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ORIGINAL ARTICLE

The Utility of Magnetic Resonance Imaging [MRI] in The Detection of Structural Brain Abnormalities and Cerebellar Volume Changes in Pediatric Patients with Chronic Kidney Disease.

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ABSRACT:

Background: Chronic kidney disease (CKD) is considered an important risk factor for acute and chronic subclinical brain injury and its sequel on the brain remains inadequately outlined. This study aimed to detect different structural brain abnormalities that may occur in pediatric patient with chronic kidney disease [PCKD] and to detect cerebellar volume reduction compared to healthy controls of same age group using magnetic resonance imaging (MRI) and Vol brain system.

METHODS: The sample size was 70 pediatric patients. A total of 35 children [age group ranging from 2–15 years old], with a diagnosis of CKD stages 3–5, [GFR up to 59 mL/min/1.73m2], and 35 healthy peers of same age group were included. Volumetric data from MRI and Vol brain system and neurocognitive tests were compared between two studied groups.

RESULTS: Total cerebellar volume and cerebellar gray matter volume were significantly reduced in pCKD in comparison to control group of same age group, [**p≤0.001]. In contrast, the cerebellar white matter volume wasn't significantly affected [p>0.05]. And despite the significant reduction in neurocognition in pCKD in comparison to control group, there was non-significant relation between this reduction and brain volume changes in the cerebellum.

CONCLUSIONS: This study provides preliminary prove of the role of MRI as a qualitative method to diagnose possible structural abnormalities that can occur with pCKD , and as a quantitative measure to detect possible volume changes that can occur in the cerebellum.

Keywords: pediatric chronic kidney disease; Brain volumetry; neurocognition; brain structural abnormalities.

INTRODUCTION

Chronic kidney disease (CKD) describes the progressive dynamic decrease in kidney work driving to end-stage kidney disease (ESKD), up to half of patients with CKD will encounter a diminish in kidney function so extreme as to need dialysis.

Chronic kidney illness is a long-lasting condition driving to multiple different distinctive systemic complications, including critical neurocognitive dysfunction [1], Neurocognitive deficits have been well-described in both the adult and pediatric chronic kidney disease (CKD) and end-stage kidney disease (ESKD) populations These deficits are more associated with longer duration of kidney disease, metabolic acidosis , proteinuria/microalbuminuria , anemia and hypertension , also The accumulation of neurotoxic metabolites, hormonal disturbances

and an imbalance in excitatory and inhibitory neurotransmitters have been suggested to play a role in its pathogenesis.[2-3]

Different structural abnormalities have been described in children with CKD, such as focal and multifocal white matter injuries ,global cerebral atrophy, silent white matter infarcts, ventriculomegaly, and abnormal basal ganglion lesions [4] .

Most of the previous studies done to assess brain of PCKD used subjective or non-quantitative methods. Recent advances in MRI-based brain volumetry allow for non-invasive, objective assessment of structural and volumetric changes in the brain, which may be crucial in understanding the neurobiological underpinnings of cognitive deficits in pediatric CKD [5].

This study aimed to assessing the structural brain changes and cerebellar volume changes that can occur in pediatric patients with chronic kidney disease using MRI brain volumetry and correlate the brain volumetric changes with neurocognitive deficit.

METHODS

Our university Institutional Review Board [IRB#10704] approved a prospective cross-sectional study that was conducted from march 2024 to December 2024. The Helsinki Declaration of the World Medical Association for experiments involving humans was followed in the conduct of this study. our study was composed of 70 children with age group ranging from 2–15 years and were divided into two groups: 35 cases [17 female and 18 males] with moderate to severe pCKD and 35 healthy controls [14 females and 21 males] of same age group and were free from any chronic illness or receive long term medication., informed consents were taken from all patients and guardians at time of participation.

Inclusion criteria for disease group were pediatric patient (age group from 2 up to 15 years old) with Stage 3 to 5 CKD (eGFR [up to 59 mL/min/1.73m2], including dialysis and non-dialysis patients, they were referred from the pediatric Department to Magnetic Resonance Imaging (MRI unit) complaining from different symptoms as disturbed conscious level, convulsions, headache and blurred vision

Inclusion criteria for control group were pediatric with similar age group, sex [both males and females], race, socioeconomic status and same maternal education level, who came to Magnetic Resonance Imaging (MRI unit) for MRI complaining from different symptoms as high fever, first attack of convulsion, headache and free from any chronic illness or receive long term medication. Their MRI exam was unremarkable

Exclusion criteria for two groups were children with history of very preterm, patient diagnosed with epilepsy or on antiepileptic medications, patient with known congenital hydrocephalus or with ventriculoperitoneal shunt or known chromosomal anomalies or cardiac disease.

Detailed clinical history was taken from all participants [Personal history (name, age, …), birth history, any current complaints, other medical diagnoses, medications, and family medical history, Laboratory investigations: Kidney functions tests (with creatinine level), eGFR [ml/min/1.73m2, and blood pressure. Neurocognitive assessment [by Stanford Binet Intelligence Scale, Fifth Edition (SB5)] which is was done by child psychiatrist to all participants [35cases and 35 control], it's an intelligence and cognitive capacities test for people aged 2 to 85. it measures different cognitive capacities in both verbal and nonverbal format as fluid reasoning, knowledge, quantitative thinking and memory**. [6]**

MR Imaging Techniques:

All participant (cases and controls) were scanned by 1.5 T closed scanner (Philips Achieva) using a 16-channel sensitivity

encoding. Main sequence of the used protocol: 3 plain localizers + sagittal 3D auto-align localizer was obtained to verify the precise position of the patient and to act as a localizer for subsequent slices (TR: 4.52, TE: 2.3, matrix: 160×160×110.4, time: 24 sec.), then multiple pulse sequences were obtained **.**Axial T2 BLADE, TR: 3300, TE: 107, matrix: 320×320, time: 1:59 min as Axial T1[TR: 1340, TE: 7.3, matrix: 256 ×256, time: 1:30 min], Axial T2 FLAIR[TR: 8000, TE: 77, TI: 2372, matrix: 168×256, time: 1:54 min], Axial Diffusion-Weighted Image [TR: 4150,TE: 79 matrix: 100×100, time: 1:54 min] and the whole brain has a scan with a 3d T1 space sequence in axial plane, with slice thickness:[1mm, TR: 550, TE: 8.5, AVERAGE: 1, matrix: 256×256×204.8, time: 4:02 min] .

The total cerebellar volume, cerebellar grey and white matter volume are measured by utilizing the 3D T1WI Axial plane and Vol Brain system (http://volbrain.upv.es) which is an online MRI brain volumetry system that provides free automated brain analysis and segmentation for different areas in the brain in a very short time , precise and detailed results .[7]

Image analysis:

in our Magnetic Resonance imaging department, brain MRI was interpreted with consensus by expert radiologists with average 10 years' experience in radiodiagnosis who have proper clinical data about patients. Image interpretation protocol for brain MRI include detection of any abnormalities in conventional images [T1WI,T2WI,FLAIR and DWI] that may be related to the effect of chronic kidney disease on the brain in absence of any other causes , then we upload a single anonymized T1 MRI study in neuroimaging informatics technology initiative (NIFTI) format to the volBrain web server and then distributed across multiple available machines, reducing the computational load, volBrain then generates CSV and PDF reports containing results, which are then emailed to the user

Statistical analysis:

The information was collected, modified, coded, and accessed using the Statistical Package for Social Science (IBM SPSS Statistics for Windows, Version 23.0, IBM Corp., Armonk, NY, USA).

The T test was used to evaluate the parametric information, displayed as mean and SD. The Mann Whitney test was utilized to assess the non-parametric information, displayed as the median and interquartile range (IQR). Chi-square test was utilized to examine the qualitative data, displayed as frequency and percentage. Parameters with $P < 0.05$ were considered significant.

RESULTS

This study was done at our radiology department and included 35 pediatric cases with chronic kidney disease between 2-15 years old and 35 healthy controls of same age group. In this study, the average age of the case group was 4 years (2-12 years) in which 48.6% were female and 51.4% were males, and the average age of control group was 5years [3-9 years] in which 40% were females and 60% were males, and there was no statistically significant difference between the two studied groups regarding age or gender. We also measured the GFR for all pediatric patients as we only included patients with moderate to severe CKD in our case group [including dialysis and non-dialysis patients] in which 34.3% of pediatric patients had stage 3 CKD [eGFR≥30<60 ml/min/mm2], (20%) had stage 4 CKD [eGFR≥15<30 ml/min/mm2]and 45.7% had stage 5 CKD eGFR<15ml/min/mm2. All pediatric patients within control group had normal GFR [eGFR≥90 ml/min/mm2]**.** And we studied the history and frequency of dialysis as being on dialysis a strong independent predictor of cognitive impairment that may occur in PCKD mostly due to Chronic exposure to uremic toxins before dialysis initiation, combined with dialysis-related hemodynamic instability, electrolyte shifts, and inflammation, leading to impairment of neuroplasticity and

white matter development , in our study [16 cases on dialysis [54%] and 19 cases with no previous history of previous dialysis [46%], and larger percentage of patients who underwent dialysis had frequency of three times/week (42.9%) and dialysis duration ranged from 1 to 13 years with median 3 years [table1].

In this study There was a statistically significant difference between the studied groups regarding structural brain abnormalities [including any brain abnormality detected by conventional MRI and related to kidney disease], about 0% within control group versus 28.5% within case group had structural brain disorders [P<0.001**] [table2]. And there was also a statistically significant difference between the studied groups regarding the cerebellar total volume, cerebellar gray matter (both were significantly lower among case group) [**p≤0.001]. and a non-significant difference regarding cerebellum white matter volume [p>0.05] [table3].

Also, there was a statistically significant difference between the studied groups regarding neuro cognitive assessment[*p<0.05]. About 37% within case group versus 11.4% within control group had diminished neurocognitive function [table4]. But there was non-significant relation between neurocognitive function and cerebellar total volume, cerebellar gray matter volume [p>0.05] [table5].

Table 1: Comparison between the studied groups regarding demographic data

	Case group	Control group	χ^2	p
	N=35 (%)	N=35 (%)		
Gender Female Male	 17 (48.6%) 18 (51.4%)	 14 (40%) 21 (60%)	0.521	0.47
	Median (IQR)	Median (IQR)		
Age (year)	4(2 – 12)	5(3 – 9)	-0.629	0.529
Stages Stage 1[eGFR≥90 ml/min/mm2] Stage 2[eGFR≥60<90ml/min/mm2] Stage 3 [eGFR≥30<60ml/min/mm2] Stage 4 [eGFR≥15<30 ml/min/mm2] Stage 5 [eGFR<15ml/min/mm2]	 0 (0%) 0 (0%) 12 (34.3%) 7 (20%) 16 (45.7%)	 35 (100%) 0 (0%) 0 (0%) 0 (0%) 0 (0%)	61.17	<0.001**
Frequency of dialysis Two times/week Three times/week No dialysis	 1 (2.9%) 15 (42.9%) 19 (54.3%)	 -		
	Median (IQR)	Range		
Dialysis duration (year)	3 (2 – 5)	1-13		

**p≤0.001 is statistically highly significant χ^2Chi square for trend test

Table 2: Comparison between the studied groups regarding presence of structural abnormalities

	Case group	Control group	χ^2	p
	N=35 (%)	N=35 (%)		
Structural anomalies Absent Present	 25(%71.5) 10(28.5%)	 35 (100%) 0 (0%)	Fisher	<0.001**

*p<0.05 is statistically highly significant χ^2Chi square test

Table 3: Comparison between the studied groups regarding cerebellum total volume, grey and white matter volume:

Volume (cm^3)	Case group	Control group	F	P
	Mean ± SD	Mean ± SD		
Cerebellum total volume	97.47 ± 26.28	120.63 ± 19.74	-4.169	<0.001**
Cerebellum WM matter	20.3 ± 6.19	22.73 ± 5.73	-1.691	0.095
Cerebellum GM matter	80.11 ± 24.01	105.13 ± 18.01	-4.931	<0.001**

t independent sample t test Z Mann Whitney test *p<0.05 is statistically significant **p≤0.001 is statistically highly significant.

Table 4: Comparison between the studied groups regarding neurocognitive assessment

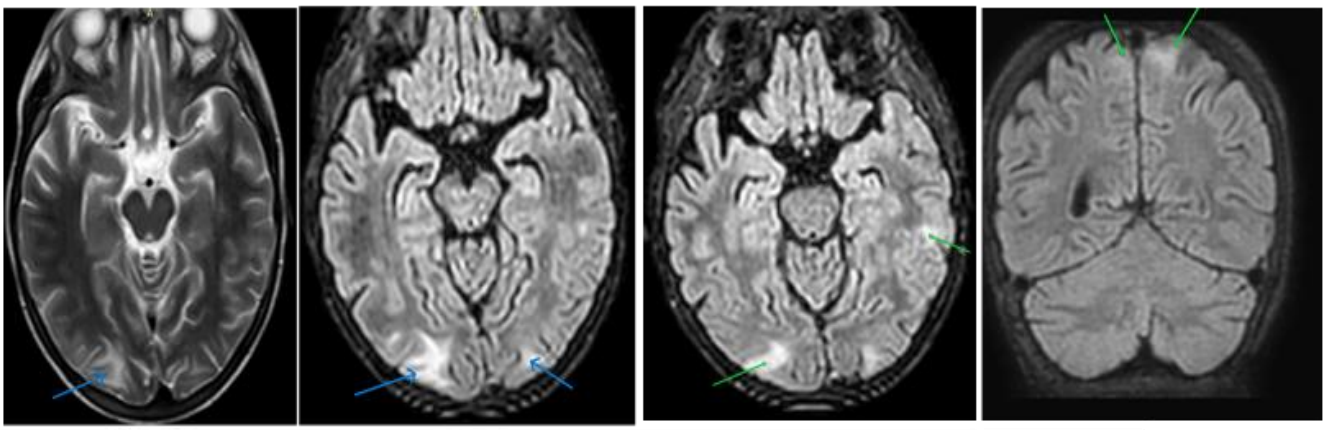
	Case group	**Control group**	χ^2	**p**
	N=35 (%)	**N=35 (%)**		
Neurocognitive				
Decreased	**13 (37.1%)**	**4 (11.4%)**	**6.293**	**0.012***
Normal	**22 (62.9%)**	**31 (88.6%)**		

*p<0.05 is statistically significant χ^2Chi square test

Table 5: Relation between nonrecognition and volume of cerebellum [total cerebellar volume and cerebellar grey matter volume]

Volume (cm^3)	Decreased (n=13)	Normal (n=22)	t	P
	Mean ± SD	Mean ± SD		
Cerebellum volume	87.97 ± 24.3	103.09 ± 26.3	-1.689	0.101
Cerebellum GM matter	72.61 ± 24.12	84.54 ± 23.35	-1.442	0.159

t independent sample t test *p<0.05 is statistically significant.



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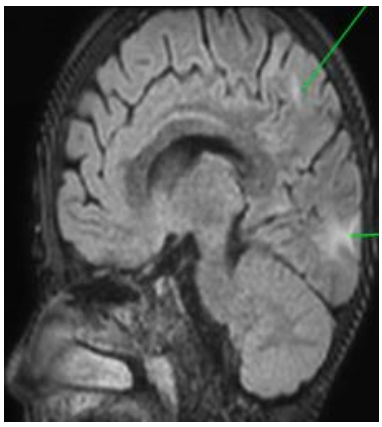

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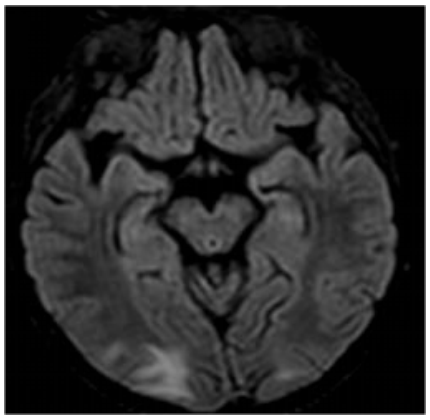

F

vol2Brain volumetry report

version 1.0 release 23-11-2021.

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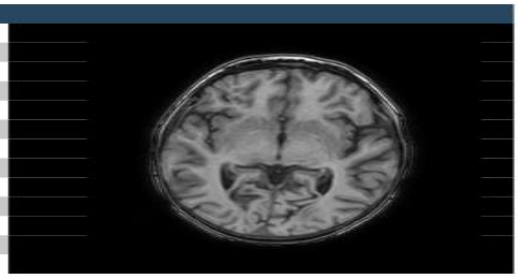

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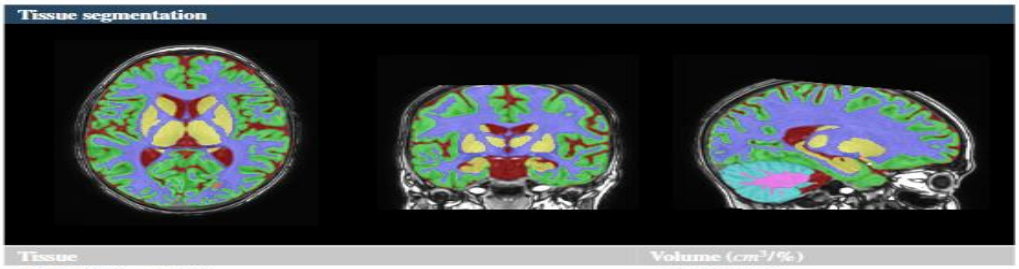
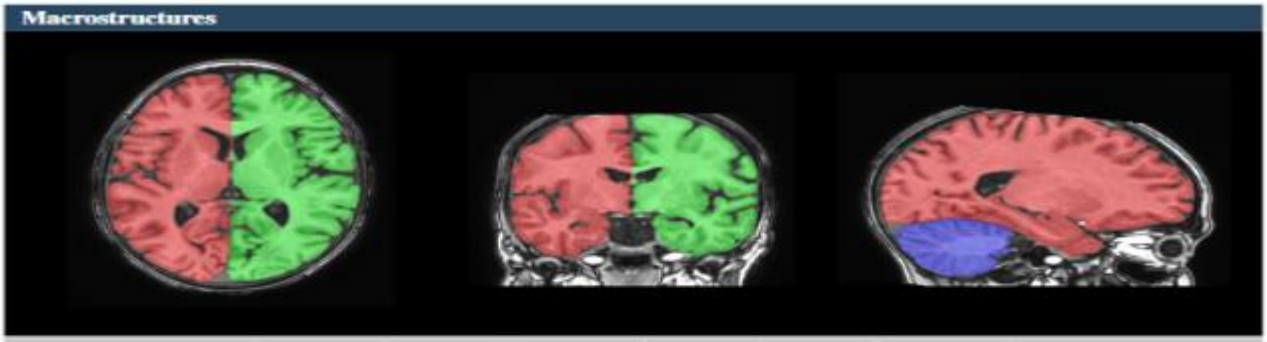


Tissue	Volume (cm^3/%)	
White Matter (WM)	432.61 (32.773)	[30.738, 40.289]
Normal Appearing White Matter	432.11 (32.735)	[30.643, 40.202]
Abnormal Appearing White Matter	0.49 (0.037)	[0.000, 0.290]
Grey Matter (GM)	685.53 (51.933)	[49.907, 57.597]
Subcortical Grey Matter	39.49 (2.991)	[2.846, 3.546]
Cortical Grey Matter	540.54 (40.949)	[39.041, 45.701]
Cerebellar Grey Matter	105.51 (7.993)	[7.020, 9.350]

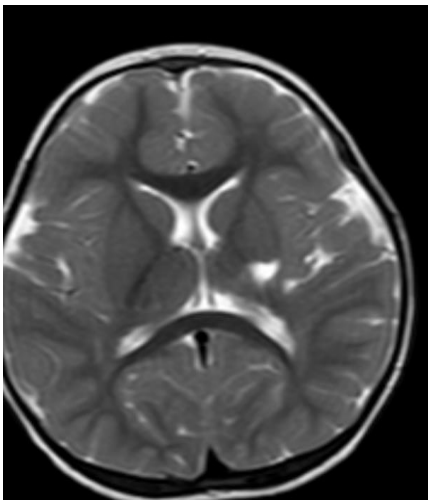


Structure	Total (cm^3/%)	Right (cm^3/%)	Left (cm^3/%)	Asymmetry (%)
Cerebrum	985.59 (74.665) [74.339, 83.442]	494.49 (37.461) [37.039, 41.698]	491.10 (37.204) [37.257, 41.788]	0.6876 [-2.070, 1.273]
Cerebrum WM	405.57 (30.724) [28.787, 37.860]	203.25 (15.398) [14.325, 18.980]	202.31 (15.326) [14.444, 18.898]	0.4637 [-2.470, 2.254]
Cerebrum GM	580.02 (43.941) [42.103, 49.032]	291.24 (22.063) [20.993, 24.439]	288.79 (21.878) [21.095, 24.607]	0.8441 [-2.228, 0.904]
Cerebellum *	125.01 (9.471) [8.392, 10.957]	62.45 (4.731) [4.193, 5.509]	62.57 (4.740) [4.188, 5.459]	-0.1882 [-3.018, 4.134]
Cerebellum WM	27.04 (2.049) [1.686, 2.694]	13.69 (1.037) [0.839, 1.358]	13.35 (1.011) [0.842, 1.340]	2.5330 [-5.089, 6.597]
Cerebellum GM	105.51 (7.993) [7.020, 9.350]	48.76 (3.694) [3.195, 4.309]	49.22 (3.728) [3.200, 4.266]	-0.9393 [-3.646, 4.795]
Vermis	7.54 (0.571) [0.568, 0.832]			
Brainstem	16.46 (1.247) [1.180, 1.592]			

Figure 1: 10 years old male patient with chronic interstitial nephritis for 2 years [not on dialysis] , comes to MRI unit with altered conscious level and seizures after sudden attack of high blood pressure. MRI revealed bilateral non symmetrical cortical and sub cortical abnormal high signal at T2WI and FLAIR [A-B-C-D-E] seen at parieto-occipital region with faint diffusion restriction at bilateral occipital lobes in DWI [F] suggesting posterior reversible encephalopathy syndrome [PRES] with acute ischemic insult on top

Vol brain report: revealed normal total cerebellar volume, cerebellar white and grey matter volume.

This case represents an example of acute brain injury that may occur in pediatric with chronic kidney disease with no brain volumetric changes.



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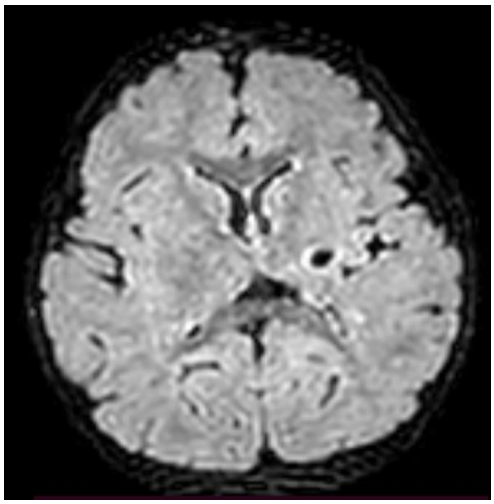

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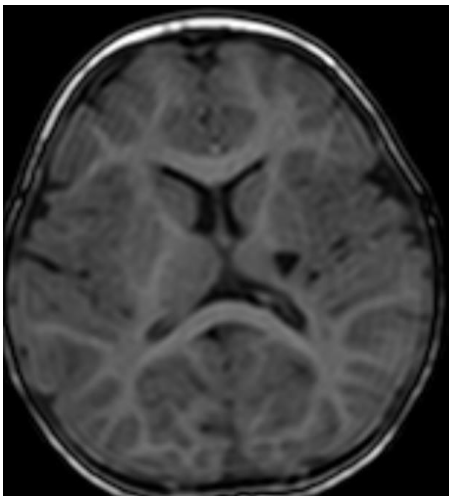

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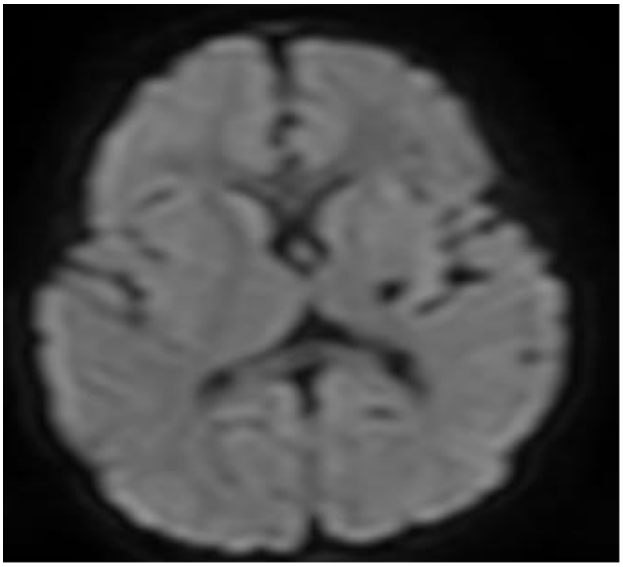

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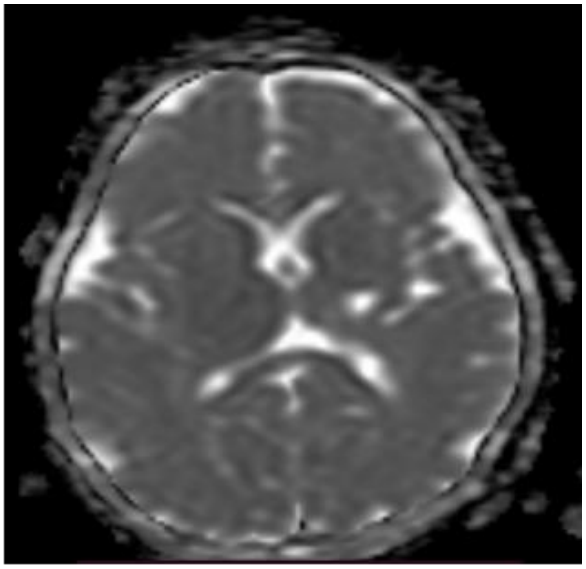

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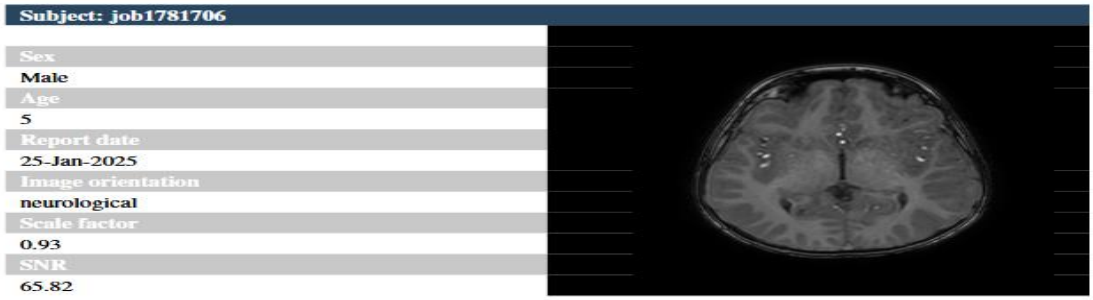

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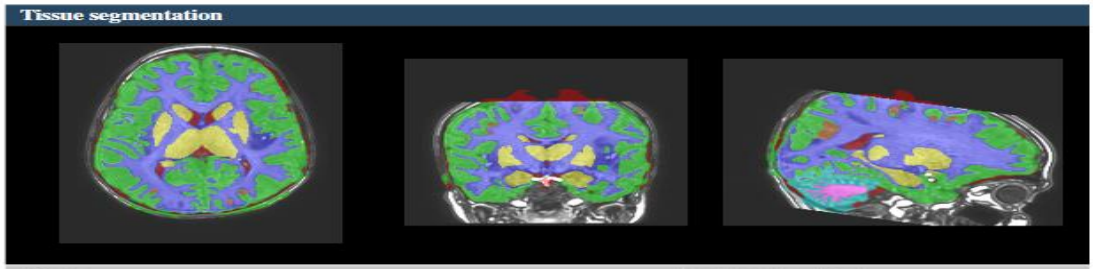
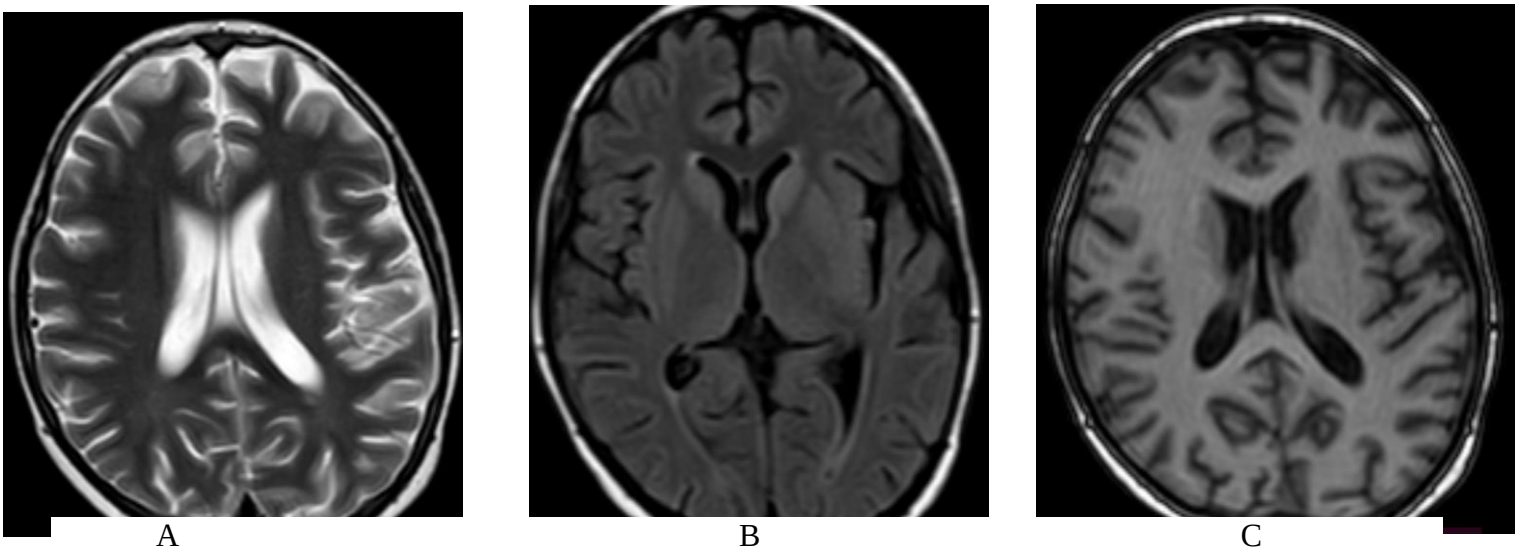


Tissue	Volume (cm^3/%)	
White Matter (WM)	577.52 (37.054)	[29.490, 39.408]
Normal Appearing White Matter	568.67 (36.486)	[29.362, 39.290]
Abnormal Appearing White Matter	8.85 (0.568)	[0.000, 0.330]
Grey Matter (GM)	865.82 (55.552)	[50.747, 58.733]
Subcortical Grey Matter	55.15 (3.538)	[2.868, 3.596]
Cortical Grey Matter	723.51 (46.421)	[39.755, 46.672]
Cerebellar Grey Matter	87.16 (5.593)	[7.084, 9.505]
Cerebro Spinal Fluid (CSF)	95.59 (6.133)	[4.676, 14.212]
Brain (WM+GM)	1443.34 (92.606)	[84.464, 93.915]
Intracranial Cavity (IC)	1558.59 (100.000)	[100.000, 100.000]

*All the volumes are presented in absolute value (measured in cm^3) and in relative value (measured in relation to the ICV).
*The Asymmetry Index is calculated as the difference between right and left volumes divided by their mean (in percent).
*Segmentation images are located in the MNI space (neurological orientation).
*Values between brackets show expected limits (95%) of normalized volume in function of sex and age for each measure for reference purpose. Values outside the limits are highlighted in red.

Cerebrum WM	557.87 (35.793)	273.55 (17.551)	284.32 (18.242)	-3.8621
	[27.629, 37.051]	[13.736, 18.570]	[13.874, 18.500]	[-2.635, 2.272]
Cerebrum GM	778.66 (49.959)	392.75 (25.199)	385.91 (24.760)	1.7563
	[42.848, 50.043]	[21.347, 24.925]	[21.486, 25.133]	[-2.477, 0.775]
Cerebellum *	100.93 (6.476)	51.43 (3.300)	49.50 (3.176)	3.8333
	[8.355, 11.019]	[4.173, 5.539]	[4.171, 5.491]	[-3.205, 4.222]
Cerebellum WM	19.65 (1.261)	10.02 (0.643)	9.63 (0.618)	3.9754
	[1.586, 2.633]	[0.785, 1.324]	[0.796, 1.313]	[-5.866, 6.269]
Cerebellum GM	87.16 (5.593)	41.41 (2.657)	39.87 (2.558)	3.7989
	[7.084, 9.505]	[3.223, 4.379]	[3.223, 4.330]	[-3.656, 5.110]
Vermis	5.88 (0.378)			
	[0.580, 0.854]			
Brainstem	19.66 (1.261)			
	[1.153, 1.581]			

Figure 2: 5 years old male patient complaints of blurred vision and headache, history of obstructive uropathy since birth [bilateral pelvi ureteric junction obstruction [PUJO] with marked backpressure and kidney failure], on dialysis [2 times per week for 2years], mild cognitive deficit Conventional MRI images revealed left internal capsule old ischemic insult displaying high signal at T2WI [A] , low at FLAIR and T1WI [B-C], surrounded with high FALIR SI of gliosis[B] , no diffusion restriction in DWI or ADC map [D-E] .Vol brain report[F]: revealed decreased cerebellar total volume, cerebellar grey and white matter volume[colored in red] ……..denoting an example of subclinical chronic brain injury that may occur in CKD with brain volumetric changes.



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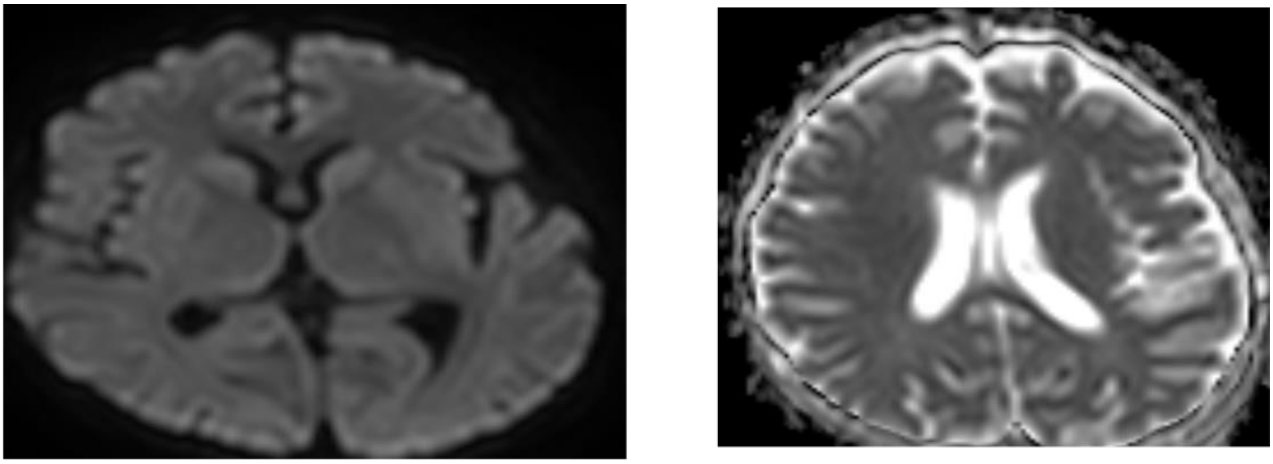
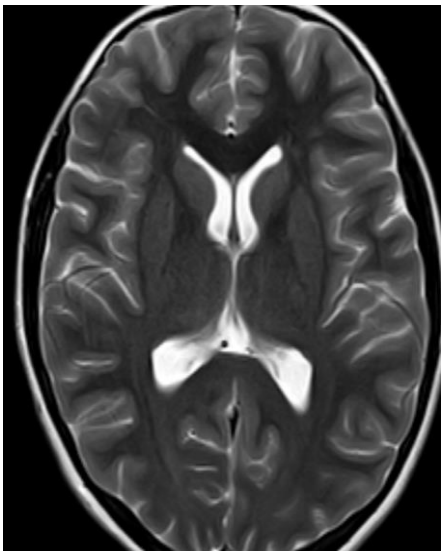


D E

Figure 3: 4 years old female , history of nephronophthisis with stage 5 renal disease , on dialysis [3 times per week for 2years , low socioeconomic , mild cognitive abnormalities , comes to MRI unit with delayed language development , MRI exam revealed diffuse brain atrophy in form of prominent examined sulci , gyri, extra axial CSF spaces seen at axial T2WI, FLAIR ,T1WI [A-B-C] , no areas of diffusion restriction at DWI and ADC map [D-E]

Vol brain: decreased total brain volume, total cerebral volume, cerebral grey matter volume, total cerebellar volume, cerebellar grey matter volume [colored in red]



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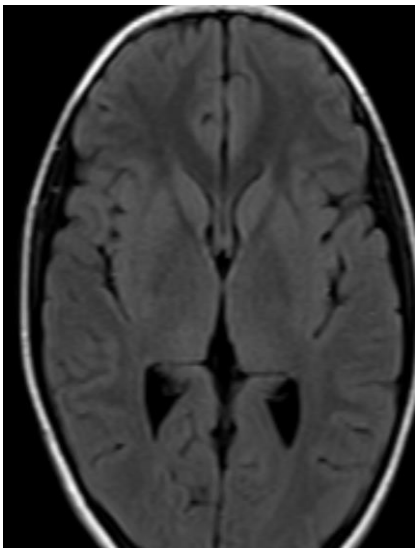
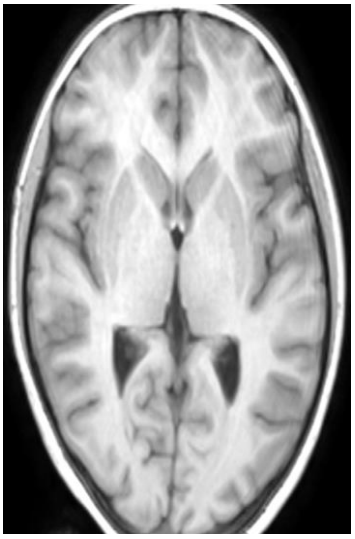
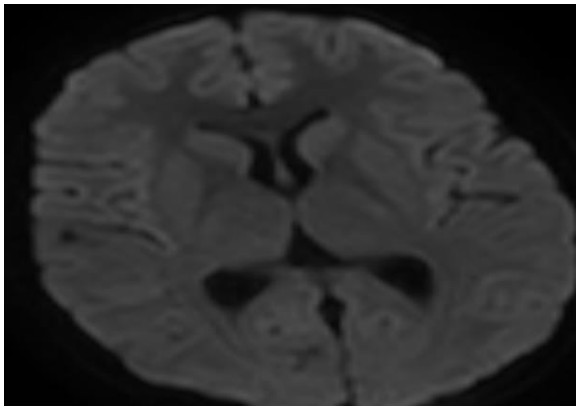


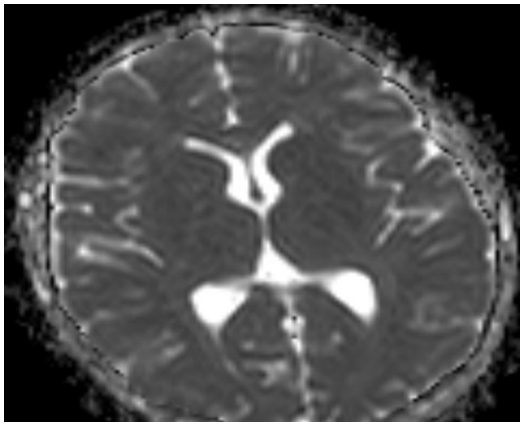
B



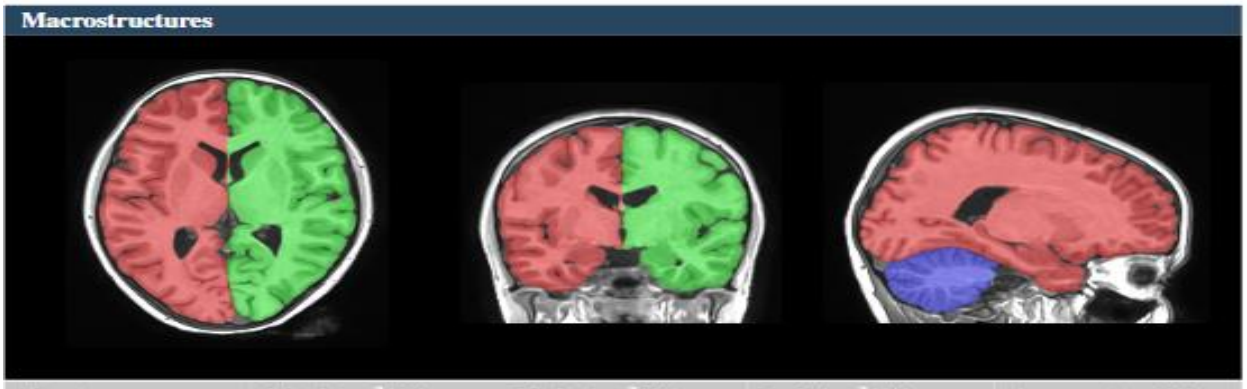
C



D



E



Structure	Total (cm^3/%)	Right (cm^3/%)	Left (cm^3/%)	Asymmetry (%)
Cerebrum	1176.74 (79.154) [76.441, 85.047]	584.77 (39.335) [38.181, 42.546]	591.97 (39.819) [38.197, 42.564]	-1.2242 [-2.006, 1.919]
Cerebrum WM	525.30 (35.335) [29.402, 38.986]	261.98 (17.622) [14.704, 19.509]	263.32 (17.712) [14.681, 19.494]	-0.5107 [-2.175, 2.515]
Cerebrum GM	651.44 (43.820) [43.041, 50.060]	322.79 (21.713) [21.491, 25.023]	328.65 (22.107) [21.525, 25.061]	-1.7996 [-2.207, 1.841]
Cerebellum *	132.76 (8.930) [8.261, 10.999]	66.24 (4.455) [4.146, 5.519]	66.53 (4.475) [4.106, 5.488]	-0.4345 [-2.623, 4.002]
Cerebellum WM	31.65 (2.129) [1.688, 2.841]	15.83 (1.065) [0.845, 1.441]	15.82 (1.064) [0.838, 1.404]	0.0300 [-3.808, 8.124]
Cerebellum GM	109.89 (7.392) [6.749, 9.284]	50.41 (3.391) [3.099, 4.279]	50.70 (3.411) [3.086, 4.267]	-0.5799 [-3.755, 4.357]
Vermis	8.78 (0.591) [0.513, 0.788]			
Brainstem	18.67 (1.256) [1.141, 1.590]			

Figure 4: 12 years old female, no history of medical disease, moderate socioeconomic status, no hypertension or anemia, comes to MRI unit complaining of headache, MRI exam revealed normal brain at [axial T2WI[A], axial FLAIR[B], axial T1WI[C], no diffusion restriction at DWI[D] and ADC map] [E] Vol brain report: Normal total brain volume, cerebral and cerebellar volume, normal cerebral and cerebellar grey matter volume

= this study is an example of control group with normal brain in MRI and no volumetric abnormalities

DISCUSSION

children with chronic kidney disease are at increased risk of negative impact on brain development and neurocognition [8]. The aim of this study is to evaluate the role of MRI exam in the detection of structural and volumetric brain differences in pediatric patients with CKD in comparison to healthy controls of same age group.

CT and MRI imaging at previous studies provided evidence of sub clinical chronic white matter infarction, and brain atrophic changes with subsequent ventricular system enlargement in advanced pediatric CKD , as in Jung E, Kogon et al.,2020, In which Patients with CKD were found to have increased risk of ischemic stroke with focal and multifocal white matter injuries compared to healthy controls, most of these injuries were subclinical and chronic injuries seen in the internal capsule and the periventricular white matter [9]. And this was in agreement with our study in which There was a statistically significant difference between the studied groups regarding structural brain disorder [0% within control group versus 28.5% within case group had structural brain disorders] , these structural abnormalities included evidence of old sub-clinical ischemic insult , acute brain

injury in form of posterior reversible encephalopathy syndrome [PRES] , bilateral almost symmetric abnormal BG signal and nonspecific foci of abnormal white matter signal..

Our research also demonstrated that the cerebellar total volume and cerebellar gray matter were statistically significantly lower among pediatric with CKD in comparison to control group of same age group [p<0.001**]. And this was in agreement with the study done by MA Solomon et al., 2021 in which Cerebellar gray matter volume was significantly smaller in pCKD, p = 0.01 and this reduction was associated with cognitive deficit in these patients [10].

In previous studies as [Harshman et al., 2020 , Chu et al., 2021 ,and Lijdsman et al.,2022] ,Severe chronic kidney disease in children was associated with impairment of neurocognitive and psychosocial brain development, characterized by behavioral, social, learning, problems [[1-11-12] , And this was in agreement with our study as There was a statistically significance difference between the studied groups regarding neurocognitive assessment [by using IQ test Stanford-Binet Intelligence Scales] as About 37% within case group versus 11.4% within control group had diminished neurocognitive function.

Also, in Solomon et al., 2021 Volumetric reduction in the cerebellar gray matter was associated with poorer performance in cognitive tests [10], but in our study, there was no significant relation between neurocognitive function and cerebellar gray matter volume.

Strength points and limitations: The current study has several strengths, as it included a wide and different spectrum of brain structural abnormalities that may occur in pediatric CKD including [acute and chronic sub clinical brain injuries], and brain volume changes in PCKD even in patients without any brain structural abnormalities visible in conventional MRI. However, our study faced some limitations. First, the sample size was small [70 participants], which may restrict the generalizability of the findings and the statistical power to distinguish significant differences. second, it is possible that that the neurocognitive tests in our study could be affected by interviewer bias. finally, in our cases group pediatric patient had different disease stages and etiologies, making it difficult to distinguish the mechanism of neurocognitive deficits.

Conclusion:

In conclusion, this study is evidence that pediatric patients with moderate to severe CKD are at increased risk of structural brain abnormalities, volumetric brain changes and neurocognitive deficit in comparison to healthy subjects of same age group.

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Conflict of interest:

The authors declare that they have no conflicts of interest with respect to authorship or publication oflethis artic .

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