Brief Report: Intellectual and Academic Functioning in Pediatric Chronic Kidney Disease

Peter J. Duquette,1 BA, Stephen R. Hooper,2 PhD, Crista E. Wetherington,1,3 PhD, Phil F. Icard,1 MS, and Debbie S. Gipson,4 MD

1School of Education, University of North Carolina, 2Department of Psychiatry and the Clinical Center for Development and Learning, University of North Carolina School of Medicine, 3Children’s Medical Center Dallas, and 4UNC Kidney Center, University of North Carolina School of Medicine

Objective Examine the intellectual and academic functioning in children with chronic kidney disease (CKD). Methods Using a cross-sectional design, children with CKD (n = 30) were compared to matched controls (n = 41) on measures of intelligence, achievement, and rates of learning disabilities (LD) variously defined. Results Children with CKD were at higher risk for grade retention (p < .001) and absenteeism (p < .01), and evidenced mild impairments on measures of intelligence (p < .001), math (p < .01), reading (p < .05), and satisfied criteria for a low achievement definition of LD (p < .01) more frequently than control group participants. Renal function was a significant predictor (p < .02) of intellectual and academic scores in the CKD group. Conclusions Educational and psychosocial supports are critical for children with CKD, and it may be important to monitor their cognitive functioning and academic progress over time.

Key words chronic renal insufficiency; cognition; end-stage renal disease; intelligence; learning.

Despite recent advances in pediatric nephrology, children with chronic kidney disease (CKD) are at continued risk for neurocognitive impairment. High rates of developmental delays and lower IQ scores have been reported for children with end-stage renal disease (ESRD), including dialysis and transplant groups (Bawden et al., 2004; Brouhard et al., 2000; Warady, Belden, & Kohaut, 1999). Follow-up studies of adults with ESRD since childhood have found similar neurocognitive impairments to persist (Groothoff et al., 2002). Results have been mixed, however, with regards to differential neurocognitive functioning among ESRD treatment modalities (Warady et al., 1999). Lawry, Brouhard, & Cunningham (1994) found higher IQ scores for transplanted children when compared to those who were dialysis-dependent (Lawry et al., 1994), whereas Brouhard and colleagues (2000) could not replicate these results and found no differences between dialysis and transplant groups. Intellectual functioning in children with mild or moderate chronic renal insufficiency (CRI) prior to dialysis or transplant dependence has not been adequately defined in the literature (Gipson, Wetherington, Duquette, & Hooper, 2004), and further investigation is needed to potentially improve academic outcomes for this population through hospital-based intervention and special education planning.

Investigations of the academic achievement of children with CKD have also been inconclusive. One study found kidney transplant recipients to outperform dialysis-dependent patients in the broad areas of reading, math, and language (Lawry et al., 1994). Conversely, Brouhard and colleagues (2000) reported no differences between transplant and dialysis groups; however, overall group comparisons showed that the combined ESRD group (transplant and dialysis) had lower achievement scores than their sibling controls in spelling, math, and reading. Bawden and colleagues (2004) also found no group differences on various measures of basic reading, spelling, math, reading comprehension, and phonological processing when ESRD children were compared to sibling controls. However, studies of adults with ESRD since childhood have shown these individuals to have lower educational attainment than healthy controls (Groothoff et al., 2002).
Although high rates of neurocognitive impairment have been reported, observational studies of school placements revealed that 79–94% of children with CKD attended regular education settings with or without remedial tutoring, while 13–15% received special education services not related to visual or hearing impairments (Qvist et al., 2002; Warady et al., 1999). Data from two European retrospective studies have shown that approximately 16–22% of patients who started renal replacement therapy as children attended schools for the disabled or handicapped (Ehrich et al., 1992; Rosenkranz et al., 1992). Proportions of children with CKD receiving additional educational support are approximately equal to national rates of enrollment in special education services among all disabilities (13% for the 2001–02 school year; US Department of Education, 2004). Additional research is needed to better understand the special education needs of children with CKD.

The purpose of this study was to provide a preliminary examination of the intellectual and academic functioning of children with CKD, as it relates to implications for pediatric psychologists in medical settings. Given the neurotoxicity associated with the accumulation of unfiltered waste products in the blood in CKD, addressing the potential effects on intellectual functioning and academic development in these pediatric patients is critical.

Methods

Participants

The patient sample consisted of children and adolescents with CKD recruited from a pediatric nephrology subspecialty clinic in an academic medical center. Eligible participants ranged from 6 to 18 years old and had experienced kidney dysfunction for at least 3 months with one of the following: a) glomerular filtration rate (GFR) < 75 ml/min/1.73 m² calculated by Schwartz, et al.; (1976) formula; or b) dialysis-dependency for at least 3 months. Patients were excluded if they had a kidney transplant in the past or had a comorbid condition associated with severe CNS anomalies. Participants in the CKD group (n = 30) consisted of individuals receiving maintenance dialysis therapy (n = 15) and those managed with conservative therapies (n = 15). The etiologies of CKD included obstructive uropathies/dysplasias (60%), glomerular disease (33%), and genetic disorders (7%).

The control group (n = 41) was comprised of children and adolescents recruited by posted fliers, newspaper advertisements, and electronic (e.g., e-mail, website) postings within the catchment area of the pediatric nephrology practice. Eligible control group participants ranged from 6 to 18 years old, and had no history of chronic health conditions, developmental disorders, head trauma, frank neurological illness, or medication usage other than a multivitamin.

Instruments

Intellectual and academic functioning was assessed using the Wechsler Abbreviated Scale of Intelligence (WASI) and the Wechsler Individual Achievement Test—Second Edition (WIAT-II). All tasks yielded age-based standard scores (M = 100, SD = 15) with higher scores indicating more intact functioning. Trained examiners administered the tests under the supervision of a child neuropsychologist.

Wechsler Abbreviated Scale of Intelligence (WASI)

Designed for ages 6 years through adulthood, the WASI employs a fluid-crystallized model of intelligence (Wechsler, 1999). The WASI was administered to gain a brief four-subtest Full Scale IQ score (FSIQ). The Vocabulary and Similarities subtests were also used to obtain a Verbal IQ (VIQ) score, while the Block Design and Matrix Reasoning subtests provided a nonverbal Performance IQ (PIQ) score.

Wechsler Individual Achievement Test—Second Edition (WIAT-II)

The WIAT-II is an individually administered measure of academic achievement (Wechsler, 2002). Three subtests, Word Reading, Mathematics Reasoning, and Spelling, were used as an academic achievement screener tapping the broad areas of reading, mathematics, and written language.

Definitions of Learning Disability

Three definitions were selected that were consistent with current conceptualizations of learning disabilities (LD) (Fletcher, Denton, & Francis, 2005; Hooper, 2004). The first definition used the ability–achievement discrepancy approach (Elliot, 1981; Hanna, Dyck, & Holen, 1979), which required an academic standard score to be at least 15-points lower than a FSIQ standard score. The second definition used a regression approach (Shepard, 1980; Wilson & Cone, 1984), which is a statistical adaptation of the discrepancy definition, taking into account predicted achievement (PA) scores based on FSIQ scores. The regression definition was employed by calculating the correlation (r = .80) between FSIQ scores from the WASI and WIAT-II in the current sample. The correlation coefficient was then used to calculate...
a standard error of estimate (SEe). The regression definition required that at least one academic achievement domain score fall below a cut score set at 1.75 SEe below the PA score, defined by the following equation: PA = [1.80 × (FSIQ − 100)] + 100. The third definition was based on low achievement (Ysseldyke, Algozzine, Shinn, & McGue, 1982), which required that at least one academic achievement domain fall below the 25th percentile for age (standard score <90). A response-to-intervention (RTI) model was not available for comparison at this time.

Procedures
Participants were tested as part of an ongoing study examining the neurocognitive effects of CKD and concurrent treatment modalities. The protocol was approved by the IRB, and all participants and their parent/guardian provided consent prior to testing. Demographic and academic data, including race and maternal education (given the associations with IQ; see Brooks-Gunn, Keblanov, & Duncan, 1996), individualized education plan (IEP) status, previous grade retention, and recent school absences, were collected by informal parent questionnaire. Socioeconomic status (SES) was defined by maternal education, which was nominally coded (1 = some high school, 2 = high school graduate or General Educational Development (GED) degree recipient, 3 = progress towards bachelor’s degree or completed associate’s degree, 4 = completed bachelor’s degree, 5 = completed graduate or professional degree). Recent school absences were defined as number of absences in the last 30 days or in the last month of the school year, if the visit occurred when classes were not in session. All participants received 50 dollars in compensation for completion of the study visit.

Data Analyses
Analyses were conducted using SPSS 12.0 version computer program (SPSS, 2003). Means and standard deviations were calculated for all continuous variables. The assumptions of normality, linearity, and homogeneity of variance were assessed, and adjusted values were reported when these assumptions were violated. Group differences on demographic variables were evaluated using independent t-tests for continuous variables and chi-square tests ($\chi^2$) for categorical variables. Zero-order correlations were performed using Pearson product–moment correlations ($r$) to determine the association between IQ and academic scores with age of CKD onset, duration of CKD, and school absences. Multivariate analysis of variance (MANOVA) was used to examine intellectual and academic functioning across groups, with analysis of variance (ANOVA) used as follow-up analytical procedures. Estimates of effect sizes (ES) were calculated using Cohen’s $d$ (Cohen, 1988). Linear regression was conducted to determine the degree to which intellectual and academic functioning was accounted for by renal function (GFR). Mantel–Haenszel comparisons were performed to compare the groups on proportions meeting one of the three definitions of LD (i.e., simple discrepancy, regression, and low achievement definitions). An alpha level of .05 was used for all statistical analyses.

Results
Demographics
Initial group comparisons indicated that the CKD and control groups were similar in age ($p = .23$) and gender ($\chi^2 = .53, p = .82$). The groups did differ in relation to race ($\chi^2 = 4.01, p = .045$) and maternal education ($\chi^2 = 20.06, p < .001$). Demographic data for age, race, gender, maternal education, previous grade retention, recent school absences, age of CKD onset, and duration of CKD are shown in Table I.

Intellectual and Academic Functioning
Intellectual scores from the WASI (FSIQ, VIQ, and PIQ) and academic achievement scores from the WIAT-II (Word Reading, Math Reasoning, and Spelling) were adjusted for covariates (race and maternal education) and analyzed in the MANCOVA (Table II). The CKD and control groups differed across these scores as evidenced by a significant MANCOVA using Wilks’ Lambda, $F(6, 62) = 5.26, p < .001$, with the control group outperforming the CKD group on FSIQ, VIQ, PIQ.

Table I. Personal Characteristics for the CKD ($n = 30$) and Control ($n = 41$) Groups

<table>
<thead>
<tr>
<th></th>
<th>CKD</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronological age</td>
<td>12.70 (.32)</td>
<td>11.73 (.36)</td>
</tr>
<tr>
<td>Caucasian* (%)</td>
<td>50.0</td>
<td>73.2</td>
</tr>
<tr>
<td>Female (%)</td>
<td>46.7</td>
<td>43.9</td>
</tr>
<tr>
<td>Maternal education***</td>
<td>3.00 (1.12)</td>
<td>4.15 (.91)</td>
</tr>
<tr>
<td>Age of CKD onset</td>
<td>5.11 (6.18)</td>
<td>—</td>
</tr>
<tr>
<td>Duration of CKD</td>
<td>6.40 (4.73)</td>
<td>—</td>
</tr>
<tr>
<td>Hypertensive (%)</td>
<td>50.0</td>
<td>—</td>
</tr>
<tr>
<td>Anemic (%)</td>
<td>30.0</td>
<td>—</td>
</tr>
<tr>
<td>with IEP* (%)</td>
<td>16.7</td>
<td>2.4</td>
</tr>
<tr>
<td>Previous grade retention** (%)</td>
<td>40.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Recent school absences**</td>
<td>1.97 (2.74)</td>
<td>.49 (1.39)</td>
</tr>
</tbody>
</table>

Notes. *p < .05; **p < .01; ***p < .001; Continuous variables presented as mean (standard deviation).
Word Reading, and Math Reasoning scores; spelling scores did not differ between the two groups (Table II). The percentage of FSIQ scores falling below the 25th percentile was differentially higher ($\chi^2 = 13.98$, $p < .001$) for the CKD group (57%) than for the control group (15%). Renal function among participants with CKD, as measured by GFR, was positively correlated with all intellectual (FSIQ: $r = .64$; VIQ: $r = .57$; PIQ: $r = .64$) and academic (Word Reading: $r = .51$; Math Reasoning: $r = .65$; Spelling: $r = .44$) scores. Results from the regression analysis indicated that renal function (GFR) was a significant predictor ($p < .02$) of intellectual and academic scores, accounting for $47\%$ of the variance. Neither age of CKD onset nor duration of CKD was significantly associated with intellectual or academic functioning. Recent school absences were negatively correlated to a moderate degree with FSIQ ($r = -.28$), VIQ ($r = -.25$), PIQ ($r = -.29$), and Math Reasoning ($r = -.35$) scores.

### Learning Disability Definitions

Results indicated striking differences for the presence of learning problems based on the LD definition employed. When using a simple IQ-achievement discrepancy or a regression definition, there were no statistically significant differences between the CKD and control groups based on proportions of participants fulfilling LD definition criteria (Table II). The low achievement definition of LD produced quite different results, as the CKD group demonstrated a higher proportion of participants meeting LD criteria on Word Reading, Math Reasoning, and Spelling than the control group (Table II).

### Discussion

Research on the neurodevelopment of children with CKD has identified a number of findings indicative of cognitive dysfunction, with several studies showing specific deficiencies in intellectual functioning and academic achievement (Bawden et al., 2004; Brouhard et al., 2000; Groothoff et al., 2002; Lawry et al., 1994; Qvist et al., 2002; Warady et al., 1999). The current study provides preliminary findings on the intellectual functioning and academic achievement of children with CKD using direct measurement of skills and comparison to a control group. Of particular importance are findings suggesting that children with CKD were more likely than controls to have intelligence scores below the average range, along with differential psychoeducational outcomes as a function of declining kidney functioning. The latter finding is noteworthy when one considers that the CKD literature is inconclusive as to the onset of cognitive dysfunction prior to ESRD. Although several limitations

| Table II. Adjusted IQ/Academic Scores and Proportions Satisfying LD Definitions for CKD ($n = 30$) and Control ($n = 41$) Groups |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | CKD             | Control         |                 |                 |                 |
|                 | $M$             | $SD$            | $M$             | $SD$            | $F$-Tests       | ES ($d$)        |
| WASI full scale IQ*** | 94.45           | 20.49           | 110.79          | 17.12           | 23.15           | .87             |
| WASI verbal IQ***   | 94.94           | 21.47           | 111.85          | 17.94           | 22.59           | .85             |
| WASI performance IQ*** | 94.69          | 19.46           | 106.89          | 16.25           | 14.32           | .68             |
| WIAT-II word reading* | 99.83          | 19.03           | 105.59          | 15.90           | 3.32            | .33             |
| WIAT-II math reasoning** | 98.78         | 23.35           | 111.97          | 19.51           | 11.61           | .61             |
| WIAT-II spelling    | 102.53          | 20.29           | 102.47          | 16.95           | .04             | —               |

Discrepancy Definition
- Reading (%) 7 22
- Math (%) 7 12
- Spelling (%) 7 22

Regression Definition
- Reading (%) 10 9
- Math (%) 10 5
- Spelling (%) 10 20

Low Achievement Definition
- Reading** (%) 43 7
- Math** (%) 37 2
- Spelling** (%) 40 5

Notes: *$p = .07$; **$p < .01$; ***$p < .001$
of this study that are discussed below preclude large-scale generalization, these results provide preliminary evidence of the moderately detrimental effects of declining kidney function on cognition in the context of gradual progression for CKD.

Analysis of how each group satisfied various LD definitions revealed that, in general, children and adolescents with CKD were more likely to satisfy basic criteria for LD services only when the low achievement definition was employed. No differential rates between groups were observed on the simple discrepancy and regression definitions. This suggests that children with CKD do not exhibit the significant discrepancies between their intellectual abilities and academic achievement scores that are typically seen in the LD population. However, a proportion of children with CKD in this study, particularly those with ESRD, exhibited academic delays that may benefit from educational support services targeting hierarchical school-based learning in a manner similar to instruction used with LD populations. Additionally, the elevated proportion of CKD group participants with previous grade retention suggests that current educational support services may not be sufficient. Such findings are important to note in states that intervene with learning problems based on the low achievement or RTI models.

The current findings have real world implications for psychologists that interact with this population. Pediatric psychologists in healthcare settings play an important role in alleviating illness-related anxiety and emotional dysfunction for children with CKD through individual or family therapy. These fears, worries, and stressors may negatively impact academic functioning for a child with CKD if no therapeutic intervention is provided. Psychologists may also benefit children with CKD through annual or biennial neuropsychological assessments to evaluate cognitive functions over time. Findings from these assessments have important implications with regard to classification in the schools, as pediatric psychologists can provide guidance and encourage parents to advocate for special education support services for children with CKD broadly under a general medical heading (e.g., Other Health Impaired—OHI). A secondary classification of LD may also be considered during IEP team meetings for individual cases of specific academic delays, to better document the specific educational needs of a child with CKD. This consideration for multiple special education classifications would provide documentation and pre-specified strategies to account for extended absenteeism for medical visits, fatigue related to chronic illness, or psychoeducational deficits secondary to CKD. Further, individual cases of children with CKD who exhibit patterns of low achievement—for whatever reason—are likely to be more vulnerable to disruptions in hierarchical learning patterns. Providing the most appropriate services to children with CKD also includes educating teachers and staff as to the specific areas of cognitive difficulty and the nature and nuances of CKD.

Several limitations inherent to this preliminary study should be taken into account before generalizing the current findings. The differences in race and maternal education between the CKD and control groups made the comparison of IQ and academic scores problematic, due to the historical disparities in intelligence and academic scores for racial and ethnic minorities and individuals from families of SES (Brooks-Gunn, Keblanov, & Duncan, 1996). However, epidemiological data indicate that CKD disproportionately affects racial minorities and individuals from low SES backgrounds (US Renal Data System, 2006), which suggests a possible sampling or selection bias for lower IQ and academic scores in the CKD population. Therefore, future research should focus on the potential moderating effects of race and maternal education on intellectual and academic functioning in homogenous CKD samples to determine if these deficits remain when their contributory effects are removed. Additionally, because the results of this study were obtained from a broad battery of neuropsychological testing, both the intelligence (WASI) and academic achievement (three subtests from the WIAT-II) screeners used were condensed measures designed to obtain an estimate of functioning in these areas. Therefore, more comprehensive measures of intelligence (e.g., the WISC-IV) and academic achievement (e.g., the full battery of the WIAT-II) could provide a more detailed picture of the differences in these areas between the CKD population and controls. Furthermore, the three WIAT-II subtests used in this study (Word Reading, Math Reasoning, and Spelling) do not tap into the entire spectrum of federal LD categories in reading (basic reading, reading comprehension), math (math calculation and math reasoning), and writing (written expression), nor does their use satisfy most states’ criteria for LD services. The use of thorough psychoeducational assessments with this population should provide additional and necessary information with respect to their academic needs and special education eligibility.
The results of this study suggest slightly lower intellectual and academic functioning for children with CKD when compared to the general population. Higher rates of special education needs, grade retention, and school absences were also evident for the CKD group, along with a positive linear relationship between renal function and intellectual/academic scores. The current findings warrant further investigation, and certainly clinical monitoring, of the intellectual and academic functioning of children with CKD, as well as more attention from pediatric psychology and school personnel to the individualized educational needs of children with CKD. Future research should differentiate cognitive abilities among children with mild, moderate, or severe CRI versus children with ESRD, dialysis dependence, and kidney transplantation. Examining the differential contributions of hyperparathyroidism, hypertension, and anemia to the cognition of children and adolescents with CKD also will provide postulated mechanisms of psychoeducational dysfunction in this population, particularly for children with CRI who have not progressed to uncontrolled levels of uremia. Differences between groups in intellectual functioning and academic achievement in this study raise important questions regarding cognitive decline in the CKD population, particularly as these differences may relate to the effects of disease chronicity, disease progression, age of onset, and treatment modalities. Through long-term, systematic follow-up, the issue of psychoeducational functioning in CKD may be addressed in reference to the timeliness, type, and response to various individualized educational interventions for these children.

Conflict of Interest: None declared.

Received March 7, 2006; revisions received April 8, 2007; accepted April 19, 2007

References


