RBC casts, further studies are needed to compare the performance characteristics of the manual sediment examination when carried out by trained nephrologists to those of modern laboratory-based automated analyzers.

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SUPPLEMENTARY MATERIAL
Supplementary Methods.
Figure S1. Overview of analysis cohort.
Table S1. Primary clinicopathologic diagnoses of patients in the analysis cohort.

SUPPLEMENTARY MATERIAL is linked to the online version of the paper at www.kireports.org.

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To the Editor: Chronic kidney disease (CKD) is a public health problem worldwide. It is due to permanent kidney damage which ultimately leads to end-stage renal disease (ESRD). The Kidney Disease Improving Global Outcomes initiative defines CKD as structural or functional abnormalities of the kidney that last for 3 months or more and affect the well-being of the patient.1 Children with CKD constitute a small but very important proportion of the CKD population. These children are at risk of long-term complications, such as growth retardation and alteration of cognitive development.2–4

There are limited data on the epidemiology of CKD in children, especially for early stages, as most children are asymptomatic.5 Most earlier studies on pediatric CKD were based on hospital records, largely representing children presenting in late stages, and used different definitions for CKD.3 More recent publications, however, have been using the CKD classification published by the National Kidney Foundation’s Kidney Disease Outcome Quality Initiative in 2003.6,7

Oman is one of the Arab Countries located in the southeastern corner of the Arabian Peninsula. According to the 2018 Statistical Yearbook report of the National Center for Statistics and Information, in mid-year 2017, the population size was 4.55 million with a population of approximately 1 million age 14 years and younger.8

The aim of this study was to establish data about CKD in children in Oman, including the annual incidence, etiology, and long-term outcomes based on the experience at a major tertiary referral center that provides pediatric nephrology services for the entire population being the only pediatric nephrology center catering for children with CKD.

RESULTS
Over a study period of 12 years (between 2004 and 2015) there were 208 cases of CKD, the patient demographics are illustrated in Table 1. The mean

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incidence rate of CKD in children in this study was 24.0 per million child population (Figure 1). Sixty-three percent of our patients were boys. The mean age at diagnosis of CKD was 3.6 ± 3.5 years (median 2.0); 61% were younger than 3 years, 14% were 3 to 6 years, and 25% were 6 to 13 years old at time of diagnosis. Consanguinity was observed in 41.8% of the patients and 31.3% of them had positive family history of renal disease (Table 1).

A minority of patients (27 patients, 12.9%) presented in stage II CKD. Fifty-two patients (25%) had stage III CKD, 43 patients (20.7%) had stage IV CKD, and 86 children (41.3%) had stage V CKD at diagnosis (Figure 2).

The etiologies of CKD in this cohort are shown in Table 2. The most common etiology of CKD found was congenital anomalies of the kidney and urinary tract (CAKUT) in 110 children (52.9%) of whom 59 patients (28%) had obstructive uropathy followed by renal dysplasia/hypoplasia in 29 (14%) of the children. Thirteen (6%) and 9 (4%) children had vesicoureteric reflux and neurogenic bladder respectively. Hereditary renal disease was seen in 66 (32%) children with the leading cause in 25 patients (12%) being autosomal recessive polycystic kidney disease. Other hereditary diseases included primary hyperoxaluria type 1 (7%), familial focal segmental glomerulosclerosis (5%) and congenital nephrotic syndrome (4%). The third cause of CKD in our patients was chronic glomerulonephritis in 17 (8.2%), including 5 lupus nephritis, 5 primary focal segmental glomerulosclerosis, 1 membranoproliferative glomerulonephritis, 1 mesangio proliferative glomerulonephritis, and 1 crescentic glomerulonephritis. Four cases of glomerulonephritis could not be classified because of lack of kidney biopsy.

Family history of renal disease was more common in children who had primary hyperoxaluria, followed by polycystic kidney disease and then primary glomerulopathy with the following percentages: 100.0%, 64.0%, and 51.7%, respectively; in comparison, only 13.0% of children with CAKUT had positive family history.

Fifty-eight percent of our patients had hypertension at diagnosis. It was more common in children with glomerulopathy (90%), followed by

| Variable                  | Number | Percentage |
|---------------------------|--------|------------|
| Total                     | 208    | 100        |
| Sex                       |        |            |
| Male                      | 131    | 63.0       |
| Female                    | 77     | 37.0       |
| Age (yr)                  |        |            |
| < 3                       | 127    | 61.0       |
| 3 to <6                   | 30     | 14.4       |
| 6 to 13                   | 51     | 24.5       |
| Mean age ± SD             | 3.6 ± 3.5 |          |
| Consanguinity             | 87     | 41.8       |
| Family history            | 65     | 31.3       |

Median follow-up in year/range in year 4.3 (SD ± 3.7)(0.5–12).
with cystic kidney disease (84%) and CAKUT (39%). Children with CKD stage V had a significant high proportion of growth failure compared with children with stages II to IV ($P = 0.033$); other complications of CKD, dialysis modality, and outcomes are shown in Table 3. Forty percent of children with CAKUT required dialysis compared with 93.8% with chronic glomerulonephritis, 58.8% with hereditary renal disease, 75.5% with hemolytic uremic syndrome, and 66.7% with other ($P = 0.001$). During follow-up, 18.5% of children with CAKUT and 5.9% of children with hereditary renal disease had stable or improved glomerular filtration rate compared with none from other etiology ($P = 0.236$). We noted children with CAKUT has slightly lower mortality compared with children who had other etiology of CKD but not reach statistical significance ($P = 0.284$).

During a mean follow-up period of 4.3 years, 36 of the patients (17.8%) died (Table 3). Twenty-two (10.7%) of these patients were on dialysis, and 4 (7%) died after kidney transplantation. Two of them died secondary to sepsis and the other 2 died after transplant graft failure secondary to chronic allograft nephropathy.

**DISCUSSION**

The present study is the first of its kind in Oman. It included 208 children with CKD who were diagnosed and followed at our center over a 12-year period.

The mean annual incidence rate of CKD in children in Oman was 24.0 per million child-populations over the study period. In a study from Kuwait that involved children aged 0 to 15 years with estimated glomerular filtration rate less than 50 ml/min per 1.73 m$^2$, the incidence was 38 per million age-related population and prevalence was 329 per million age-related population in 2003; the incidence was higher compared with our study. However, other studies have shown lower incidence rates of CKD. A report from Saudi Arabia that studied children younger than 13 years showed an incidence of 15.8 per million age-related population, and that of ESRD of 9.2 per million age-related population. Other studies from Jordan, Italy, Sweden, and France show similar data. Overall, the incidence of

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**Table 2. Chronic kidney disease (CKD) etiology**

| Diagnosis                       | Male, n (%) | Female, n (%) | Total, n (%) |
|---------------------------------|-------------|---------------|--------------|
| CAKUT                           | 86 (41.3)   | 24 (11.5)     | 110 (52.9)   |
| Obstructive uropathy            | 56 (27.0)   | 3 (1.4)       | 59 (28.4)    |
| Renal hypoplasia/dysplasia      | 18 (8.7)    | 11 (5.3)      | 29 (13.9)    |
| Vesico-ureteric reflux          | 9 (4.3)     | 4 (1.9)       | 13 (6.3)     |
| Neurogenic bladder              | 3 (1.4)     | 6 (2.9)       | 9 (4.3)      |
| Hereditary renal disease        | 29 (13.9)   | 37 (17.8)     | 66 (32.0)    |
| ARPKD                           | 10 (4.8)    | 15 (7.2)      | 25 (12.0)    |
| Familial FSGS                   | 4 (1.9)     | 7 (3.4)       | 11 (5.3)     |
| Primary Hyperoxaluria type 1    | 7 (3.4)     | 7 (3.4)       | 14 (6.7)     |
| Congenital nephrotic syndrome   | 3 (1.4)     | 6 (2.9)       | 9 (4.3)      |
| Juvenile nephronphthisis        | 5 (2.4)     | 2 (1.0)       | 7 (3.4)      |
| Chronic glomerulonephritis      | 9 (4.3)     | 8 (3.9)       | 17 (8.2)     |
| HUS                             | 1 (0.5)     | 3 (1.4)       | 4 (1.9)      |
| Others                          | 2 (1.0)     | 1 (0.5)       | 3 (1.4)      |
| Unknown                         | 5 (2.4)     | 3 (1.4)       | 8 (3.8)      |

ARPKD, autosomal recessive polycystic kidney disease; CAKUT, congenital anomalies of the kidney and urinary tract; FSGS, focal segmental glomerulosclerosis; HUS, hemolytic uremic syndrome.
CKD in children in Oman is higher compared with other countries, likely related to involvement of children with all stages of CKD in this study compared with other studies. Other reasons may be attributed to the high prevalence of consanguinity. Another reason for this observation is the late diagnosis for some cases leading to a delay in implementing preventive measures to halt or delay the progression of CKD.

The most common cause of CKD in our patients is CAKUT in 52.9%, similar to findings shown in previous studies from the Middle East10,11,21 and other parts of the world.17,18 The second most common etiology of CKD in the current study is hereditary renal conditions, including familial focal segmental glomerulosclerosis, congenital nephrotic syndrome, polycystic kidney disease, and primary hyperoxaluria. This finding was also seen in other studies from Oman9,20 and from the Middle East.9,11,21 These findings are expected, as consanguinity is common in these countries.

Hypertension is a common complication of CKD in our patients, being present in 58% of them, especially in children with CKD stages IV and V in which the rate was 60.9% compared with 39.2% in children with CKD stages II and III. Similar trends were also seen in reports from Iran, North America, and Europe.22–24 Growth failure, another common complication seen in our patients, was more significant in children with CKD stage V (P = 0.033); this finding is in line of previous reports.17,25

At our center, all children who progress to ESRD are offered dialysis except when patients have other organ dysfunction precluding dialysis or when dialysis is not possible. A higher proportion of children in our study were on hemodialysis compared with those on peritoneal dialysis, which can be explained by the fact that in the past, hemodialysis was the main dialysis modality in children in Oman due to the unavailability of a pediatric peritoneal dialysis program. Also, most children with primary hyperoxaluria were on hemodialysis, as it is the preferred dialysis modality for them. At present, there is a well-established local pediatric peritoneal dialysis program and most of children requiring renal replacement are offered automated peritoneal dialysis first, unless contraindicated.

More than 66% of children in our study were already at stage V CKD during last follow-up, but only 27.8% received kidney transplantation. This is explained by unavailability of an active living renal transplant program before 2009, lack of a deceased donor transplant program in our country, and the shortage of appropriate donors. The latter is as a result of social pressure in addition to local beliefs about the nature and consequences of kidney transplantation. As illustrated in Table 3, we noted in our study that children with CAKUT have lower progression rate to ESRD and required dialysis compared with other etiologies of CKD. This result is comparable to data from ItalKid Project, which showed that 57.5% of their patients with CKD had renal hypodysplasia but only 39.6% of patients with ESRD had the same etiology.12 Our results also showed that children with chronic glomerulonephritis progress more rapidly to ESRD compared with children who had CAKUT; this finding is similar to previous reports.18,26

The current study provides a first of its kind insight into pediatric CKD in a country with high consanguinity such as Oman. The limitations of our study, in addition to being retrospective with a relatively short follow-up period, include that it is a hospital-based study in which other children who have CKD and not yet diagnosed or referred to our center may have been missed. Also we used Kidney Disease Outcome Quality Initiative staging criteria for CKD for all children, although it is only applicable for children older than 2 years, which might result in inaccurate staging of CKD in younger children.

Table 3. Complications, treatment and outcome

| Characteristic, n (%) | Stage II, n (%) | Stage III, n (%) | Stage IV, n (%) | Stage V, n (%) | Transplanted | P |
|-----------------------|----------------|-----------------|----------------|---------------|--------------|---|
| Complication          |                |                 |                |               |              |   |
| Hypertension, 115 (57.5) | 14 (12.2)     | 31 (27)         | 26 (22.6)      | 44 (38.3)     | 0.378        |   |
| Anemia, 125 (63.1)     | 16 (12.8)      | 33 (28.4)       | 33 (28.4)      | 43 (34.4)     | 0.381        |   |
| Growth failure, 121 (59.6) | 7 (6.8)       | 17 (14%)        | 20 (16.5)      | 49 (40.5)     | 0.033        |   |
| Treatment             |                |                 |                |               |              |   |
| Oral iron, 160 (79.8)  | 22 (13.8)      | 42 (28.2)       | 43 (26.9)      | 53 (33.1)     | 0.031        |   |
| Erythropoietin, 125 (62.8) | 14 (11.2)     | 24 (19.2)       | 34 (27.2)      | 53 (42.4)     | 0.001        |   |
| Phosphate binders, 156 (77.6) | 18 (11.5) | 35 (22.4)       | 44 (28.2)      | 59 (37.8)     | 0.001        |   |
| Active vitamin-D, 156 (77.6) | 19 (12.2)   | 37 (23.7)       | 41 (26.3)      | 59 (37.8)     | 0.001        |   |
| Outcome               | CAKUT (%)      | Hereditary renal disease (%) | Chronic GN (%) | HUS (%) | Other (%) | Unknown (%) | P |
| Dialysis, 110 (57.9)   | 40.4           | 58.8            | 93.8           | 75.0          | 66.7         | 75.0         | 0.001 |
| KT, 57 (27.4)          | 20.2           | 26.5            | 62.5           | 52.0          | 33.3         | 50.0         | 0.007 |
| Stable or improved GFR, 24 (11.6) | 18.5 | 5.9             | No             | No            | No           | No           | 0.236 |
| Death, 36 (17.3)       | 11.0           | 23.5            | 25.0           | 25.0          | No           | 25           | 0.284 |

CAKUT, congenital anomalies of the kidney and urinary tract; GFR, glomerular filtration rate; GN, glomerulonephritis; HUS, hemolytic uremic syndrome; KT, kidney transplantation.
CONCLUSION

We report the demographic and clinical characteristics of children with CKD who were followed at our center over a 12-year period. CAKUT was the most common CKD etiology, followed by hereditary nephropathies due to high consanguinity rates among the population. In addition, the number of patients undergoing kidney transplantation was low, reflecting the need for establishment of a deceased donor renal transplant program. Further efforts are also required to continue promoting living organ donation. The findings of this study will help to increase awareness among health care providers and improve the delivery of health care to this population with more emphasis on genetic counseling and prevention.

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DISCLOSURE

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SUPPLEMENTARY MATERIAL

Supplementary Methods.

Supplementary material is linked to the online version of the paper at www.kireports.org.

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