ORIGINAL RESEARCH ARTICLE

# Diffusion Brain Imaging in Patients with Subcortical Arteriolosclerotic Leukoencephalopathy

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## ABSTRACT

**Introduction:** Subcortical arteriolosclerotic leukoencephalopathy is characterized by brain white matter hyperintensities. Magnetic resonance imaging of the brain and diffusion allowed detection of periventricular and deep white matter hyperintensities. Aim: To identify the adequacy of DWI and ADC map in evaluation of brain white matter hyperintensities in relation to their grades.

**Material and methods:** This study is a retrospective case control study where 34 cases with periventricular arteriolosclerotic leukoencephalopathy were referred from outpatient clinics to the department of Radiodiagnosis, Kasr Alainy hospital. Another 35 healthy controls were also included in the study. MRI brain and diffusion were done to patients and controls. Axial brain FLAIR images were examined for the degree of periventricular and deep white matter hyperintensities and were graded according to Fazekas scale. Values of DWI and ADC map for white matter hyperintensities were obtained. Statistics: Independent t –test was done to compare mean values of DWI and ADC map between patients and controls. Pearson correlation between DWI, ADC map values and grades of white matter hyperintensity was done. A P-value ≤ 0.05 was considered significant.

**Results:** Brain DWI and ADC map highly correlated with grades of WMHs ($r=0.773$, $P<0.0001$ and $r=0.952$, $P<0.0001$) respectively.

**Conclusion:** Magnetic resonance imaging of the brain especially FLAIR sequence was valuable in assessment of grades of white matter hyperintensities. Values of DWI and ADC map complied with severity of brain white matter hyperintensities.

**Keywords:** Subcortical Arteriolosclerotic Leukoencephalopathy, Brain, White Matter Hyperintensities, Magnetic Resonance Imaging, Diffusion

## INTRODUCTION

Subcortical arteriolosclerotic leukoencephalopathy (SAE) is a part of small vessel disease spectrum characterized by brain white matter hyperintensities (leukoaraiosis).[1,2,3,4]

White matter hyperintensities (WMHs) identified in T2 weighted brain images are classified according to location into periventricular (PWMH) and deep white matter hyperintensities (DWMH).[5,6,7] WMHs commonly occur in elderly people.[8,9,10]

Magnetic resonance imaging of the brain (MRI), Fluid-attenuation inversion recovery (FLAIR) and diffusion-weighted imaging (DWI) are valuable imaging modalities in evaluation of parenchymal white matter hyperintensities.[10,11,12,13,14]

### Aim of the study

To identify the adequacy of DWI and apparent diffusion coefficient (ADC map) in estimation of brain WMHs in relation to their grades.

### Methods

This study is a retrospective case control study where 34 cases with periventricular arteriolosclerotic leukoencephalopathy were referred from outpatient clinics to the department of Radiodiagnosis, Kasr Alainy hospital from February 2014 to June 2020.

Patients with SAE were selected retrospectively through evaluation of brain WMHs in old aged patients in T2 and FLAIR. Another 35 healthy control cases with normal MRI brain were also included in the study.

Imaging was performed on a 1.5 Tesla MRI superconducting scanner (Intera; Philips Medical Systems, Best, the Netherlands). Images were obtained using phased-array head coil. MRI brain and diffusion were done to patients and controls.

### Acquisition parameters

Magnetic resonance imaging (MRI) of the brain was performed including axial T1-weighted images with repetition time (TR)/echo time (TE) = 477ms/15s, T2-weighted axial, coronal and sagittal images TR/TE = 3659ms/100s, and axial Fluid attenuation inversion recovery images with TR/TE/TI: 4948ms/120s/2000. A slice thickness of 6 mm, with



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an intersection gap of 1.5 mm, sections were acquired with a 240 mm × 240 mm field of view (FOV) and image matrix of 256 × 256.

Diffusion-weighted images were acquired in the axial plane by using a single-shot Echoplanar imaging-spin echo pulse sequence with the following parameters: (TR)/ (TE) = 3909/95, field of view = 24 cm × 24 cm, slice thickness = 5.5 mm, interslice gap = 1mm, matrix size of 128 × 128.

ADC maps were generated from the diffusion-weighted images (b = 1000 s/mm2). All procedures followed were in accordance with the ethical standards of Code of Ethics of the World Medical Association (Declaration of Helsinki).

Magnetic resonance images of the brain were transferred to workstation (Extended MR workspace. Philips Medical systems Nederland B.V.). A circular region of interest (ROI) was drawn in the periventricular parietal white matter hyperintensity (ROI area 3.5-6 $mm^2$) to measure DWI and ADC map values in patients and were compared to normal periventricular regions in controls.

Diffusion images were inspected for recent infarctions in patients with SAE. Axial brain FLAIR images were examined for the degree of periventricular and deep white matter hyperintensities and were classified according to Fazekas scale and were graded from 1 to 6 according to increasing severity of WMHs.[15]

## STATISTICAL ANALYSIS

Independent t –test was done to compare mean values of DWI and ADC map between patients and controls. Pearson correlation between grades of white matter hyperintensity in relation to DWI, ADC map values and patients' age were done.

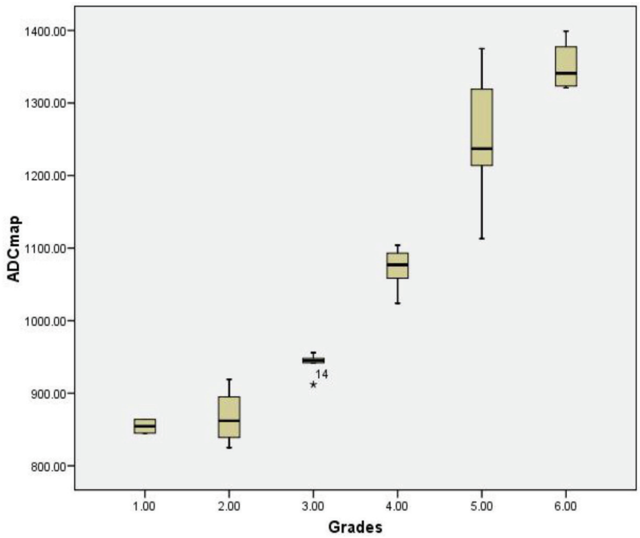
A P-value ≤ 0.05 was considered significant. Data were expressed as mean ± standard deviation using the Statistical Package for Social Science version 15 (SPSS Inc., Chicago, IL, USA).

## RESULTS

The present study included 34 cases with periventricular subcortical arteriolosclerotic leukoencephalopathy with Fazekas grading of WMHs from 1-6 according to severity. 35 normal control individuals (24 males, 11 females) with mean age 49.5 ±8.7 SD were also included in the study. Patient's demographic data were demonstrated in Table 1.

| Category | n |
|---|---|
| Age, mean (± SD) years | 64±10 SD |
| <50 years n(%) | 2 (5.8%) |
| 50-59 years n(%) | 12 (35.3 %) |
| 60-69 years n(%) | 9 (26.4 %) |
| 70-79 years n(%) | 7 (20.5 %) |
| 80-89 years n(%) | 4 (11.7 %) |
| Gender, M:F | 21 M:13F |
| Hypertensives, n(%) | 26 (76%) |
| Diabetics, n(%) | 11 (32%) |
| Fazekas grades, n(%) | |
| Grade 1 | 2 (5.8 %) |
| Grade 2 | 11 (32.35 %) |
| Grade 3 | 5 (14.7 %) |
| Grade 4 | 7 (20.58 %) |
| Grade 5 | 5 (14.7 %) |
| Grade 6 | 4 (11.7 %) |

**Table-1:** Demographic characteristics of patients (n=34) and distribution of Fazekas grades:




**Graph-1:** A Boxplot graph for ADC map and Fazekas grades of WMHs in patients with SAE. *: extreme outlier.

| Items | Patients | Controls | t | P-value* |
|---|---|---|---|---|
| DWI x$10^{-3}$ $mm^2$/s. mean ±SD (range) | 445.8 ± 48 SD (353-570) | 338.3±41.2 (250-415) | 9.9 | <0.0001 |
| ADC map x$10^{-3}$ $mm^2$/s. mean ±SD (range) | 1032 ± 184.9 SD (825-1399) | 764±38 SD (668-827) | 8.4 | <0.0001 |

* P-value ≤0.05 is considered significant.

**Table-2:** Comparison between mean values of DWI and ADC map in WMHs in patients and controls:

| Patients | Fazekas Grade Pearson correlation (r) | P-value* |
|---|---|---|
| DWI | 0.773 | <0.0001 |
| ADC map | 0.952 | <0.0001 |

* P-value ≤0.05 is considered significant.

**Table-3:** Correlation between mean values of DWI, ADC map and Fazekas grades of white matter hyperintensities in patients with SAE (n=34):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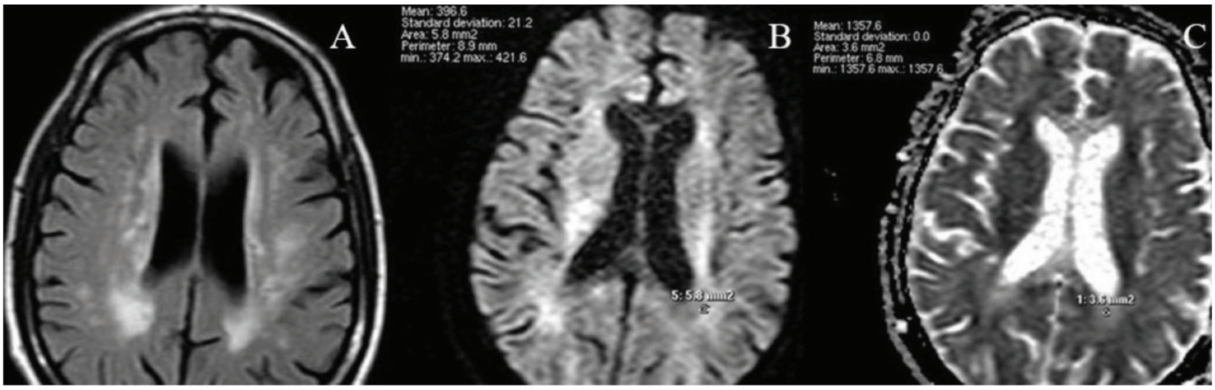


**Figure-1:** A. Axial Brain FLAIR, B.DWI and C.ADC map images in a 62 –year old male patient with SAE. Bilateral periventricular smooth halo and large confluent deep white matter hyperintensities (Fazekas grade 5) were noted in FLAIR images. A circular ROI was placed within the deep parietal region in areas with WMHs in DWI and ADC map and mean values were demonstrated.

**Image interpretation**

Brain WMHs were hyperintense in T2 and FLAIR images. Periventricular and deep WMHs were hyperintense in both DWI and ADC map (figure 1). Using FLAIR images, brain WMHs were graded from 1 to 6 according to Fazekas scale. (Table 1)

Two cases with SAE (5.8 %) sustained recent acute thalamic infarctions with restricted diffusion and hypointense ADC map with mean DWI was 522 x $10^{-3}$ $mm^2/s$ and mean ADC map 567 x $10^{-3}$ $mm^2/s$.

Mean values of DWI and ADC map in white matter hyperintensities in patients with SAE were significantly higher than normal-appearing white matter (NAWM) in controls (table 2).

Significant positive correlation between Fazekas grades of brain WMHs and patients' age with Pearson correlation r=0.422, p=0.013 was noted.

Strong significant positive correlation between DWI, ADC map values and grades of WMH was noted. (Table 3). Patients with WMHs Fazekas Grade 6 sustained the highest ADC map values. (Graph 1).

## DISCUSSION

Age and hypertension were principal risk factors for brain WMHs.[16] Both were related to impairment of brain microcirculation.[17]

The prevalence of brain WMHs increases with aging and pertinence of coexisting risk factors as hypertension and diabetes.[18] In the current study, grades of WMHs were high as the age increases which was in agreement with Guan et al who deduced that age and hypertension highly correlated with leukoaraiosis.[19]

In the current study, values of DWI and ADC map of WMHs were significantly higher than normal appearing white matter (NAWM). Also, the higher the grade and severity of WMHS, the higher the values of DWI and ADC map which was in accordance with diffusion studies conducted by Helenius et al and Ropele et al, on patients with leukoaraiosis essentially including elderly population.[20,21]

WMHs were frequent sequalae of small vessel disease and microangiopathy.[22,23] The pathogenetic mechanisms of leukoaraiosis were axonal and myelin loss, periventricular collagenosis and perivascular degeneration.[5,6,24,25,26] PWMH were associated with accumulation of periventricular interstitial fluid.[6,27] Interstitial edema can lead to high ADC values.[28]

DWI is highly sensitive in detection of acute and hyper acute brain ischemia.[28] Cali et al, reported that DWI can distinguish acute ischemic lesions from leukoaraiosis.[29]

In the present study, DWI was capable of detection of recent brain infarctions with restricted diffusion and hypointense ADC map in patients with SAE which concurred with other relevant studies.[30,31]

Limitations of the study included retrospective analysis of the research and patient selection. However, the strengths of this study were the capability of MRI brain in assorting the scores of WMHs in patients' group.

## CONCLUSION

MRI brain especially FLAIR sequence was efficient in assessment of grades of WMHs. Brain DWI and ADC map highly correlated with grades of WMHs. Values of DWI and ADC map complied with severity of brain WMHs.

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