australia focused on screening the general population, and more specifically, individuals at risk for CKD. Information from these studies led to the recognition that the CKD burden in Australia is a public health problem and contributed to the development of national health policies and priorities. At present, apart from the Australia and New Zealand Dialysis and Transplant Registry (ANZDATA) that reports on CKD patients undergoing renal replacement therapy (RRT), long-term surveillance to describe the natural history of the CKD population not on RRT has only recently started. Entities such as CKD. Queensland and the Western Australian Nephrology Database are able to fill the gap and provide opportunities for collaborative research of CKD in Australia. Establishment of a National Health and Medical Research Centre–funded CKD Centre of Excellence in 2015 and the Better Evidence and Translation–Chronic Kidney Disease in 2016 are likely to change the future of CKD surveillance and research in Australia.

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Chronic kidney disease (CKD) is a major international public health problem.[1–3] The burden of CKD varies, and accurate incidence and prevalence rates are not available in many countries. Most of the published literature describes patients on dialysis or extrapolates information from end-stage kidney disease (ESKD) registries.[4–6] The natural history in the nondialysis stages of CKD is not known; it is confounded by over diagnosis of CKD, intercurrent nonrenal death, and stable kidney dysfunction. CKD is a powerful risk factor for all-cause mortality and particularly for cardiovascular (CV) risk, with CV deaths outnumbering the onset of ESKD >10-fold.[7,8]

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In 2002, the American National Kidney Foundation (NKF) published a classification of CKD based on the estimated glomerular filtration rate (eGFR).[9] This was endorsed at the 2004 Kidney Disease Improving Global Outcomes (KDIGO) Controversies Conference on "Definition and Classification of Chronic Kidney Disease."[10] The classification system forms the framework on which we define, diagnose, and manage CKD. It has been translated into a tool and is used by epidemiologists to report CKD as a public health problem internationally. Recently updated CKD classification and management guidelines add precision to the international efforts to tackle this important public health problem.[11]

The 2006 KDIGO CKD Conference addressed the issue of CKD from a public health perspective and strongly recommended all countries should have screening and surveillance programs to identify CKD.[12] Surveillance is the systematic tracking and forecasting of population-level health status, events, outcomes,

risk and/or protective factors, or other determinants through the collection, integration, analysis, and interpretation of data, ideally, together with the timely dissemination of the information to those who need to know it, to inform action.[13,14] The products of such surveillance systems can be used for targeted action. In contrast, screening programs involve populations at risk and produce estimates of prevalence of a particular disease or condition(s). Screening may be included but cannot replace surveillance systems.

In Australia, CKD has been the focus in many, mostly community-based screening programs that involved high-risk cohorts in the past. There has been no specifically targeted national CKD surveillance except for the Australia and New Zealand Dialysis and Transplant Registry (ANZDATA), which only reports on patients on renal replacement therapy (RRT).[6] However, it is evident from studies that CKD is not synonymous with ESKD.[15] This current theme has evolved with the establishment of regional surveillance systems, such as CKD in Queensland (CKD.QLD), the Western Australia Nephrology Database (WAND), and other collaborations.[16,17] More recently, 2 more programs have been established to engage in translational and evidence-based CKD research.[18,19] The National Health and Medical Research Centre (NHMRC) funded CKD Centre of Excellence (CKD.CRE) has several defined streams of CKD research, and the Better Evidence and Translation–Chronic Kidney Disease (BEAT-CKD) aims to improve the lives of people living with CKD in Australia and globally. Here, we review some of the important population-based CKD research performed in Australia and look at where it is heading in the future. These studies can be broadly divided into screening programs and surveillance systems. Studies related to the end-stage renal disease population were excluded from this review.

The Past: Screening Programs

National surveys in the 1980s focused on estimation of prevalence of risk factors associated with CV disease and/or renal disease, but there were no systematic effort to define accurate incidence and prevalence of CKD in Australia.[20] The Australian Diabetes, Obesity and Lifestyle Study (AusDiab) was the first such study to address this issue.[2] Thereafter, many studies were conducted to address CKD-related issues. Collectively, these studies highlighted the burden of CKD in Australia in general and in specific vulnerable populations (e.g., indigenous Australians). Many of these studies were specific to the state and/or province. We reviewed some of the important studies conducted in the past by analyzing their design, merits, and limitations.

The Australian Diabetes, Obesity and Lifestyle Study

As noted, the AusDiab study, which was designed to describe the natural history of diabetes and its complications, was the first to report the public health burden of CKD in Australia.[2] A total of 11,247 Australians older than 25 years of age were recruited using a stratified cluster selection method, with 7 strata (6 states and the Northern Territory [NT]) and cluster ordered by census collector districts. Participants were tested for proteinuria, hematuria, reduced kidney function (Cockcroft-Gault estimate of creatinine clearance: abnormal: <60 ml/min per 1.73 m^2), diabetes, and hypertension. The study reported that 1 in 7 adult Australians had at least 1 of the 3 biomarkers for kidney disease.[3]

The AusDiab study acknowledged its limitations. The identification of CKD was based on either a single measurement or 2 measurements <3 months apart, which resulted in an anticipated overestimation of prevalence from the inclusion of false-positive values or cases of acute kidney injury. The formula used to calculate creatinine clearance was best practice in the era predating the seminal work of the NKF.[21] More precise formulas have been validated in clinical practice in the intervening years.[22,23] The AusDiab study was also vulnerable to problems inherent in any screening study, including selection bias of voluntary participation and possible over representation of people who actively sought out health consultations. It excluded important groups like indigenous Australians and youths aged younger than 25 years. Moreover, the mean age of the study population was 51.5 years and might not represent current patient cohorts seen in CKD clinics, where the mean age is 64.8 years, as reported by the CKD.QLD Registry data.[24] Despite these limitations, the AusDiab study was a watershed study in establishing CKD as a public health problem in Australia.

The AusDiab cohort was re-screened 5 years later to measure the progression of kidney disease in both diabetic and nondiabetic populations.[25] Of the 10,788 participants eligible for testing in 2004 to 2005, 81.6% contributed to the rescreening study results in some form, through physical attendance, blood testing, and/or telephone questionnaire. About 1% of the study cohort who did not have evidence of kidney disease in the initial study had developed CKD each year, as evidenced by the emergence of low GFR (Modification of Diet in Renal Disease [MDRD] formula), albuminuria, and/or hematuria. Of the whole group, 13.4% had CKD when GFR was estimated by the MDRD formula. The prevalence was subsequently adjusted down to 11.5% when the data were re-analyzed using the newer

Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula.[26]

Kidney Evaluation for You Program

The Kidney Evaluation for You (KEY) program was a smaller study with an expanded set of point-of-care biological sampling in 3 targeted diverse Australian communities: a rural mining town, a regional city, and a metropolitan capital city of a state (New South Wales).[27] The community was invited to participate, and those at high risk for CKD with diabetes, hypertension, a first-degree relative with kidney failure, or age older than 50 years were specifically targeted.

The mean age of participants was 58.0 ± 11.1 years; 84% were aged older than 50 years. Biomarkers of kidney damage were detected in 82 of the 402 (20.4%) participants. Of those with evidence of CKD, 69% had hypertension, 30% had diabetes, and 40% had either elevated total cholesterol or were taking cholesterol-lowering medication. More than one-half (58%) were referred to their general practices (GP) because at least 1 abnormality was found in the CKD or CV risk screening.

KEY focused on the complexity of CKD defined by multiple co-existing conditions. It was limited by a small sample size, selection bias generated by the method of recruitment, short follow-up times, and self-reporting of some of the test variables. The study did not include hematuria in the panel of biomarkers of kidney damage. Despite these limitations, the KEY program was successful in proving the concept of point-of-care testing in screening, the logistics of screening in distant communities, detection of unrecognized kidney injury, and discriminating streaming of participants to medical practitioners.

Burden of CKD in Australian Patients With Type 2 Diabetes in GPs

Adults with type 2 diabetes presenting to 348 Australian GPs between April and September 2005 were included in this study.[28] The primary care practices were statistically selected by the stratified cluster method across Australia with expression of interest from GPs stratified in every state by location (urban and rural). Data were collected from 10 to 15 consecutive adults with type 2 diabetes, irrespective of the reason for their presentation.

Of 3893 individuals, 1 in 4 patients with type 2 diabetes who consulted their GPs had low eGFR (MDRD eGFR <60 ml/min per 1.73 m^2) and more than 1 in 3 (34.6%) had albuminuria, with 10.4% of participants having both. Overall, 47.1% of participants had evidence of kidney damage, indicating that CKD was common in patients with type 2 diabetes who consulted their GPs. A substudy found that 55% of type 2 diabetics with low eGFR had no albuminuria.[29] The limitations of this study included selection bias. Despite >80% of the Australian population attending a primary practice each year, important groups at risk for CKD, such as lower socioeconomic groups, remote residents, and Australian Aboriginals, were under-represented.[30]

CKD in Tasmania

Investigators accessed the results of 375,460 adults aged 18 years or older, whose serum creatinine was measured between January 1, 1995 and December 31, 2007 in the data repository of 4 community-based laboratories that serviced most of the population of Tasmania.[31] Demographic information available for the de-identified participants was age, sex, and postcode location. The group was predominantly white, with a median age of 39.0 years. At least 11.4% of women and 8.6% of men had a low eGFR (MDRD <60 ml/min per 1.73 m^2) during 2007, and the prevalence rates increased between 1995 and 2007.

There was significant geographic variation in the prevalence of CKD, with the northwest region showing higher rates. This study also demonstrated increased mortality with low eGFR. Only 9.4% of participants with low eGFR had formal albuminuria testing, which suggested suboptimal profiling for kidney disease. The main strength of the study was the large sample size, with representation of the entire state. However, it was limited by the deficiencies inherent in de-identified demographic data, potential inclusion of the same participants many times, or participants on dialysis or who had an acute kidney injury, and the limitations of the modeling prevalence and mortality based on clinical assumptions.

CV Risk Management in CKD in GP

The AusHEART (The Australian Hypertension and Absolute Risk) study, conducted by Razavian *et al.*, was an attempt to identify CV risk management in CKD patients from GPs.[32] This study was a nationally representative, cluster-stratified, cross-sectional survey among 322 GPs. Each GP was asked to provide data for 15 to 20 consecutive patients (age 55 years or older) who presented between April and June 2008. The main outcome measures were CKD prevalence based on proteinuria and decreased eGFR. GPs were required to complete a 1-page questionnaire on CV risk factors, medical history, including CKD, and currently prescribed CV medication for each eligible consenting patient. Kidney function test data were available for 4966 patients, 1845 (37%) of whom had abnormal kidney function. Only 235 of 1312 patients with abnormal kidney function known to GPs were correctly identified as having CKD. Similar gaps were also found with reference to identification and

management of CV risk in CKD patients. This study provided evidence of high prevalence rates of CKD in GPs in Australia and also highlighted the knowledge gap in identifying CKD and associated CV risk stratification. Some of the weaknesses identified in the study included single point measurement of renal function, urine protein assessment based largely on dipstick analysis, missing renal function data on 6.1% patients, and lack of repeated assessment of blood pressure and other parameters during the study.

Australian Health Survey 2011 to 2013

The Australian Government Department of Health and Aging commissioned the Australian Bureau of Statistics to conduct the most comprehensive study of the health of Australians ever undertaken—the Australian Health Survey (AHS).[33] It collected information from approximately 50,000 adults and children selected from all parts of Australia in a statistically robust method.[34] It differed from previous surveys by including biomedical data derived from collections of blood and urine samples. The National Health Measure Survey measured 2 aspects of kidney function: eGFR and the presence of albuminuria. Based on these 2 measures, it was estimated that from 2011 to 2012, 3.6% or approximately 620,000 people aged 18 years and older had impaired eGFR, with no significant difference between men (3.3%) and women (3.9%). Rates of impaired eGFR were low for people aged younger than 54 years (<1%) but then markedly increased to 29.6% of people aged 75 years and older.[35] Similarly, in 2012 to 2013, almost 1 in 5 (17.9%) Aboriginal and Torres Strait Islander people aged 18 years or older had indicators of CKD, with most in stage 1 (11.8%) with no major difference between men (18.9%) and women (16.9%).[36] Commissioned by Kidney Health Australia (KHA), the Australian Bureau of Statistics team provided customized analyses of estimates and proportions of CKD stages according to predefined medical administrative geographic regions (Medicare Local). This analysis identified CKD hotspots in Australia where the estimated prevalence was higher than the national average.[37] Regrettably, however, indigenous youth (younger than 18 years) were excluded from the biomedical measures component of this survey, which was a loss of a unique opportunity to define early markers of risk and disease in indigenous people in both remote and urban settings.[38]

CKD in the Top End of the Northern Territory of Australia, 2002 to 2011: A Retrospective Cohort Study Using Existing Laboratory Data

This recently published study (2015) estimated the prevalence and rate of progression of measured CKD over a decade using available laboratory data.[39] Similar to the study conducted in Tasmania, this study also used retrospectively de-identified records with serum creatinine or urinary albumin to creatinine ratio (February 2002 to December 2011) from the single largest pathology provider in the NT. The study personnel estimated the yearly total and age-specific prevalence of micro- and macroalbuminuria and eGFR (CKD-EPI equation). It showed that the prevalence of measured moderate to severe CKD (eGFR <60 ml/min per 1.73 m^2) sharply increased with age. Comparisons were also drawn with the Australian National Health Measures Survey. Rates of measured moderate to severe CKD in the age group of 35 to 65 years in the Top End of NT were double the national rates. In contrast, rates of albuminuria were significantly lower than the national averages for all age groups. Similar to the Tasmanian study, this study also had the inherent problems associated with using laboratory-based data to estimate the prevalence of disease. Nevertheless, in the absence of long-term CKD surveillance, these studies provided valuable information for healthcare providers and policymakers to have a measure of the burden of CKD.

CKD Studies in Aboriginal Population

There was an early realization of an excess of kidney disease in Aboriginal and Torres Strait Islanders in Australia.[40] Incidence of end-stage renal disease in the mid-1990s was estimated to be 15 to 30 times that of non-indigenous Australians. In the late 1980s, Tiwi islanders had the highest described rates of renal failure in the world, and an age-adjusted mortality rate 6 times that of residents of Australia's national capital.[41,42] A multitude of pioneering studies followed, in both the Aboriginal and Tiwi island population. Some of them are described in the following.

Epidemiology and Prevention of Aboriginal Renal Disease

This project predates the AusDiab study and highlighted the multitude of factors interacting in the development of CKD in Australian Aboriginal populations.[43] A community-wide screening program was conducted between 1992 and 1995 in the Tiwi community and included >90% of the population aged 5 years and older. The urinary albumin to creatinine ratio was used as the primary marker. The results showed that albuminuria was evident in early childhood and increased dramatically with age; 26% of adults had microalbuminuria and 24% had overt albuminuria. Overt albuminuria was noted to be least frequent in adults of normal birth weight and lower body mass index (BMI), and most common in low birth

weight adults with higher BMIs. A second screening of the same community was performed in 2004 to 2006, with >85% participation that supported these findings, although it hinted at some improvement over time.[44]

Kidney Function and CV Risk Markers in a Remote Australian Aboriginal Community

A cross-sectional study in a remote NT coastal Aboriginal community recruited 237 participants (60% of all adults).[45] Residents were screened for urinary albumin to creatinine ratio and serum creatinine, blood pressure, glycemia, history of diabetes, and serum lipids. Microalbuminuria was present in 31% and overt albuminuria in 13%. Serum creatinine was elevated (≥120 mmol/l) in 10%, eGFR (MDRD formula) was <60 ml/min per 1.73 m^2 in 12%, and a further 36% had an eGFR of 60 to 79 ml/min per 1.73 m^2. This study established the high prevalence of markers of kidney disease in the Aboriginal community.

Additional studies were conducted from 2000 to 2003 in 3 remote communities in the Top End of the NT study, and from 2002 to 2006 in 2 community-controlled health services in Western Australia (WA).[46] Briefly, 1070 adults were screened in the NT, with estimated participation of 67%. Median age was only 34.6 years; 52% were women. This summary highlighted a high prevalence of CKD and related high-risk conditions, which was impressive for such a youthful population (Table 1).

Albuminuria in a Remote South Australian Aboriginal Community: Results of a Community-Based Screening Program for Renal Disease

In 2003, this published study was a 3-year, cross-sectional adult screening program called the Umoona Kidney project.[47] The participants included 158 adult volunteer members of the Umoona community, a remote aboriginal region in South Australia (58 men and 100 women). This study found high rates of renal disease and associated risk factors in the form of microalbuminuria (19%), macroalbuminuria (9%), hypertension (42%) diabetes (24%), and overweight or obesity (65%). This was the first such screening program in a remote Aboriginal community in South Australia that identified a significant burden of incipient and established renal disease among adult members. One of the drawbacks of this program was measurement of renal function, which was not included and potentially underestimated the burden of renal disease.

Darwin Region Urban Indigenous Diabetes Study

A larger but urban dwelling group of Aboriginal people was studied in the Darwin Region.[48] The Darwin Region Urban Indigenous Diabetes (DRUID) study recruited 860 volunteers who identified as Aboriginal and/or Torres Strait Islanders, were aged older than 14 years, and self-reported living in a private dwelling within a geographically defined area around Darwin for at least 6 consecutive months before participation. Participants were assessed for albuminuria and low eGFR. Associations between risk factors and these kidney disease markers were explored. Albuminuria was prevalent in 14.8%. However, low eGFR (MDRD <60 ml/min per 1.73 m^2) was found in only 2.4%. Compared with the AusDiab study, DRUID participants had a 3-fold higher adjusted risk of albuminuria, but not of low eGFR.

DRUID was limited by its cross-sectional design and had other weaknesses. The single eGFR estimate incorporated a serum creatinine assay before isotope-dilution mass spectrometry standardization. Despite such limitations, these data represented the largest data set of indigenous Australians living in urban areas, which represented 73% of the total indigenous population of Australia.

Natural History of CKD in Australian Indigenous and Non-Indigenous Children: A 4-Year, Population-based, Follow-up Study

The aim of this study was to investigate the natural history of early CKD risk factors in indigenous children. The data come from a well-executed prospective

Table 1. Prevalence of chronic kidney disease–related conditions[a] in Aboriginal communities in Australia[46]

Conditions	Western Australia AMS 2 2003–2006	NT community 1 2000–2003	NT community 2 2000–2003	NT community 3 2000–2003	*P* value
Hypertension	24.6 (23.4–5.9)	29.2 (25.2–33.5)	42.9 (36.3–49.6)	51.7 (46.9–56.6)	<0.0001
Kidney disease	16.9 (15.8–8.0)	28.1 (24.1–32.4)	42.9 (36.3–49.6)	46.3 (41.5–51.2)	<0.0001
Diabetes	14.1 (13.1–5.2)	15.1 (12.1–18.7)	19.5 (14.7–25.4)	29.0 (24.7–33.6)	<0.0001
Any condition	32.5 (31.1–33.9)	40.4 (35.9–44.9)	62.9 (56.1–69.1)	66.3 (61.6–70.8)	<0.0001
Multiple conditions	16.0 (14.9–17.1)	22.4 (18.8–26.4)	31.9 (26.0–38.5)	40.8 (36.1–45.7)	<0.0001

AMS, Aboriginal Medical Service; NT, Northern Territory.
Values are percentages (95% confidence intervals).
[a]Age- and sex-adjusted values are similar, and their trends and significance are identical.
Reprinted with permission from Hoy WE, Davey RL, Sharma S, et al. Chronic disease profiles in remote Aboriginal settings and implications for health service planning. *Aust NZ J Public Health.* 2010;34:11–18.[46]

screening of 2266 Aboriginal and non-Aboriginal children attending primary schools throughout New South Wales between February 2002 and June 2004.[49] The children were then followed for 4 years. The mean age was 8.9 years; 55% were Aboriginal children. Between 2% and 7% had at least 1 CKD risk factor, including hematuria, albuminuria, obesity, and systolic and/or diastolic hypertension. However, most of these abnormalities were transient, with low prevalence at follow-up. There was no difference between indigenous and non-indigenous children.

The data were unexpected because of the increased risk for CKD reported in adult Aboriginal Australians.[50,51] They either defined important health differences between groups of Australian Aborigines or described healthy precursor states in the natural history of CKD in Australian Aborigines.

Many important studies replicated these findings in the Aboriginal population across the nation.[52,53] To enumerate all the important work conducted in the field of CKD in Aboriginal communities in Australia is beyond the scope of this review. Two recent reviews provided a detailed and an expanded view of CKD in the Aboriginal population in Australia.[54,55]

Table 2 outlines summary data of some of the important CKD screening studies in Australia.

The Present: Surveillance Programs

The most well-recognized registry is the ANZDATA, which reports on the profile and outcomes of the ESKD population on RRT in Australia.[6] Registry annual reports, dating back to 1978, are on public record.[56] Individual practice performance reports are distributed to the contributing sites, with comparison to the aggregated national outcomes for the purposes of improvement of delivered kidney care. However, newer CKD surveillance networks have emerged recently to address the natural history of the CKD population who are not on RRT or those who were never in an RRT cohort, which is not represented in ANZDATA.

Renal Diseases Health Network, Western Australia

Clinicians and policymakers came together in a forum/workshop in WA in 2007.[17] Information generated from the WA Health and Wellbeing Surveillance System (HWSS), which was based on self-reported data from individuals aged 16 years or older, were tabled at the forum. The CKD risk factors of hypertension were prevalent in 24.7% and diabetes in 5.8% from 2005 to 2006.[57] Underestimation of prevalence of both risk factors in the WA population was noted compared with the AusDiab data set. The HWSS data set was complemented by laboratory data from PathWest, sorted by a unique patient identifier number. Information of 10,161 discrete individuals living in the Northern and Southern metropolitan areas were extracted for 3 months in 2007 and reported at the forum. Data included sex, age, and postcode, and laboratory results

Table 2. Important chronic kidney disease screening studies in Australia

Year	Author (ref)	Study population	Numbers	Study design	Prevalence of CKD			
					eGFR (<60 ml/min)	UACR/PCR	Combined CKD risk	Hematuria
1992–1995	Hoy *et al.*[43]	Children and adults, costal Aboriginal community	382 children 487 adults	Community wide screening	NA	26%[a]	NA	25.5%
1999–2000	Chadban *et al.*[2]	Adults aged >25 yr	11,247	Cross-sectional survey	11.2%	2.4%	16%	4.6%
2003	McDonald *et al.*[45]	Remote indigenous >18 yr	237	Cross-sectional survey	36%[b]	13%[c]	NA	NA
2003	Shephard *et al.*[47]	Remote indigenous >18 yr	158	Community screening	NA	28%	Hypertension (42%) Diabetes (24%) Obesity (31%)	NA
2003–2005	Maple-Brown *et al.*[48]	Indigenous (urban) >15 yr	860	Cross-sectional survey	2.4%	14.8%	NA	NA
2002–2006	Haysom *et al.*[49]	Children 55% aboriginal	2266	Screening of school children	NA	2.4%	NA	1.9%
2005	Thomas *et al.*[28]	Adult with type 2 DM	3893	Cross-sectional study of GP	23.1%	34.6%	10.4%	NA
2007	Mathew *et al.*[27]	At risk population for CKD	402	Community screening	10%	13%	20.4%	13%
1995–2007	Jose *et al.*[31]	Adults >18 yr	375,460	De-identified laboratory data	11.4% (f) and 8.6% (m)	Low level of ACR testing[d]	NA	NA
2008	Razavian *et al.*[32]	Adults ≥55 yr	4966	Cross-sectional study of GP	17.3%	33%	Diabetes (22%) Obesity (32%) Current smoker (8%)	NA
2002–2011	Lawton *et al.*[39]	>15 yr	127,526	De-identified laboratory data	1.1%–2.3%[e]	1.6%–8.1%	NA	NA

CKD, chronic kidney disease; eGFR, estimated glomerular rejection rate; GP, general practice; PCR, protein:creatinine ratio; UACR, urine albumin:creatinine ratio.
[a]Twenty-six percent of adults had overt proteinuria and 24% had microalbuminuria.
[b]Clevated serum creatinine (≥120 μmol/l) was seen in an additional 10%.
[c]Microalbuminuria (urine ACR 30–299 mg/g) was seen in 31%.
[d]Only 9.4% of individuals with low eGFR had albuminuria tested.
[e]Rates based on geographical location: urban versus rural and/or remote.

for creatinine, eGFR, glucose, and hemoglobin. Low eGFR (MDRD <60 ml/min per 1.73 m^2) was reported in 22.4%, with the highest rates in those aged older than 65 years (38.6%). These results were a biased sampling but were also a valuable reference point at the forum. The forum also facilitated the development of WAND. The network is currently engaged in multiple projects, including the Renal Demand Modelling Project, which will study a new methodology for acquiring data on disease progression of CKD, working with pathology laboratories across WA.[58] WAND will be a valuable source of data from CKD patients in WA into the future.

CKD in Queensland

CKD.QLD was established in 2009 as a research and practice platform for CKD across all renal practices in the public health system in Queensland.[16] This is the first comprehensive longitudinal CKD surveillance program for predialysis CKD patients in Australia.[59] CKD.QLD is a multidisciplinary collaboration between Queensland Health (QH), the University of Queensland, and the Queensland University of Technology. Members include medical, nursing, allied health, epidemiologists, statisticians, health economists, and researchers. An early achievement was the establishment of the CKD.QLD Registry with recruitment of >8000 patients to date. All adult (18 years or older) patients with an assigned diagnosis of CKD attending renal specialist clinics are enrolled in the registry irrespective of the stage of CKD. Patients on RRT are not included in the registry because they are represented in the ANZDATA registry, but enrolled CKD patients who develop ESKF can continue to be followed through their RRT course. Data are collected in multiple formats from each site into a central data repository, and missing information is sought from each unit. Registry data exposed important information about CKD in older adults, sex distribution, diagnosis of kidney disease, socioeconomic status and CKD, predictors of RRT and of deaths without RRT, urban and/or rural differences, hospitalizations, and economic impact on health services. Products from the CKD.QLD Registry will provide new data on the natural history of CKD and the effects of different practice models. CKD.QLD has developed data linkage across multiple existing platforms in QH.[60] It includes a biobank for patient samples and a basic study of biomarkers in the diagnosis, prognosis, and treatment response in CKD. The strengths of the registry are comprehensive longitudinal data on CKD patients from the public system in QH. Various substudies and projects can further identify and probe important and pertinent research questions related to CKD on an ongoing basis. CKD.QLD is recognized as a prominent member of the International Network of Chronic Kidney Disease cohort studies (International Society of Nephrology iNET-CKD).[61]

However, there are some limitations in the Registry. The registry data are limited to specialist renal clinics in public hospitals, barring an overlap of shared care with private patients, and do not represent CKD in primary care. The collaborative project now underway with Queensland Health will disclose hospital service utility and costs associated with CKD patients in the registry and within the QH system more broadly.

The Future: National CKD Research Programs

The future of CKD surveillance and research in Australia received a major boost with the successful launch of NHMRC-funded programs recently. They are major collaborative networks at the national level with an impressive array of investigators involved with renal research in Australia.

CKD Centre of Research Excellence

The NMHRC-funded CKD Centre of Research Excellence (CKD.CRE) was established in late 2015.[62] This center is dedicated to improving knowledge of CKD and its management across the health care spectrum. Based at the University of Queensland, the center includes collaborators in almost every state and/or territory from Australia. Its core research streams are CKD surveillance, practice improvement, biomarker research, and health economics. Indigenous perspectives are embedded in all research streams. The CKD.CRE has a strong focus on research capacity building, and multiple research projects are at various stages of progression as showcased in a recent CKD.CRE forum.[62]

The Better Evidence and Translation–Chronic Kidney Disease

This NHMRC-funded program (2016) is not strictly a CKD surveillance system. It is a collaborative research program that brings together a strong team of people with clinical and research expertise in the areas of cohort studies, disease registries, data linkage, biostatistics, and epidemiology.[19] A multitude of projects are underway involving the Australian Kidney Trials Network, the Centre for Kidney Research at Westmead Hospital, the ANZDATA Registry, the Cochrane Centre for Kidney and Transplant, and the Standardized Outcomes in Nephrology (SONG) initiative.[63] Important initiatives have emerged, like SONG-Hemodialysis (HD), which has engaged the international renal community, including consumers, in

identifying core outcomes in hemodialysis-related research trials.[64]

Discussion

This review outlined the evolution of CKD screening and surveillance across multiple geographic locations in Australia (Figure 1). Population-based studies in Australia highlighted the burden of CKD in this country in the past. However, studies performed previously had many limitations when examined in contemporary circumstances. One of the difficulties faced by these studies was the change in the definition of CKD, with more accurate, internationally referenced serum creatinine assays and refinement of the formula to calculate eGFR. The AusDiab data was reevaluated with newer eGFR equations, which led to readjustment of CKD prevalence rates.[26] Most of these studies were specific to each state and/or province in Australia, which allowed for comparative analysis of data and identified state-specific mechanisms in managing the burden of CKD. Pioneering studies conducted in Aboriginal Australians not only highlighted the disproportionately higher rates of kidney disease in this population, but also showed encouraging results with basic medical management in preventing mortality and renal failure.[65] All these efforts brought CKD into the national agenda, with the current Australian Health Survey incorporating CKD-specific questions and biochemical data. CKD was recognized as an important disease entity rather than being relegated to the previously used term of chronic renal failure, which was considered a mere complication of chronic conditions like hypertension and diabetes. Long-term systematic surveillance systems like CKD.QLD and WAND, together with the ANZDATA Registry continue to generate significant knowledge on the complete spectrum of CKD.

This review has broader ramifications for the international community, especially for those in the Asia-Pacific region. Any such group involved in establishing CKD surveillance and research programs in their countries can gain from the information and knowledge available on the evolution of CKD screening and surveillance in Australia. There is also scope for such programs to collaborate and develop common methodologies and outcome measures to benefit the larger community.

Conclusions

CKD research in Australia has evolved over the decades from earlier screening studies to long-term surveillance of predialysis cohorts, together with data on patients on RRT. Projects like CKD.CRE and BEAT-CKD will facilitate significant shifts in the perception of both the medical community and public that CKD is not equal to ESKD. The power of these systems will be amplified through integration with and/or cross linking with collaborations with other Australian states and regions to deliver a nationally sustainable CKD surveillance system. These mechanisms, with their focus on

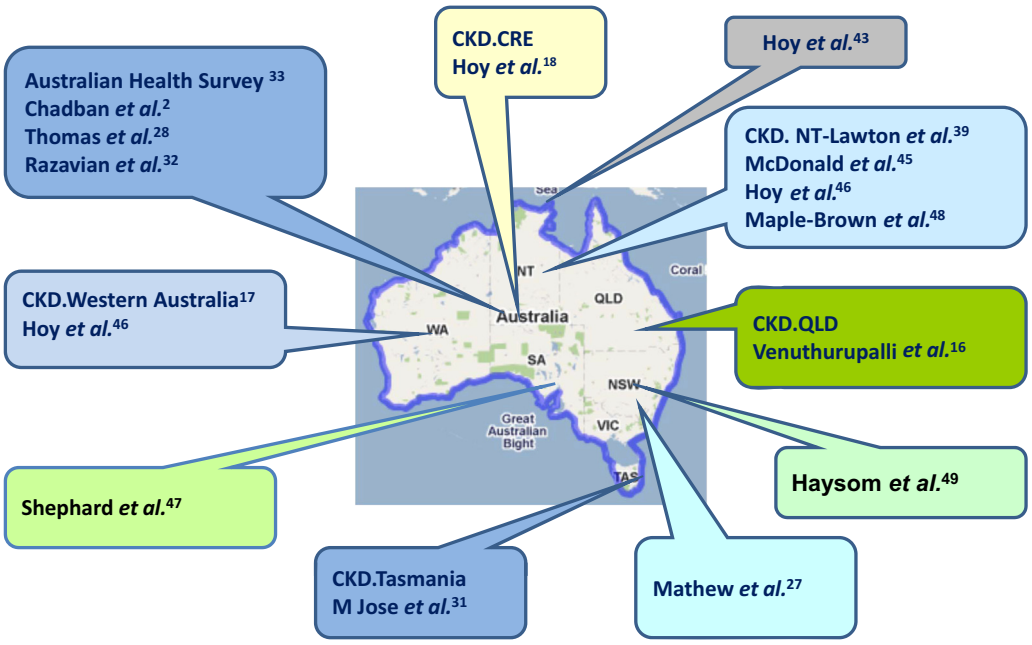

Figure 1. Geographical distribution of chronic kidney disease (CKD) screening and studies across Australia. *Better Evidence and Translation–Chronic Kidney Disease (BEAT-CKD) is a collaborative research program that aims to improve the lives of people living with CKD.[19] AusHeart, The Australian Hypertension and Absolute Risk Study.

research, are expected to generate significant outcomes for the larger benefit of the community in Australia and the world.

DISCLOSURE

All the authors declared no competing interests.

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