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Review Article

Epidemiology of Pediatric Chronic Kidney Disease and Pediatric kidney Failure: what we Learn from the Studies

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Abstract

CKD (chronic kidney disease) has become a growing concern worldwide, with its rates showing a significant increase in recent years. Data on the prevalence and incidence of CKD in the pediatric population are limited. It is estimated that CKD affects approximately 1 to 3% of the global pediatric population, with regional variations. The prevalence ranges from 56 to 74.7 cases per million of the age-related population (pmarp). This increasing prevalence is reflected in the higher risk of various causes of mortality, progression to advanced stages, and the emergence of cardiovascular disease.

The most common cause of CKD among children is congenital anomalies of the kidney and urinary tract (CAKUT). With progressing CKD, various complications occur, and end-stage renal disease (ESRD) can develop.

The epidemiology of CKD in children and adolescents also encompasses issues related to access to proper medical care, early diagnosis, and effective treatment. Identifying at-risk groups and implementing screening programs can play an important role in reducing the incidence and morbidity of CKD in this population.

Furthermore, epidemiological research aims to gain a better understanding of the ethnic, socioeconomic, and geographic disparities associated with CKD in children and adolescents, allowing for more targeted prevention and intervention strategies.

In conclusion, the epidemiology of chronic kidney disease in children and adolescents is an evolving field, essential for guiding public health policies and clinical practices aimed at preventing, early diagnosing, and treating this complex disease, thereby promoting renal health and overall well-being among this vulnerable population.

Keywords: children; adolescents; epidemiology; incidence, survival; chronic kidney disease

1.Introduction

The kidneys are fundamental organs for maintaining the homeostasis of the human body. The decline in the function of these organs can occur abruptly, classified as acute kidney injury, or progressive, with variable time during its evolution, characterizing chronic kidney disease (CKD) and end-stage renal disease (ESRD) when the loss of function is permanent [1,2].

CKD affects both the structure and function of the kidneys, with multiple causes and prognostic factors. In this condition, there is a progressive decline in glomerular filtration rate, loss of regulatory, excretory and endocrine functions, which can affect other organs in the individual. Several factors can be associated with both the etiology and progression of kidney function loss such as hypertention, proteinuria, anemia, dyslipidemia, metabolic acidosis, prematurity, low birth weight, small for gestational age, lower socioeconomic status, inadequate parental health literacy, etc [3]. Therefore, it is important to recognize individuals who are at risk of developing CKD through early diagnosis and identify factors associated with a worse prognosis, defined as those factors related to a faster progression of renal function loss [4].

CKD is defined as persistent renal structural or functional abnormalities for a greater period than or equal to three months and with health implications, such as glomerular filtration rate (GFR) less than 60mL/min/1.73m^2, urinary sediment alterations, tubular disorders, and abnormalities in imaging or histology of the renal parenchyma, regardless of the cause or specific clinical presentation [5,6].

The individual in an advanced stage of CKD has a reduced life expectancy and increased risks of cardiovascular disease. They face significant dietary restrictions and should take use a large number of medications, which dramatically worsens their quality of life. The repercussions of the disease also extend to the patient's mental and behavioral health, impacting the family, particularly in low socioeconomic populations with diverse cultural backgrounds, who receive treatment subsidized by the Brazilian Unified Health System (SUS), which covers 85% to 90% of patients on Renal Replacement Therapy (RRT) [7-9].

The available modalities for RRT are hemodialysis (HD), peritoneal dialysis (PD), and kidney transplantation (Tx). Ideally, family physicians, pediatricians and other pediatric specialists would be aware of the epidemiology of CKD before the need for RRT in order to provide effective guidelines for preventing or delaying the progression of the disease. This would facilitate better adherence in any RRT modality. Preparation before and after the start of treatment is also important, with multidisciplinary follow-up essential to help the patient and his family understand and accept the treatment, as this is the only guarantee of survival [8].

Patients with CKD have a high mortality rate that can be influenced by individual factors such as age, primary cause of CKD, comorbidities, and even factors related to healthcare utilization. Additionally, individuals on RRT have lower survival rates compared to the general population [7].

The patient should be referred to a nephrologist or pediatric nephrologist as soon as possible for follow-up, with the aim of delaying the initiation of RRT, having permanent vascular access, and avoiding urgent dialysis treatment [8-10]. Early diagnosis and referral to a nephrologist are essential steps in managing these patients, enabling a focus on pre-RRT education and implementing preventive measures to slow down the progression to more advanced stages of CKD, as well as reducing morbidity and mortality [10].

CKD is recognized as one of the main public health priorities worldwide. Its global prevalence is estimated at ~ 10% of the general population, affecting > 800 million adults worldwide, of which approximately 4 million require RRT [11,12]. This global increase in CKD is due to the increased prevalence of diabetes, hypertension, obesity and aging. In addition to being a significant clinical problem, CKD also raises economic and organizational concerns, as RRT consumes a substantial proportion of healthcare resources [12].

In Brazil, RRT has been performed since the 1970s, but it was only in 2004 that the Ministry of Health established a Public Policy for the Care of Patients with CKD, following the principles of the Brazilian Unified Health System (SUS) [13]. This public policy defines care strategies that aim at providing equitable and quality care for patients at all stages of CKD through the integration of various levels of health care, with a focus on prevention, treatment and rehabilitation [14].

As mentioned above, the progressive growth in the incidence and prevalence of patients requiring RRT is considered a major global public health problem [15]. According to the Brazilian Institute of Geography and Statistics (IBGE), the Brazilian population in March 2023 was 189,4 million people, with over 92% of the Brazilian population being registered [16]. In 2022, the Brazilian Society of Nephrology (SBN) census found that there were 872 registered dialysis units in Brazil. The SBN sent questionnaires to all units, but unfortunately, only 243 RRT clinics answered. Due to the low answer's rate, the SBN estimates that there are currently 153,831 people with some degree of CKD in Brazil, with a calculated prevalence of approximately 716 per 1,000 inhabitants [17]. The annual SBN census presents an approximate overview of dialysis treatment in Brazil, providing data and analyzes that will contribute to the direction of public policies and strategies aimed at improving RRT in the country [17,18].

2. Pediatric Chronic Kidney Disease and Renal Failure

Although the concept of CKD in children and adolescents is similar to that of adults, this pediatric disease presents some peculiarities. There is little evidence and many factors involved are not yet known. It brings serious consequences associated with significant impairment of growth and development in these individuals, resulting in a significant reduction in life expectancy at birth [19].

To date, there is limited data on the epidemiology of this condition in the pediatric population. Unfortunately, most of this data is still underestimated because registration is only done when the individual already requires dialytic treatment. These epidemiological data are mainly concentrated on patients undergoing RRT, which represents only a portion of the pediatric population with CKD during childhood. A considerable number of children will progress to ESRD only in adulthood [12,19].

One of the main characteristics of pediatric CKD is that the underlying disease is different from that in adults. As mentioned before, there are specific severe complications such as growth and developmental disorders and urological problems [19,20]. Once the patient reaches renal failure, they will require a long-term RRT, including kidney transplantation. Therefore, long-term prognosis after transitioning to RRT is extremely important, considering that patient and graft survival rates are the primary goals in children and adolescents.

These studies on epidemiological data of pediatric CKD and pediatric renal failure are important for better management of these patients. In recent years, pediatric cases of CKD or records of renal failure, as well as cohort studies, have been reported worldwide (Table 1) [21-47].

2.1 Diagnosis of pediatric CKD

The diagnosis CKD in adults is performed by estimating the glomerular filtration rate (eGFR) from a filtration marker, such as serum creatinine or cystatin C, using formulas, or by testing urine for the presence of protein or albumin. However, there is no ideal method to accurately estimate GFR in children, considering that it varies with age, sex, race, ethnicity and size, which pose challenges in developing precise eGFR equations for children, especially in the early stages of the disease. Another limitation is the diversity of laboratory methods for measuring serum creatinine or cystatin C, and currently, the revised Schwartz and CKiD formulas are used [48,49].

CKD was first defined by the KDOQI guidelines in 2002 and endorsed in KDIGO 2012 [50,51]. These classifications have shown limitations as the classification of CKD is based on arbitrary eGFR cutoffs, ignoring age and sex-related changes. They only apply to children over two years old and give more importance to albuminuria, while most of these children have non-glomerular diseases. Stages 1-2 would be better defined by associated abnormalities rather than being classified as pediatric CKD [52-55].

Pediatric studies evaluating the prevalence of CKD in the last 10 years have followed CKD guidelines using only eGFR to report the incidence and prevalence of CKD stages 3-5. However, none of them combined the presence of albuminuria and reduced eGFR to report CKD in stages 1-5. Thus, to differentiate CKD from transient fluctuations in renal function or acute kidney injury, the definition of CKD includes a criterion of chronicity, meaning a low eGFR or high albuminuria that must be observed for at least three months, requiring repeated assessments over time [12].

CKD is also defined as the presence of renal structural alterations [51]. These alterations have been defined as pathological abnormalities (markers of renal damage: albuminuria), abnormalities in the urinary sediment, tubular disorders, histological abnormalities, history of kidney transplant, or structural abnormalities in imaging exams, with implications for health. However, not all abnormalities are related to prognosis [56].

2.2 Classification

CKD is classified into five stages (Table 1) according to the National Kidney Foundation Outcomes Quality Initiative (NKF-K / DOQI), with stage 1 being the mild form of the disease and stage 5 representing ESKD [51,56].

CKD stages	GFR (mL/min/1.73 m^2)	Description
1	> 90	Normal or high
2	60 a 89	Slightly reduced
3a	45 a 59	Slightly/moderately reduced
3b	30 a 44	Moderate/severely reduced
4	15 a 29	Severely reduced
5	< 15	Kidney failure

Table 1: Glomerular Filtration Rate and Classification of CKD

Modified from Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2012 Clinical practice guideline for the evaluation and management of chronic kidney disease, 2013 [51].

There is also a recommendation for the classification of CKD based on urinary albumin loss [51,57]. It is believed that this new classification, which includes albuminuria, may better characterize the prognosis of patients (Table 2).

Category	Albuminuria 24hours	Albumin/creatinine rate	Description
A1	< 30 mg	< 30 mg/g	Normal or moderately elevated
A2	30 a 300 mg	30 a 300 mg/g	Moderately high
A3	> 300 mg	> 300 mg/g	Severely elevated

Table 2 : Categories of albuminuria in CKD

Modified from Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2012 Clinical practice guideline for the evaluation and management of chronic kidney disease, 2013 [51].

2.3 Incidence and prevalence

Considering that CKD is often asymptomatic in its early stages, obtaining reliable data about the initial stages of this disease in the pediatric population is challenging. Unfortunately, these data are underestimated because registration is only done when the individual already requires RRT [12,20]. Although some reports of pediatric CKD are emerging in the literature, only a few reports on its epidemiology in stages 2 to 5 are available, especially in developing countries. For these countries, most data are obtained from reports of tertiary care referral centers. However, the quality of these data varies [20,30,36].

The European societies of pediatric nephrology have provided data on the all stages of CKD [30-32,34-36]. The incidence was 11 to 12 per million of the population of the same age (pmpa) for CKD stages 3 to 5, and 8 pmpa for CKD stages 4 to 5. While an increase in incidence has been observed in France since the 1970s, this was not found in Sweden [30,58]. The prevalence of pediatric CKD in stages 2-5 was estimated to be between 30 and 100 per million of the population related to age per year (pmpay) [12].

A low prevalence of CKD stages 3-5, 30 pmpay, was found in Japan. However, this was a survey sent to all institutions in the country, and reports of pediatric CKD cases < 15 years old in 2010 were incomplete [45]. On the other hand, the prevalence was higher in the United Kingdom (90 pmpay), but the study was conducted in a hospital setting, and there were uncertainties about the geographical area covered [59]. In Kuwait, a higher prevalence of CKD (330 pmpay) was reported in children with eGFR< 50 ml/min/1.73 m^2, between 1996 and 2003, suggesting the role of genetic factors [60]. A similar finding (prevalence of CKD stages 2-5 of 330 pmpay) was found in the southern part of Israel in 2008 [61]. The prevalence ranged from 55 to 60 to 70 to 75 pmpa in Spain and Italy, depending on the definition of CKD used in the studies [35,55].

One factor that affects the epidemiology of CKD in the pediatric population is race [19]. In North America, the incidence of this disease is two to three times higher in African-American children, compared to Caucasian children, regardless of gender [24].

A study conducted in Latin American countries (Argentina, Brazil, Chile, Colombia, Mexico, Uruguai and Venezuela) showed a wide variation in the incidence of pediatric CKD, ranging from 2.8 to 15.8 new cases per million of the population per year (pmpy) [62]. A national survey in Chile estimated an incidence of 5.7 pmpy and a prevalence of 42.5 pmpy in children under 18 years old [63]. Half of these patients were receiving conservative treatment, and the rest were undergoing RRT. In the Middle East and Southeast Asia, an average incidence of CKD in children and adolescents aged 0 to 15 years old was found to be 38 pmpy in a referral center in Kuwait. The prevalence increased from 188 in 1996 to 329 pmpya in 2003 [64]. In children from Jordan, an incidence of 11 pmpy and a prevalence of 51 pmpya were reported [65]. Two reports from Vietnam showed an annual incidence of hospitalization due to CKD in children of 5 pmpy, and most of the patients had already reached ESRD [66,67].A study conducted in a single center in Africa identified a very low incidence of CKD, estimated at 3 pmpy in Nigeria and 1 to 2 pmpy in South Africa [68,69]. Peco-Antic' et al., described the results of the Serbian Pediatric Registry of Chronic Kidney Disease (SPRECKID). The authors found that the annual median incidence of pediatric CKD in stages 2 to 5 was 14.3 per million of the population in the same age group (pmpy), while CKD in stages 2 to 4 or CKD stage 5 were 9.1 and 5.7 pmpy, respectively. The median prevalence of CKD in stages 2 to 5 was 96.1 pmpy, 52.8 pmpy for CKD in stages 2 to 4, and 62.2 pmpy for CKD stage 5 [33]. In 2021, Masalskienė et al., reported that the prevalence of pediatric CKD in stages 2 to 5 was 48.0 per million of the population in 1997; 88.7 in 2006; and 132.1 in 2017 [70]. Numerous risk factors (prematurity or low birth weight, obesity, smoking, hyperuricemia, acute

kidney injury) have contributed to this increase, as observed in several other countries [71-73].

Regarding ESRD, the data on its incidence and prevalence in the pediatric population vary across different countries. Approximately 80% of patients on RRT worldwide live in Europe, Japan, or North America, where all pediatric patients with this condition have access to RRT. On the other hand, in developing countries, limited human resources, lack of training, and limited healthcare for patients with CKD and ESRD result in rationing or even lack of RRT [55].

Studies have shown that in 2008, the median incidence of RRT in children under 20 years of age was 9 per million population per year (pmpy), ranging from less than 4 in Russia to 18 pmpy in New Zealand. The incidence of RRT was 9.5 pmpy in 11 countries in Western Europe and Australia, compared to 15.5 pmpy in the United States [74-76]. In all registries, the incidence was higher in adolescents. This incidence was twice as high in the United States as in Western Europe for patients aged 15 to 19 years old (30.6 *vs.* 15.3) and was also higher in the age group of 0 to 14 years old (10.5 *vs.* 6.5). This difference can be partially explained by the timing of RRT initiation (mean GFR of 10.4 ml / min / 1,73 m^2 in Europe *vs.* mean GFR of 11.3 to 13.6 ml / min / 1,73 m^2 in the United States [77,78]. The incidence in Malaysia was comparable to Europe, suggesting good access to RRT, despite being a country with a public and government-funded dialysis program [79]. Previous reports from countries offering RRT showed that the incidence rates ranged from 6.5 pmpy in Brazil in the late 1980s to 17 pmpy in Kuwait in the period 1995-2002 [80,81].

In 2015, Konstantyner et al., showed that the incidence of CKD in children and adolescentes undergoing dialysis treatment in Brazil was 6.6 cases per million population per year (pmpy) in 2012. The Southern region showed the highest rate of new pediatric cases under this therapy: 11.0 cases pmpy, while the northeastern region had the lowest rate: 3.8 pmpy [81]. The authors concluded that the incidence of pediatric ESRD in dialysis treatment in Brazil was similar to those lower incidences reported in the literature and related this finding to the significant socioeconomic diversity and the level of human development index in the different regions of the country, which may favor the underdiagnosis of CKD and ESRD [81]. In developing countries where RRT is not accessible to all, the incidence rates are extremely low (<1 in Bangladesh and Nepal).[19] Regarding the prevalence of children on RRT in 2008, it was 65 pmpy in Australia, Canada, Malaysia and Western Europe. The highest prevalence was observed in the United States (85pmpy), while Japan had the lowest prevalence (34 pmpy) [81]. A study conducted in Brazil showed that during the year 2012, the prevalence of pediatric patients with ESRD on chronic dialysis was 20.0 cases pmpy, and the Southern region presented the highest prevalence of patients under this therapy [81].

As already known, incidence and prevalence of ESRD also differ according to race [74]. The US Renal Data System (USRDS) in 2010 showed that African-American children had an incidence almost twice as high as white children [74]. In Australia and New Zealand, renal disease is more common in Maori, Pacific Islander, and indigenous Australian populations than in non-indigenous populations, although the difference in ESRD incidence is mainly among those aged over 15 years old [47,75]. In the UK in 2008, the prevalence and incidence of RRT in children from the South Asian population were 2.5 and 1.5 times higher than those in the white population aged 0 to 15 years old [82].

As mentioned above, the incidence and prevalence of ESRD vary worldwide in children [83-87]. The United States Renal Data System (USRDS), the Australia and New Zealand Dialysis and Transplant Registry (ANZDATA), and the European Renal Association-European Dialysis and Transplant Association (ERA-EDTA) Registry were used to compare the incidence and prevalence among children and adolescents. All rates were expressed as per million population related to age (pmpy) [26,47,87]. The incidence of pediatric ESRD has been decreasing according to the USRDS registry and remains constant according to the ANZDATA and ERA-EDTA registries. Consistent trends were observed in all age groups except for American children under 5 years old. Unlike the overall decreasing trend in the United States, the incidence rate has been increasing in this specific population [19].

The prevalence rates have slightly increased according to the USRDS and ANZDATA registries, while in Europe they have been decreasing over time. When stratified by age, there was an increase among children under 5 years old in Australia, New Zealand and the United States [19]. These rates were higher in the United States (incidence: 13 pmpy; prevalence: 77 pmpy [ages 0-17 years old between 2005 and 2017]) than in Australia and New Zealand (incidence: 9 pmpy; prevalence: 55 pmpy [ages 0-17 years old between 2007 and 2018]) and Europe (incidence: 9 pmpy; prevalence: 60 pmpy [ages 0-19 years old between 2005 and 2017]) [19].

A study from the ERA-EDTA registry demonstrated a small reduction of 2.5% per year in the incidence of European patients <19 years old between 2001 and 2011 [88]. Another study with children <15 years old from the ERA-EDTA registry showed stable incidence and an increase in prevalence between 2007 and 2016 [89]. In others national registries, particularly in Asia, the incidence in Taiwan and Malaysia was similar to that reported by the ANZDATA and ERA-EDTA registries, with incidence rates of 8.12 pmpy and 10-11 pmpy, respectively. Incidence and prevalence were lower in Japan, with rates of 4.0 pmpy and 22 pmpy, respectively [41,90,91]. It is believed that the improvement of analysis techniques for young children may have contributed to the increase in incidence among children under five years old in the United States, unlike the overall decreasing trend. These children may have died before transitioning to complete kidney failure due to the lack of resources for dialysis [19].

According to Geylis et al., studies found in the literature suggest that up to one in 10,000 children may have CKD [92]. However, all studies conducted in hospitals underestimate the prevalence, as only patients with manifest CKD, followed in pediatric nephrology centers, are evaluated in these studies [92]. As previously mentioned, there are only a limited number of studies in the general pediatric population, and they present a very different reality from that suggested by current hospital-based studies. In fact, a much higher prevalence of undiagnosed pediatric CKD in stages 2-5 (around 1%) has been reported in cross-sectional studies in Turkey, Iran and China, suggesting a possibly 100 times higher prevalence of pediatric CKD than estimated in hospital-based studies [93-95].

In addition to national health surveys, another approach to estimate the prevalence of evident chronic conditions is to identify cases from administrative data sources, such as health insurance records. Based on data from a single health insurance company in the US, including nearly two million individuals in the pediatric age group (< 21 years old), the prevalence of children and adolescents with a diagnosis code for CKD (ICD-9 and ICD-10) was 27 per 10,000 (0.27%) in 2016 [96], which was a number close to other population-based studies. In this report, the prevalence of pediatric CKD was comparable to that of pediatric diabetes mellitus (31 per 10,000).

In a recent issue of the Pediatric Nephrology Journal, the population prevalence of CKD in Southern Israel was estimated using hospital data

and laboratory data [92]. The strength of the aforementioned study was to use all serum creatinine measurements available after two years of age in the electronic medical records to define CKD as ≥ 2 eGFR values below 60 ml/min/1.73 m^2 at least three months apart, thus including the criterion of chronicity which was overlooked by other studies [92]. The estimated prevalence of children meeting these criteria in 2019 was 1,033 per million population (pmp) (0.1%). The prevalence of children still classified as having CKD at the last follow-up was slightly lower (882pmp) and may be overestimated. Another interesting finding of this study is that a reduction of -1 ml/min/1.73 m^2 in eGFR per year could suggest that it might take decades before these children with mild to moderate CKD (average age of 12 years old and eGFR of 50 ml/min/ 1.73 m^2) reach advanced CKD or kidney failure [92].

According to hospital-based studies on the prevalence of pediatric CKD (ranging from 0.3 to 1 per 10,000 children) and the results of the few population-based studies suggesting a much higher prevalence (from 1 to 10 per 1,000 children), the current total number of children and adolescents in stages 2-5 of CKD worldwide can be extrapolated to two million cases of CKD in a population of two billion children [12]. This is concerning because pediatric CKD falls within the same range as the estimated number of children with cancers, the estimated number of children with type 1 diabetes, and is 10 times higher than the number of children affected by cystic fibrosis [12].

Thus, CKD is one of the most non-communicable pediatric diseases. However, unlike the aforementioned illnesses, public awareness, political attention, and the necessary investment for pediatric CKD are still very poor. This is partly due to the complexity of pediatric CKD, which encompasses many etiologies and a wide spectrum of presentations, ranging from a silent disease in its early stages to its devastating impact on quality of life and life expectancy [12]. As a result, the understanding of pediatric CKD among the public, physicians and health authorities is very low. The lack of awareness among policymakers about pediatric kidney diseases and the consequences of delays in diagnosis and appropriate treatment are major contributors to alarming situations [12]. For example, the rate of late presentation of pediatric CKD, defined as the first visit to pediatric nephrology with complete loss of kidney function, is unacceptably high (> 40%), especially in low-and middle-income countries, reflecting the lack of timely diagnosis and referral to pediatric renal care [97]. Another long-term concern is the demand for better prevention and treatment by pediatric nephrologists [98]. Finally, it has been demonstrated that public investment in specialized and multidisciplinary pediatric renal care is cost-effective in optimizing outcomes such as access to the best treatment and survival [99,100].

Interestingly, pediatric CKD and ESRD in developing countries are lower than in developed countries. However, this may be related to underdiagnosis of the causes of CKD, differences in access to healthcare and regional socioeconomic inequalities. That is the most likely explanation on the differences in prevalence and incidence rates of CKD and ESRD among developed and developing countries. Thus, the importance of pediatric CKD prevention policies is highlighted [81].

2.4 Gender and age

Data from the literature showed that the average age of children with CKD was 10 years old with a predominance of males. The male-to-female ratio ranged from 1:1.05 to 1:1.31), which is also consistent with literature findings. This occurrence is due to the fact that the main cause of CKD was congenital abnormalities of the kidneys and urinary tract (CAKUT), and it was identified more frequently among boys [20,33,70].

A study conducted with 82 children and adolescents undergoing RRT, at a single center in southeastern Brazil (Belo Horizonte) showed a predominance of males, and the average age of the patients was 9.25 years old at the beginning of RRT [54]. This finding is very close to those described in studies on RRT in Serbia [33] (9.8 years old), Korea [101] (9.7 years old), and also in another part of Brazil (12.5 years old) [80]. It can be observed that these are developing countries. Reports from developed countries showed a lower average age at the start of RRT, such as in Italy (6.9 years old) and Spain (3.9 years old) [31,36]. This is likely because in these countries there is greater accessibility to diagnosis, and the main causes of CKD are CAKUT and hereditary diseases, which are diagnosed earlier [31,36].

2.5 Causes and initial modality of RRT

In the three largest registries (USRDS, ANZDATA, ERA-EDTA), the main cause of complete loss of renal function is CAKUT (30%), followed by glomerulonephritis (15-30%). The proportion of CAKUT decreases with advancing age, while glomerulonephritis increases [19]. Similar results have been reported in Japan [19]. However, a systematic review of children requiring dialysis in sub-Saharan Africa demonstrated that primary glomerulonephritis was the main cause (50%) of renal function loss [102]. A similar finding was also reported by Rezende et al., in Belo Horizonte, MG, southeastern Brazil. The authors found that 36.6% of the patients had glomerulonephritis as the cause of renal function loss [54].

Among children and adolescents, the proportion of those who initiated RRT with HD represented approximately half of all incident patients, according to the three major registries (USRDS, ANZDATA, ERA-EDTA) [19]. However, PD was the predominant initial modality of RRT in Japan. When data were stratified by age, PD was prevalent among children under five years old, and HD was more prevalent among the ones aged 15 years old or older [19]. Interestingly, the proportion of HD has decreased in Australia, New Zealand and the United States over time among those aged 15 years old or older, while PD has increased. However, the percentage of HD has increased among children under five years old in all three registries (USRDS, ANZDATA, ERA-EDTA) [19]. The reason for the increasing trends of HD among children under five years old is not clear, and PD remains preferrable to HD in this population.

Regarding preemptive kidney transplantation, its proportion has remained unchanged in the last decade. This type of transplant seems to be more common in Europe than in the other two regions, accounting for approximately 25%. However, its proportion varies within European countries, and the rate of preemptive transplantation was 17% according to a more comprehensive survey of European children, which is similar to the rates in the other two regions [103].

Social contexts influence the choice of RRT, including economic, ethnic, religious factors, and the transplant allocation system. As a result, the distribution of RRT modalities varies between countries. According to the Global Registry of the International Pediatric Nephrology Association for Renal Replacement Therapy, the prevalence of RRT, especially regarding transplantation, varies considerably among countries. Additionally, pediatric RRT is not available in countries with limited resources [104,105]. As mentioned earlier, a systematic review of studies in Sub-Saharan Africa showed that approximately 60% of children had access to dialysis [102]. Among them, 46% and 54% received HD and PD, respectively. It is worth noting that almost all studies included in the review were from centers with dialysis facilities, and therefore the percentages may be overestimated. RRT is not adequately available in most African countries due to limited financial resources or a shortage of dialysis clinics and pediatric nephrologists [104,105].

A study conducted at a single tertiary dialysis center in Turkey from 1998 to 2018 showed that when kidney transplantation is delayed, PD can become a long-term maintenance treatment. It is important noting that Turkey is classified as a high-middle-income country by the World Health Organization [106].

An evaluation conducted in the State of Amazonas, Brazil, with pediatric patients on TRS showed that the majority (80%) were on HD and were adolescents. Half of them did not have a diagnosis of the underlying cause

of CKD, and there was a frequency of 24 new cases per year and 16.3 per million population (pmpi) [107]. The authors reported that there are differences between the proposed RRT modalities when comparing developed and developing countries [107]. In Brazil, these differences are evident. The mentioned state is the largest in Brazil in terms of territorial extension, and the considerable distance between the capital, which is the only place that offers RRT, and the countryside becomes a significant barrier to achieving an early diagnosis in time to propose appropriate conservative treatment.

2.6 Survival

Advancements in diagnoses and treatments have increased the survival rates of children and adolescents with CKD and ESRD. Ideally, it would be beneficial to understand the epidemiology of CKD before the need for TRS, in order to effectively intervene in its prevention or delay its progression [19]. In this context, it becomes essential to assess the outcomes of renal disease progression [3]. The challenge is to verify relevant results through long-term observations and find evidence that will provide epidemiological data on CKD and ESRD (incidence, prevalence, risk factors for progression and mortality, underlying causes, age, sex, race, socioeconomic factors and medical resources), and thus propose appropriate follow-up and treatment for the pediatric population [12].

Children and adolescents with ESRD are exposed to a 30 to 60 times higher risk of mortality compared to their healthy peers [4,108]. However, there is no doubt that the mortality rate has improved over time in many countries [109-111]. Cardiovascular disease is the most common cause of death in the United States, Canada, Australia and New Zealand, where the percentages have been reported to be between 25 to 40% [110-112]. On the other hand, infection is the most common cause in other countries or regions, including those in Europe and Asia, where the reported percentages have ranged from 20 to 40% [4,42,43,113,114].

Although the various registries have heterogeneous study populations, several factors may be associated with a higher risk of mortality in the pediatric population on TRS, such as: younger age, especially under 5 years old [109,110,113]; female gender [109-111]; non-white patients [110,113,114]; patients on dialysis compared to those with a transplant [109,115] or patients on HD compared to DP among those on dialysis [110,116]; non-CAKUT etiology [110,111,113]; and the presence of comorbidities [110,117]. Other factors that may be independently associated with high mortality include: short stature [118,119], low and high body mass index [119-121], anemia [122,123], hypoabuminemia [123-125] and high eGFR at the start of dialysis [112,126]. These factors may be modifiable in clinical practice. Therefore, it is important to identify the underlying mechanisms (skin color, gender) that lead to worse outcomes considering the etiology of ESRD.

Although the study cohorts are heterogeneous, the obtained results are relatively consistent and may be applicable in clinical practice worldwide. However, studies from other countries or regions are still needed to achieve even better outcomes for these patients.

Bonthius et al., in the European Society for Paediatric Nephrology (ESPN)-ERA-EDTA Registry, included data on pediatric patients with ESRD receiving RRT in Europe over a 10-year period. During the follow-up, 225 patients died after a median of 4.1 years (1,9–6,4). Overall, the 1-year-old, 2-year-old and 5-year-old patient survival rates were 97,6% (95% CI: 97,1–98,1), 96,4% (95% CI:95,8–96,9) and 94,4% (95% CI: 93,6–95,2), respectively [73]. The majority of patients died from cardiovascular disease (28.9%), followed by infections (22,7%), and in 23.1% of patients, the cause of death was unknown [73]. For patients who started RRT between 2007-2009, the unadjusted 5-year survival probability was 93.9% (95% CI: 92.6-95.2), while it was 93.3% (95% CI:91.8-94.7) for patients who started RRT between 2010 and 2012 [73]. After adjusting for age, sex, cause of ESRD, and treatment modality at the beginning, the patient survival at 1, 2 and 5 years old did not differ between the periods (2010-2012 *vs*. 2007-2009: 0.98, 95% CI: 0.71-1.35). However, the causes of death differed between the two periods: patients who started RRT between 2007 and 2009 died more frequently from infections (31.3%), while cardiovascular disease was the most common cause of death (41.3%) in those patients who started RRT between 2010 and 2012 ($P < 0,001$) [73].

As mentioned above, the authors concluded that the survival of pediatric patients on RRT at 1 and 5 years old was 98% and 94%, respectively, and is similar or slightly higher than the rates reported in other high-income countries [73,127]. Although the mortality of pediatric patients on RRT at one year of age has decreased by 20% in the last decade in the USA, the likelihood of improvement in the 5-year survival of these patients has probably reached its limit. Unfortunately, mortality remains at least 30 times higher than in the general pediatric population [73,127].

According to worldwide data, approximately 9 out of every million patients under 20 years of age in developed countries require RRT [11,116,127]. The age of the pediatric population at the start of RRT is a determining factor for survival, and the risk of mortality in patients on RRT remains higher in the neonatal population, followed by the children's group, and then the adolescents [128]. A study conducted over 10 years in the 1960s in Australia and New Zealand identified 110 deaths per 1,000 pediatric patients on RRT. However, by the 1990s, the number of deaths in these countries had stabilized to 18 per 1,000 patients [127].

According to van der Heijden et al., a European registry from 1980 to 1984 showed a 36% decrease in the risk of mortality in pediatric patients, and from 1995 to 2000, the number of deaths decreased approximately 79% in the subgroup of children aged 0 to 4 years old [128]. In the period from 1990 to 2010, in the United States, there was an increase in survival in pediatric RRT patients. According to the authors, every five years, there was a 12% reduction in deaths for children over five years old and a 20% reduction for children under five years old [129].

The survival of these patients is determined by multiple factors, such as access to treatment, the amount of investment that each country makes in the healthcare sector, the etiology of the disease, age, possibility of transplantation, weight development issues, sex, body mass index, race and the presence of comorbidities [11]. It appears that girls have a higher risk of mortality than boys [109], and race or ethnicity can also affect the risk or mortality in the pediatric RRT population. In the United States, being black was associated with a 25% higher risk of death compared to white recipients in the first transplant, and a 64% higher risk of death in patients on RRT [110].

Data taken from the Swiss Pediatric Renal Registry by Maurer et al., evaluating 367 children and adolescents undergoing RRT, demonstrated over four decades (1970-80, 1981-90, 1991-2000 and 2001-10) that the one-year-old graft survival rate improved from 0.76 to 0.80, 0.89 and then 0.96, respectively [130]. The five-year-old graft survival rate improved from 0.44 to 0.64, 0.84 and 0.89, respectively. The five-year-old patient survival rates for the four decades were 0.83, 0.99, 0.93 and 0.94; and the ten-year-old patient survival rates were 0.75, 0.96, 0.88 and 0.94, respectively [130]. In the four cohorts that started RRT in the 1970s, 1980s, 1990s and 2000s, the number of children alive after five years of this therapy increased from 15 to 24, 47, and then 45, respectively. In total, 29 patients (8%) died during chronic RRT before the age of 20. The authors concluded that over time a greater number of children on RRT survived and graft survival improved [130].

A study conducted in a single center in Belo Horizonte, MG, showed that younger patients with less time on RRT and those who did not undergo kidney transplantation had higher mortality rates, and in 56% of cases, sepsis was the main cause of death [54]. The overall survival rate was 80.6% after 96 months, and the patients who died had less time on RRT

(p=0.023) and were significantly younger than the others (p=0.0006). The authors also concluded that patients who underwent transplantation had a higher survival rate than those who remained on dialysis treatment [54].

Regarding patient and graft survival, it is known that kidney transplantation provides survival benefits compared to dialytic treatment. However, children who undergo transplantation still face a high risk of mortality compared to the general population, and graft loss is as relevant an outcome as mortality among these patients. Epidemiological studies report that both graft and patient survival have improved over time in both developed [131] and developing [132] countries. Considering independent risk factors for mortality among kidney transplant recipients, we can mention: female sex [133], non-ESRD/non-CAKUT etiology [131,134], non-preemptive kidney transplant [135], presence of comorbidities [133], deceased donor transplant [131,133], childhood and adolescence [112,131].

Regarding graft failure, the following factors are considered high independent risk factors: adolescence [101,112,136,137], female sex [137-139], non-white race [137,139,140], glomerulonephritis and focal segmental glomerulosclerosis as causes of ESRD [134,137,139,140], non-preemptive kidney transplant [135,137], and deceased donor transplant [113,135,136,139]. In addition to the factors already mentioned, others may be independently associated with graft survival. These include: non-adherence to treatment [136,139], donor age [137], cold ischemia time [138], delayed graft function [140], obesity [141], hyperphosphatemia [142], and human leukocyte antigen incompatibility [138-140].

2.7 Conclusions

Pediatric CKD has distinct characteristics from the disease in adults and can lead to severe and specific complications. It can be caused by urological problems such as CAKUT or non-CAKUT-related issues, followed by hereditary diseases like glomerulopathies, which may vary with age and be more common in older age groups. Several risk factors for CKD and ESRD can be identified. Among the modifiable factors are metabolic acidosis, proteinuria, arterial hypertension, and underlying urological abnormalities; among the non-modifiable factors are age, sex, racial and genetic factors, low birth weight, prematurity, and socioeconomic status.

The average age of pediatric CKD is around 10 years with a predominance of males (the male-to-female ratio ranging from 1:1.05 to 1:1.32). Children and adolescents with ESRD are exposed to 30 to 60 times higher risk of mortality compared to their healthy peers, but the survival rate has improved over time in many countries.

Considering hospital-based studies examining the prevalence of pediatric CKD (0.3 to 1 per 10,000 children) and the limited population-based studies suggesting a much higher prevalence (1 to 10 per 1,000 children), the current total number of children and adolescents affected by stages 2-5 of CKD worldwide can be extrapolated to over two million cases of CKD in a population of two billion children.

Public awareness, political attention and the necessary investment for pediatric CKD and ESRD are still very poor. This is partly due to the complexity of these conditions, which encompass many etiologies (often rare diseases) and involve a wide spectrum of presentations, often starting as a silent disease. However, it can progress with devastating impact on quality and life expectancy. Lack of public awareness, lack of awareness among policy makers about pediatric kidney disease and the consequences of delays in diagnosis and appropriate treatment are major contributors to the current alarming situation. The rate of late presentation of pediatric CKD, defined as the first consultation with a pediatric nephrologist already with some loss of renal function, is unacceptably high (> 40%), especially in low and middle-income countries, reflecting the lack of timely diagnosis and referral to pediatric renal care. Another concerning long-term situation is the association of clinically evident but mild CKD in pediatric patients with an increased risk of kidney failure in young adults. This fact further highlights the demand for better prevention and treatment by pediatric nephrologists.

Therefore, there is a need to raise awareness about pediatric CKD to improve health outcomes. This requires collecting more population-based data, registries, and cohorts that include not only ESRD but also the early stages of CKD where kidney failure can be delayed or prevented, evaluating the impact of population screening interventions in children with CKD risk factors. The implementation and execution of CKD prevention programs are essential in primary care. Identifying individuals with CKD risk factors and referring them for evaluation by a pediatric nephrologist who will provide conservative treatment along with a multidisciplinary team will delay disease progression and, consequently, the need for ESRD treatment.

Given the information presented about CKD and ESRD in children and adolescents, their therapeutic modalities, the increasing incidence and prevalence of the disease in both adult and pediatric populations, and the possibilities of prevention and delaying the progression of CKD to ESRD, it is crucially relevant to understand the detailed profile of the pediatric population on ESRD treatment to obtain important and necessary data for the adjustment of healthcare policies.

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References:

1. Yang CW, Harris DCH, Luyckx VA, Nangaku M, Hou FF, Garcia Garcia G, Abu-Aisha H, Niang A, Sola L, Bunnag S, Eiam-Ong S, Tungsanga K, Richards M, Richards N, Goh BL, Dreyer G, Evans R, Mzingajira H, Twahir A, McCulloch MI, Ahn C, Osafo C, Hsu HH, Barnieh L, Donner JA, Tonelli M. (2011) Global case studies for chronic kidney disease/end-stage kidney disease care. Kidney Int Suppl 10(1):e24-e48.
2. Dienemann T, Fujii N, Orlandi P, Nessel L, Furth SL, Hoy WE, Matsuo S, Mayer G, Methven S, Schaefer F, Schaeffner ES, Solá L, Stengel B, Wanner C, Zhang L, Levin A, Eckardt KU, Feldman HI. (2016) International Network of Chronic Kidney Disease cohort studies (iNET-CKD): a global network of chronic kidney disease cohorts. BMC Nephrol. 2;17(1):121.
3. Atkinson MA, Ng DK, Warady BA, Furth SL, Flynn JT. (Mar) The CKiD study: overview and summary of findings related to kidney disease progression. Pediatr Nephrol. 2021 36(3):527-538.
4. Chesnaye N, Bonthuis M, Schaefer F, Groothoff JW, Verrina E, Heaf JG, Jankauskiene A, Lukosiene V, Molchanova EA, Mota C, Peco-Antić A, Ratsch IM, Bjerre A, Roussinov DL, Sukalo A, Topaloglu R, Van Hoeck K, Zagozdzon I, Jager KJ, Van Stralen KJ; ESPN/ERA–EDTA registry. (2014) Demographics of paediatric renal replacement therapy in Europe: a report of the ESPN/ERA-EDTA registry. Pediatr Nephrol. 29(12):2403-2410.
5. Inker LA, Astor BC, Fox CH, Isakova T, Lash JP, Peralta CA, Kurella Tamura M, (2014) Feldman HI. KDOQI US commentary on the 2012 KDIGO clinical practice guideline for

the evaluation and management of CKD. Am J Kidney Dis. 63(5):713-735.
6. Lamb EJ, Levey AS, Stevens PE. (2013) The Kidney Disease Improving Global Outcomes (KDIGO) guideline update for chronic kidney disease: evolution not revolution. Clin Chem. 59(3):462-465.
7. Bersan SA, Amaral CF, Gomes IC, Cherchiglia ML. (2013) Letalidade e internacões de pacientes em hemodiálise em plano de saúde [Fatality and hospitalization in hemodialysis patients in a health plan]. Rev Saude Publica. 47(3):624-633.
8. Cherchiglia ML, Machado EL, Szuster DA, Andrade EI, Assis Acúrcio Fd, Caiaffa WT, Sesso R, Guerra Junior AA, Queiroz OV, Gomes IC. (2010) Epidemiological profile of patients on renal replacement therapy in Brazil, 2000-2004. Rev Saude Publica. 44(4):639-649.
9. Sesso R de CC, Lopes AA, Thomé FS, Lugon JR, Burdmann EA. (2010) Censo Brasileiro de Diálise, 2009. Braz J Nephrol [Internet]. 32(4):380–384.
10. Bastos MG, Kirsztajn GM. (2011) Doença renal crônica: a importância do diagnóstico precoce, encaminhamento imediato e abordagem interdisciplinar estruturada para melhora do desfecho em pacientes ainda não submetidos à diálise. Braz J Nephrol. 33(1):93-108.
11. Jager KJ, Kovesdy C, Langham R, Rosenberg M, Jha V, Zoccali C. (2019) A single number for advocacy and communication – worldwide more than 850 million individuals have kidney diseases. Nephrol Dial Transplant. 34:1803–1805.
12. Harambat J, Madden I. (2023) What is the true burden of chronic kidney disease in children worldwide? Pediatr Nephrol. 38(5):1389-1393.
13. Cherchiglia ML, Guerra Júnior AA, Andrade EIG, Machado CJ, Acúrcio F de A, Meira Júnior W, et al. (2007) A construção da base de dados nacional em Terapia Renal Substitutiva (TRS) centrada no indivíduo: aplicação do método de linkage determinístico-probabilístico. Rev bras estud popul [Internet]. 24(1):163–167.
14. Ministério da Saúde - Brasil. PORTARIA Nº 1.168, DE 15 DE JUNHO DE 2004-2006.
15. Grassmann A, Gioberge S, Moeller S, Brown G. ESRD patients in (2004) global overview of patient numbers, treatment modalities and associated trends. Nephrol Dial Transplant. 20(12):2587-2593.
16. Censo Brasileiro de (2022) - Instituto Brasileiro de Geografia e Estatística
17. Censo de Diálise da Sociedade Brasileira de Nefrologia 2022.
18. Sesso R de CC, Lopes AA, (2010) Thomé FS, Lugon JR, Burdmann EA. Censo Brasileiro de Diálise, 2009. Braz J Nephrol [Internet]. 32(4):380–384.
19. Harada R, Hamasaki Y, Okuda Y, Hamada R, Ishikura K. (2022) Epidemiology of pediatric chronic kidney disease/kidney failure: learning from registries and cohort studies. Pediatr Nephrol. 37(6):1215-1229.
20. Harambat J, van Stralen KJ, Kim JJ, Tizard EJ. (2012) Epidemiology of chronic kidney disease in children. Pediatr Nephrol. 27:363–373.
21. Chevalier RL (2015) Congenital urinary tract obstruction: the long view. Adv Chronic Kidney Dis. 2015; 22:312–319.
22. USRDS (2018) 2018 USRDS annual data report: volume 1: chronic kidney disease, Chapter 6.
23. USRDS (2018) 2018 USRDS annual data report: volume 2: end stage renal disease, Chapter 7.
24. North American Pediatric Renal Transplant Cooperative Study (NAPRTCS) (2008) Annual report. The EMMES Corporation, Rockville, MD.
25. Samuel SM, Tonelli MA, Foster BJ, Alexander RT, Nettel-Aguirre A, Soo A, Hemmelgarn BR, (2011) Pediatric Renal Outcomes Canada Group. (2011) Survival in pediatric dialysis and transplant patients. Clin J Am Soc Nephrol. 6:1094–1099.
26. USRDS (2019) USRDS annual data report: epidemiology of kidney disease in the United States 2019.
27. Wong CJ, Moxey-MimsM, Jerry-Fluker J, Warady BA, Furth SL. (2012) CKiD (CKD in children) prospective cohort study: a review of current findings. Am J Kidney Dis. 60:1002–1011.
28. Soares CM, Oliveira EA, Diniz JS, Lima EM, Vasconcelos MM, Oliveira GR. (2003) Predictive factors of progression of chronic renal insufficiency: a multivariate analysis. Pediatr Nephrol. 18:371–377.
29. Groothoff JW, Gruppen MP, Offringa M, Hutten J, Lilien MR, Van De Kar NJ, Wolff ED, Davin JC, Heymans HS. (2002) Mortality and causes of death of end-stage renal disease in children: a Dutch cohort study. Kidney Int. 61:621–629.
30. Esbjörner E, Berg U, Hansson S. (1997) Epidemiology of chronic renal failure in children: a report from Sweden 1986-1994. Swedish Pediatric Nephrology Association. Pediatr Nephrol. 11:438–442.
31. Ardissino G, Dacco V, Testa S, Bonaudo R, Claris-Appiani A, Taioli E, Marra G, Edefonti A, Sereni F, ItalKid Project. (2003) Epidemiology of chronic renal failure in children: data from the ItalKid Project. Pediatrics. 111:e382–e387.
32. Deleau J, Andre JL, Briancon S, Musse JP. (1975-1990) Chronic renal failure in children: an epidemiological survey in Lorraine (France) Pediatr Nephrol. 1994; 8:472–476.
33. Peco-Antic A, Bogdanovic R, Paripovic D, Paripovic A, Kocev N, Golubovic E, Milosevic B, (2012) Serbian Pediatric Registry of Chronic Kidney Disease. Epidemiology of chronic kidney disease in children in Serbia. Nephrol Dial Transplant. 27:1978–1984.
34. Mong Hiep TT, Ismaili K, Collart F, Van Damme-Lombaerts R, Godefroid N, Ghuysen MS, Van Hoeck K, Raes A, Janssen F, Robert A. (2010) Clinical characteristics and outcomes of children with stage 3-5 chronic kidney disease. Pediatr Nephrol. 25:935–940.
35. Bek K, Akman S, Bilge I, Topaloglu R, Caliskan S, Peru H, Cengiz N, Soylemezoglu O. (2009) Chronic kidney disease in children in Turkey. Pediatr Nephrol. 24:797–806.
36. Areses Trapote R, Sanahuja Ibáñez MJ, Navarro M. (2010) Epidemiology of chronic kidney disease in Spanish pediatric population. REPIR II Project. Nefrologia. 30:508–517.
37. ERA–EDTA Registry (2020) ERA–EDTA Registry paediatric data:
38. Pyart R, EvansKM, Steenkamp R, Casula A,Wong E, Magadi W, Medcalf J. (2020) The 21st UK Renal Registry annual report: a summary of analyses of adult data in 2017. Nephron. 144:59–66.
39. Hooman N, Esfahani ST, Mohkam M, Derakhshan A, Gheissari A, Vazirian S, Mortazavi F, Ghane-Sherbaff F, Falak-Aflaki B, Otoukesh H, Madani A, Sharifian-Dorcheh M, Mahdavi A, Esmaeile M, Naseri M, Azhir A, Merikhi A, Mohseni P, Ataei N, Fallahzadeh MH, Basiratnia M, Hosseini-Al-Hashemi G. (2009) The outcome of Iranian children on continuous ambulatory peritoneal dialysis: the first report of Iranian National Registry. Arch Iran Med. 12:24–28.
40. Lin HH, Tsai CW, Lin PH, Cheng KF, Wu HD, Wang IK, Lin CY, Chen W, Huang CC. (2012) Survival analysis of pediatric dialysis patients in Taiwan. Nephrology (Carlton). 17:621–627.
41. Hattori S, Yosioka K, Honda M, Ito H, (2002) Japanese Society for Pediatric Nephrology. The 1998 report of the Japanese National Registry data on pediatric end-stage renal disease patients. Pediatr Nephrol. 17:456–461.
42. Chang HJ, HanKH, ChoMH, ParkYS, KangHG, Cheong HI, Ha IS. (2014) Outcomes of chronic dialysis in Korean children with

respect to survival rates and causes of death. Korean J Pediatr. 57:135–139.
43. Hattori M, Sako M, Kaneko T, Ashida A, Matsunaga A, Igarashi T, Itami N, Ohta T, Gotoh Y, Satomura K, Honda M, Igarashi T. (2015) End-stage renal disease in Japanese children: a nationwide survey during 2006-2011. Clin Exp Nephrol. 19:933–938.
44. Chou HH, Lin CY, Chiou YH, Tain YL, Wang YF, Wang HH, Chiou YY (2016) Clinical characteristics and prevalence of complications of chronic kidney disease in children: the Taiwan Pediatric Renal Collaborative study. Pediatr Nephrol 31:1113–1120.
45. Ishikura K, Uemura O, Ito S, Wada N, Hattori M, Ohashi Y, Hamasaki Y, Tanaka R, Nakanishi K, Kaneko T, Honda M, (2013) Pediatric CKD Study Group; Japan Committee of Measures for Pediatric CKD of the Japanese Society of Pediatric Nephrology. Pre-dialysis chronic kidney disease in children: results of a nationwide survey in Japan. Nephrol Dial Transplant. 28:2345–2355.
46. Kang HG, Choi HJ, Han KH, Kim SH, Cho HY, Cho MH, Shin JI, Lee JH, Lee J, Oh KH, Park YS, Cheong HI, Ahn C, Ha IS. (2016) KNOW-Ped CKD (Korea N cohort study for outcomes in patients with pediatric CKD): design and methods. BMC Nephrol. 17:35.
47. ANZDATA Registry 42nd report 2019.
48. Schwartz GJ, Mu.oz A, Schneider MF, Mak RH, Kaskel F, Warady BA, Furth SL. (2009) New equations to estimate GFR in children with CKD. J Am Soc Nephrol. 20:629–637.
49. Pierce CB, Mu.oz A, Ng DK, Warady BA, Furth SL, Schwartz GJ. (2021) Age- and sex-dependent clinical equations to estimate glomerular filtration rates in children and young adults with chronic kidney disease. Kidney Int. 99:948–956.
50. Hogg RJ, Furth S, Lemley KV, Portman R, Schwartz GJ, Coresh J, Balk E, Lau J, Levin A, Kausz AT, Eknoyan G, Levey AS, Kidney National, Foundation's Kidney Disease Outcomes Quality Initiative (2003) National Kidney Foundation's Kidney Disease Outcomes Quality Initiative clinical practice guidelines for chronic kidney disease in children and adolescents: evaluation, classification, and stratification. Pediatrics. 111:1416–1421.
51. Kidney Disease: (2013) Improving Global Outcomes CKD Work Group. KDIGO clinical practice guideline for the evaluation and management of chronic kidney disease. Kidney Int Suppl. 3:1–150.
52. Furth SL, Cole SR, Moxey-Mims M, Kaskel F, Mak R, Schwartz G, Wong C, Mu.oz A, Warady BA. (2006) Design and methods of the Chronic Kidney Disease in Children (CKiD) prospective cohort study. Clin J Am Soc Nephrol. 1:1006–1015.
53. Querfeld U, Anarat A, Bayazit AK, Bakkaloglu AS, Bilginer Y, Caliskan S, Civilibal M, Doyon A, Duzova A, Kracht D, Litwin M, Melk A, Mir S, S.zeri B, Shroff R, Zeller R, Wühl E, Schaefer F, 4C Study Group. (2010) The Cardiovascular Comorbidity in Children with Chronic Kidney Disease (4C) study: objectives, design, and methodology. Clin J Am Soc Nephrol. 5:1642–1648.
54. Rezende CF, Penido MGMG, Alvarenga AS, Cherchiglia ML, Nery VL. (2021) Pediatric patients on renal replacement therapy: clinic, epidemiological, social and economic profile. Urol & Nephrol Open Access J (UNOAJ). 9(1):1-6.
55. Rezende CF, Alvarenga AS, Cherchiglia ML, Penido MGMG. (2021) Doença Renal Crônica e suas Consequências na Criança e no Adolescente. Arch Latin Nefr Ped 20(1):40-59.
56. National Kidney Foundation. Clinical Practice Guidelines for Chronic Kidney Disease: Evaluation, (2002) Classification and Stratification [Internet]. Vol. 39, American Journal of Kidney Diseases. 1-356 p. A
57. Stevens PE, Levin A, Bilous RW, Coresh J, de Francisco AL, de Jong P, Griffith KE, Hemmelgarn BR, Iseki K, Lamb EJ, Levey AS, Riella MC, Shlipak MG, Wang H,White CT, Winearls CG (2013) (Kidney Disease: Improving Global Outcomes Chronic Kidney Disease Guideline Development Work Group Members). Evaluation and management of chronic kidney disease: synopsis of the kidney disease: improving global outcomes 2012 clinical practice guideline. Ann Intern Med 158: 825-830.
58. Esbjörner E, Aronson S, Berg U, Jodal U, Linne T. (1990) Children with chronic renal failure in Sweden 1978-1985. Pediatr Nephrol. 4(3):249-252; discussion 253-254.
59. Kim JJ, Booth CJ, Waller S, Rasmussen P, Reid CJ, Sinha MD. (2013) The demographic characteristics of children with chronic kidney disease stages 3–5 in South East England over a 5-year period. Arch Dis Child 98:189–194.
60. Al-Eisa A, Naseef M, Al-Hamad N, Pinto R, Al-Shimeri N, Tahmaz M. (2005) Chronic renal failure in Kuwaiti children: an eight-year experience. Pediatr Nephrol. 20:1781–1785.
61. Landau D, Schreiber R, Kleinman A, Vodonos A, Shalev H. Pediatric chronic kidney disease rates in Southern Israel are higher than reported. F1000Res 2013; 2:186.
62. Orta-Sibu N, Exeni RA, Garcia C (2009) Latin America. In: Avner ED, Harmon WE, Niaudet P, Yoshikawa N (eds) Pediatric Nephrology. Springer-Verlag, Heidelberg, pp 1969-1974.
63. Lagomarsimo E, Valenzuela A, Cavagnaro F et al. (1996) Chronic renal failure in pediatrics Chilean survey. Pediatr Nephrol 1999; 13:288-291.
64. Al-Eisa A, Naseef M, Al-Hamad N et al. (2005) Chronic renal failure in Kuwaiti children: an eight-year experience. Pediatr Nephrol 20:1781-1785.
65. Hamed RM. (2002) The spectrum of chronic renal failure among Jordanian children. J Nephrol 15:130-135.
66. Mong Hiep TT, Janssen F, Ismaili K et al. (2008) Etiology and outcome of chronic renal failure in hospitalized children in Ho Chi Minh City, Vietnam. Pediatr Nephrol 23:965-970.
67. Huong NT, Long TD, Bouissou F et al. (2009) Chronic kidney disease in children: The National Paediatric Hospital experience in Hanoi, Vietnam. Nephrology (Carlton) 14:722-727.
68. Anochie I, Eke F. (1985) Chronic renal failure in children: a report from Port Harcourt, Nigeria. Pediatr Nephrol 2003; 18:692-695.
69. Bhimma R, Adhikari M, Asharam K et al. (2008) The spectrum of chronic kidney disease (stages 2-5) in KwaZulu-Natal, South Africa. Pediatr Nephrol 23:1841-1846.
70. Masalskienė J, Rudaitis Š, Vitkevič R, Čerkauskienė R, Dobilienė D, Jankauskienė A. (2021) Epidemiology of Chronic Kidney Disease in Children: A Report from Lithuania. Medicina (Kaunas). 26;57(2):112.
71. Ahn, S.Y.; Moxey-Mins, M. (2018) CKD in children: The importance of a national epidemiologic study. AJKD 72, 628–630.
72. Tasic, V.; Janchevska, A.; Emini, N.; Sahpazova, E.; Gucev, Z.; Polenakovic, M. (2016) Chronic kidney disease—Pediatric risk factors. Prilozi (Makedon Akad Nauk Umet Odd Med Nauki) 37, 9–13.
73. Bonthuis M, Vidal E, Bjerre A, Aydoğ Ö, Baiko S, Garneata L, Guzzo I, Heaf JG, Jahnukainen T, Lilien M, Mallett T, Mirescu G, Mochanova EA, Nüsken E, Rascher K, Roussinov D, Szczepanska M, Tsimaratos M, Varvara A, Verrina E, Veselinović B, Jager KJ, Harambat J. (2021) Ten-year trends in epidemiology and outcomes of pediatric kidney replacement therapy in Europe: data from the ESPN/ERA-EDTA Registry. Pediatr Nephrol. 36(8):2337-2348.
74. US Renal Data System, USRDS (2010) Annual data report: atlas of chronic kidney disease and end-stage renal disease in the

United States. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, Bethesda, MD.
75. McTaggart S, McDonald S, Henning P et al (2009) Paediatric Report. ANZDATA Registry Report 2009, Australia and New Zealand Dialysis and Transplant Registry. Adelaide, South Australia.
76. Registry ERA-EDTA (2010) ERA-EDTA Registry Annual Report 2008. Academic Medical Center, Department of Medical Informatics, Amsterdam, The Netherlands.
77. Van Stralen KJ, Tizard EJ, Jager KJ et al. (2010) Determinants of eGFR at start of renal replacement therapy in paediatric patients. Nephrol Dial Transplant 25:3325-3332.
78. US Renal Data System, USRDS (2008) Annual data report: atlas of chronic kidney disease and end-stage renal disease in the United States. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, Bethesda, MD.
79. Lim YN, Lim TO (2009) 16th Report of the Malaysian Dialysis and Transplant 2008, Kuala Lumpur. 38. Garcia C, Goldani J, Garcia V. Paediatric dialysis and renal transplantation in the state of Rio Grande do Sul, Brazil. Pediatr Nephrol 1992; 6:74-77.
80. Al-Eisa AA, Samhan M, Naseef M. (2004) End-stage renal disease in Kuwaiti children: an 8-year experience. Transplant Proc 36:1788-1791.
81. Konstantyner T, Sesso R, Camargo MF et al. (2015) Pediatric Chronic Dialysis in Brazil: Epidemiology and Regional Inequalities. PLOS One 10(8): 1-15.
82. Lewis MA, Shaw J, Sinha MD et al. UK Renal Registry 12th Annual Report (2009): chapter 14: demography of the UK paediatric renal replacement therapy population in Nephron Clin Pract 2010; 115:c279-c288.
83. Vigneau C, Kolko A, Stengel B, Jacquelinet C, Landais P, Rieu P, Bayat S, Couchoud C, REIN Registry. (2017) Ten-years trends in renal replacement therapy for end-stage renal disease in mainland France: lessons from the French Renal Epidemiology and Information Network (REIN) registry. Nephrol Ther 13:228–235
84. Calderon-Margalit R, Golan E, Twig G, Leiba A, Tzur D, Afek A, Skorecki K, Vivante A. (2018) History of childhood kidney disease and risk of adult end-stage renal disease. N Engl J Med 378:428–438.
85. Perl J, McArthur E, Tan VS, Nash DM, Garg AX, Harel Z, Li AH, Sood MM, Ray JG, Wald R. (2018) ESRD among immigrants to Ontario, Canada: a population-based study. J Am Soc Nephrol 29:1948–1959.
86. Virsilas E, Cerkauskiene R, Masalskiene J, Rudaitis S, Dobiliene D, Jankauskiene A. Renal replacement therapy in children in Lithuania: challenges, trends, and outcomes. Medicina (Kaunas) 2018; 54:78
87. ERA-EDTA Registry (2019) ERA-EDTA Registry annual report 2017
88. Pippias M, Jager KJ, Kramer A, Leivestad T, Sánchez MB, Caskey FJ, Collart F, Couchoud C, Dekker FW, Finne P, Fouque D, Heaf JG, Hemmelder MH, Kramar R, De Meester J, Noordzij M, Palsson R, Pascual J, Zurriaga O, Wanner C, Stel VS. (2016) The changing trends and outcomes in renal replacement therapy: data from the ERA-EDTA Registry. Nephrol Dial Transplant 31:831–841
89. Bonthuis M, Vidal E, Bjerre A, Aydoğ Ö, Baiko S, Garneata L, Guzzo I, Heaf JG, Jahnukainen T, Lilien M,Mallett T,Mirescu G, Mochanova EA, Nüsken E, Rascher K, Roussinov D, Szczepanska M, Tsimaratos M, Varvara A, Verrina E, Veselinović B, Jager KJ, Harambat J. (2021) Ten-year trends in epidemiology and outcomes of pediatric kidney replacement therapy in Europe: data from the ESPN/ERA-EDTA Registry. Pediatr Nephrol.
90. Hattori M, Sako M, Kaneko T, Ashida A, Matsunaga A, Igarashi T, Itami N, Ohta T, Gotoh Y, Satomura K, Honda M, Igarashi T. (2006) End-stage renal disease in Japanese children: a nationwide survey during. Clin Exp Nephrol 2015; 19:933–938.
91. Wong H, Goh B, Ghazali A, Lim Y, Lui W, Lee M (2018) 24th report of the Malaysian Dialysis and Transplant Registry 2016.
92. Geylis M, Coreanu T, Novack V, Landau D. (2023) Risk factors for childhood chronic kidney disease: a population-based study. Pediatr Nephrol. 38:1569–1576
93. Soylemezoglu O, Duzova A, Yal.inkaya F, Arinsoy T, Süleymanlar G. (2012) Chronic renal disease in children aged 5–18 years: a population-based survey in Turkey, the CREDIT-C study. Nephrol Dial Transplant 27(Suppl 3):iii146-151.
94. Gheissari A, Kelishadi R, Roomizadeh P, Abedini A, Haghjooy-Javanmard S, Abtahi SH, Mehdikhani B, Shafiei M (2013) Chronic kidney disease stages 3–5 in Iranian children: need for a school-based screening strategy: the CASPIAN-III Study. Int J Prev 4:95–101.
95. Song P, Wang M, Chang X, Wang J, Wei W, An L. (2019) Prevalence and associated factors of impaired renal function in Chinese children: the China Health and Nutrition Survey. Nephrology (Carlton) 24:195–201.
96. United States Renal Data System (2018) USRDS annual data report: epidemiology of kidney disease in the United States. Chronic kidney disease chapter 6: CKD among children and adolescents. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, Bethesda, MD.
97. Plumb L, Boother EJ, Caskey FJ, Sinha MD, Ben-Shlomo Y. (2020) The incidence of and risk factors for late presentation of childhood chronic kidney disease: a systematic review and metaanalysis. PLoS One 15:e0244709.
98. Calderon-Margalit R, Golan E, Twig G, Leiba A, Tzur D, Afek A, Skorecki K, Vivante A. (2018) History of childhood kidney disease and risk of adult end-stage renal disease. N Engl J Med 378:428–438.
99. Amaral S, McCulloch CE, Lin F, Grimes BA, Furth S, Warady B, Brunson C, Siyahian S, Ku E. (2022) Association between dialysis facility ownership and access to the waiting list and transplant in pediatric patients with end-stage kidney disease in the US. JAMA 328:451–459.
100. Chesnaye NC, Schaefer F, Bonthuis M, Holman R, Baiko S, Baskın E, Bjerre A, Cloarec S, Cornelissen EAM, Espinosa L, Heaf J, Stone R, Shtiza D, Zagozdzon I, Harambat J, Jager KJ, Groothoff JW, van Stralen KJ, (2017) ESPN/ERA-EDTA Registry Committee. Mortality risk disparities in children receiving chronic renal replacement therapy for the treatment of end-stage renal disease across Europe: an ESPN-ERA/EDTA registry analysis. Lancet 389:2128–2137.
101. Shin HS, Oh JY, Park SJ, Kim JH, Lee JS, Shin JI. (2015) Outcomes of hemodialysis in children: A 35-year experience at severance hospital. Yonsei Med J. 56(4):1007–1014.
102. Ashuntantang G, Osafo C, Olowu WA, Arogundade F, Niang A, Porter J, Naicker S, Luyckx VA. (2017) Outcomes in adults and children with end-stage kidney disease requiring dialysis in sub-Saharan Africa: a systematic review. Lancet Glob Health 5:e408–e417.
103. Harambat J, van Stralen KJ, Schaefer F, Grenda R, Jankauskiene A, Kostic M, Macher MA, Maxwell H, Puretic Z, Raes A, Rubik J, Sorensen SS, (2013) Toots U, Topaloglu R, Tonshoff B, Verrina E, Jager KJ. Disparities in policies, practices and rates of pediatric kidney transplantation in Europe. Am J Transplant 13:2066–2074.
104. Harambat J, Ekulu PM. (2016) Inequalities in access to pediatric ESRD care: a global health challenge. Pediatr Nephrol 31:353–358.

105. McCulloch M, Luyckx VA, Cullis B, Davies SJ, Finkelstein FO, Yap HK, Feehally J, Smoyer WE. (2021) Challenges of access to kidney care for children in low-resource settings. Nat Rev Nephrol 17:33–45.
106. Asi T, Düzova A, Doğan HS, Karakurt G, Bahadır ÖF, Bozacı AC, Gülhan B, Özaltın F, Aki FT, Tekgül S, Topaloğlu R. (2020) Determinants of outcomes in chronic pediatric peritoneal dialysis: a single center experience. Turk J Pediatr. 62(6):940-948.
107. Schramm AMMM, Facincani I, Carmona F. (2022) Evaluation of renal replacement therapy in children and adolescents in the state of Amazonas, Brazil. Rev Paul Pediatr. 4;40:e2021057.
108. Chavers BM, Molony JT, Solid CA, Rheault MN, Collins AJ (2015) One-year mortality rates in US children with end-stage renal disease. Am J Nephrol 2015; 41:121–128.
109. Mitsnefes MM, Laskin BL, Dahhou M, Zhang X, Foster BJ. (2013) Mortality risk among children initially treated with dialysis for end-stage kidney disease, 1990-2010. JAMA 309:1921–1929.
110. Sanderson KR, Yu Y, Dai H, Willig LK, Warady BA. (2019) Outcomes of infants receiving chronic peritoneal dialysis: an analysis of the USRDS registry. Pediatr Nephrol 34:155–162.
111. Okuda Y, Soohoo M, Ishikura K, Tang Y, Obi Y, Laster M, Rhee CM, Streja E, Kalantar-Zadeh K. (2020) Primary causes of kidney disease and mortality in dialysis-dependent children. Pediatr Nephrol 35:851–860.
112. Vidal E, van Stralen KJ, Chesnaye NC, Bonthuis M, Holmberg C, Zurowska A, Trivelli A, Da Silva JEE, Herthelius M, Adams B, Bjerre A, Jankauskiene A, Miteva P, Emirova K, Bayazit AK, Mache CJ, Sanchez-Moreno A, Harambat J, Groothoff JW, Jager KJ, Schaefer F, Verrina E, ESPN/ERA-EDTA Registry. (2017) Infants requiring maintenance dialysis: outcomes of hemodialysis and peritoneal dialysis. Am J Kidney Dis 69:617–625.
113. Tjaden LA, Noordzij M, van Stralen KJ, Kuehni CE, Raes A, Cornelissen EA, O'Brien C, Papachristou F, Schaefer F, Groothoff JW, Jager KJ, ESPN/ERA-EDTA Registry Study Group. (2016) Racial disparities in access to and outcomes of kidney transplantation in children, adolescents, and young adults: results from the ESPN/ERA-EDTA (European Society of Pediatric Nephrology/European Renal Association-European Dialysis and Transplant Association) Registry. Am J Kidney Dis 67:293-301.
114. Kramer A, Stel VS, Tizard J, Verrina E, Ronnholm K, Palsson R, Maxwell H, Jager KJ. (2009) Characteristics and survival of young adults who started renal replacement therapy during childhood. Nephrol Dial Transplant 24:926-933.
115. Chesnaye NC, Schaefer F, Groothoff JW, Bonthuis M, Reusz G, Heaf JG, Lewis M, Maurer E, Paripovic D, Zagozdzon I, van Stralen KJ, Jager KJ (2016) Mortality risk in European children with end-stage renal disease on dialysis. Kidney Int 2016; 89:1355–1362.
116. Hogan J, Bacchetta J, CharbitM, Roussey G, Novo R, Tsimaratos M, Terzic J, Ulinski T, Garnier A,Merieau E, Harambat J, Vrillon I, Dunand O, Morin D, Berard E, Nobili F, Couchoud C, Macher MA, (2018) French Pediatric Nephrology Society. Patient and transplant outcome in infants starting renal replacement therapy before 2 years of age. Nephrol Dial Transplant 33:1459–1465.
117. Ku E, Fine RN, Hsu CY, McCulloch C, Glidden DV, Grimes B, Johansen KL. (2016) Height at first RRT and mortality in children. Clin J Am Soc Nephrol 11:832–839.
118. Wong CS, Gipson DS, Gillen DL, Emerson S, Koepsell T, Sherrard DJ, Watkins SL, Stehman-Breen C. (2000) Anthropometric measures and risk of death in children with endstage renal disease. Am J Kidney Dis 36:811–819.
119. Ku E, Glidden DV, Hsu CY, Portale AA, Grimes B, Johansen KL. (2016) Association of body mass index with patient-centered outcomes in children with ESRD. J Am Soc Nephrol 27:551–558.
120. Roberts MJ, Mitsnefes MM, McCulloch CE, Greenbaum LA, Grimes BA, Ku E. (2019) Association between BMI changes and mortality risk in children with end-stage renal disease. Pediatr Nephrol 34:1557–1563.
121. Warady BA, Ho M. (2003) Morbidity and mortality in children with anemia at initiation of dialysis. Pediatr Nephrol 18:1055–1062.
122. Borzych-Duzalka D, Bilginer Y, Ha IS, Bak M, Rees L, Cano F, Munarriz RL, Chua A, Pesle S, Emre S, Urzykowska A, Quiroz L, Ruscasso JD, White C, Pape L, Ramela V, Printza N, Vogel A, Kuzmanovska D, Simkova E, Muller-Wiefel DE, Sander A, Warady BA, Schaefer F, (2013) International Pediatric Peritoneal Dialysis Network Registry. Management of anemia in children receiving chronic peritoneal dialysis. J Am Soc Nephrol 24:665–676.
123. Amaral S, Hwang W, Fivush B, Neu A, Frankenfield D, Furth S (2008) Serum albumin level and risk for mortality and hospitalization in adolescents on hemodialysis. Clin J Am Soc Nephrol 3:759–767.
124. Tsai HL, Yang LY, Chin TW,Wang HH, Liu CS,Wei CF, Chang JW (2010) Outcome and risk factors for mortality in pediatric peritoneal dialysis. Perit Dial Int 2010; 30:233–239.
125. Winnicki E, Johansen KL, Cabana MD, Warady BA, McCulloch CE, Grimes B, Ku E. (2019) Higher eGFR at dialysis initiation is not associated with a survival benefit in children. J Am Soc Nephrol 30:1505–1513.
126. Chesnaye NC, van Stralen KJ, Bonthuis M, Harambat J, Groothoff JW, Jager KJ. (2018) Survival in children requiring chronic renal replacement therapy. Pediatr Nephrol 33:585–594.
127. McDonald SP, Craig JC; (2004) Australian and New Zealand Paediatric Nephrology Association. Long-term survival of children with end-stage renal disease. N Engl J Med. 350(26):2654-2662.
128. van der Heijden BJ, van Dijk PCW, Verrier-Jones K, Jager KJ, Briggs JD. (2004) Renal replacement therapy in children: Data from 12 registries in Europe. Pediatric Nephrology. 19(2):213–221.
129. Mitsnefes MM, Laskin BL, Dahhou M, Zhang X, Foster BJ. (2013) Mortality Risk Among Children Initially Treated with Dialysis for End-Stage Kidney Disease, 1990-2010. *JAMA.* 309(18):1921–1929.
130. Maurer E, Neuhaus TJ, Weitz M, Kuehni CE, Laube GF. (2020) Paediatric end-stage renal disease and renal replacement therapy in Switzerland: survival and treatment trends over four decades. Swiss Med Wkly. 150:w20300.
131. Francis A, Johnson DW, Melk A, Foster BJ, Blazek K, Craig JC, Wong G. (2020) Survival after kidney transplantation during childhood and adolescence. Clin J Am Soc Nephrol 15:392–400.
132. Rizvi SA, Sultan S, Zafar MN, Naqvi SA, Lanewala AA, Hashmi S, Aziz T, Hassan AS, Ali B, Mohsin R, Mubarak M, Farasat S, Akhtar SF, Hashmi A, (2013) Hussain M, Hussain Z. Pediatric kidney transplantation in the developing world: challenges and solutions. Am J Transplant 13:2441–2449.
133. Laskin BL, Mitsnefes MM, Dahhou M, Zhang X, Foster BJ. (2015) The mortality risk with graft function has decreased among children receiving a first kidney transplant in the United States. Kidney Int 87:575–583.
134. Wang CS, Gander J, Patzer RE, Greenbaum LA. (2018) Mortality and allograft loss trends among US pediatric kidney transplant recipients with and without focal segmental glomerulosclerosis. Am J Kidney Dis 71:392–398.

135. Amaral S, Sayed BA, Kutner N, Patzer RE. (2016) Preemptive kidney transplantation is associated with survival benefits among pediatric patients with end-stage renal disease. Kidney Int 90:1100–1108.
136. Chisholm-Burns MA, Spivey CA, Rehfeld R, Zawaideh M, Roe DJ, Gruessner R. (2009) Immunosuppressant therapy adherence and graft failure among pediatric renal transplant recipients. Am J Transplant 9:2497–2504.
137. Kabore R, Couchoud C, Macher MA, Salomon R, Ranchin B, Lahoche A, Roussey-Kesler G, Garaix F, Decramer S, Pietrement C, Lassalle M, Baudouin V, Cochat P, Niaudet P, Joly P, Leffondre K, Harambat J. (2017) Age-dependent risk of graft failure in young kidney transplant recipients. Transplantation 101:1327–1335.
138. Smith JM, Martz K, Blydt-Hansen TD. (2013) Pediatric kidney transplant practice patterns and outcome benchmarks, 1987-2010: a report of the North American Pediatric Renal Trials and Collaborative studies. Pediatr Transplant 17:149–157.
139. Ritchie AG, Clayton PA, McDonald SP, Kennedy SE. (2018) Age specific risk of renal graft loss from late acute rejection or noncompliance in the adolescent and young adult period. Nephrology (Carlton) 23:585–591.
140. Lim WH, McDonald SP, Kennedy SE, Larkins N, Wong G. (2017) Association between slow and delayed graft function with graft outcomes in pediatric and adolescent deceased donor kidney transplant recipients. Transplantation 101:1906–1912.
141. Winnicki E, Dharmar M, Tancredi DJ, Nguyen S, Butani L. (2018) Effect of BMI on allograft function and survival in pediatric renal transplant recipients. Pediatr Nephrol 33:1429–1435.
142. Bonthuis M, Busutti M, van Stralen KJ, Jager KJ, Baiko S, Bakkaloglu S, Battelino N, Gaydarova M, Gianoglio B, Parvex P, Gomes C, Heaf JG, Podracka L, Kuzmanovska D, Molchanova MS, Pankratenko TE, Papachristou F, Reusz G, Sanahuja MJ, Shroff R, Groothoff JW, Schaefer F, Verrina E. (2015) Mineral metabolism in European children living with a renal transplant: a European Society for Paediatric Nephrology/European Renal Association-European Dialysis and Transplant Association Registry Study. Clin J Am Soc Nephrol 10:767–775.

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