Approximately 35.6 million people are followed up with the diagnosis of dementia across the world. The incidence of dementia has increased along with the prolongation of human life span, and it is a challenging process for the affected people and their relatives and a significant financial burden for the economies of countries (1). Alzheimer-type dementia, which is the most common cause of dementia, constitutes 50%-70% of all dementia cases (2).

There is still no treatment modality that could alter the pathological and clinical course of Alzheimer’s disease (AD), and numerous studies are ongoing in this regard. In recent years, there has been a belief that the diagnosis of Alzheimer-type dementia can be made before the manifestation of clinical findings and that this approach may allow application of possible new treatments in the early period (3).

Mild cognitive impairment (MCI) implies a transition state between normal cognitive functions and Alzheimer-type dementia. MCI is characterized by cognitive loss, absence of impairment in daily activities, and absence of dementia according to age and education norms which are also confirmed by the relatives of the patients. Studies have shown that MCI can be used to identify individuals with high risk in terms of the progression to Alzheimer-type dementia (4). Alzheimer-type dementia has been reported to develop in 10%-40% of patients within 1 year following the diagnosis of MCI (5).

The diagnosis of MCI is made through clinical evaluation, imaging modalities, and neuropsychometric tests. The Montreal Cognitive Assessment (MoCA) scale is a test that has been used in recent years to assess cognitive features such as attention and concentration, executive functions, memory, language, visual-spatial functions, abstract thinking, calculation, and orientation. The scale has been developed by Nasreddine et al. (6) and is recommended for use in the mild stages of cognitive impairment. Several features in the design of the MoCA test allow it to detect MCI with greater sensitivity. In MCI, executive functions, high language functions, and complex visual-spatial functions are moderately affected. This moderate decrease can be demonstrated by the
The MoCA test, which should fulfill more tasks when compared with the Standardized Mini Mental Test (SMMT) (6).

The adaptation of the scale to Turkish and validity-reliability studies were performed by Selekleier et al. It is believed that the MoCA test can distinguish individuals with Alzheimer-type dementia and MCI and healthy groups from each other and can be used in clinical practice in our country (7).

In addition to clinical history and neuropsychometric evaluation, imaging modalities also provide important contributions in the diagnosis of MCI. Magnetic resonance imaging (MRI) is used in the diagnosis of AD because it can detect cortical atrophy, sulcal/ventricular dilatation, and reduced parenchymal and hippocampal volume (8). Neuroimaging studies are also conducted in individuals having an increased risk of AD. The cases diagnosed with MCI belong to this group, and the hippocampal volumes calculated by MRI is smaller than healthy controls (9).

In this study, we aimed to compare the hippocampal volumes of patients with MCI diagnosis and healthy controls, and more importantly, we aimed to investigate whether a correlation exists between MoCA scale scores and hippocampal volumes in MCI patients and whether the MoCA test has a diagnostic value.

**Methods**

**Patient Population**

Twenty-five patients (13 females and 12 males) who attended the neurology polyclinic of our hospital and were diagnosed with MCI and 25 subjects (14 females and 11 males) who were cognitively healthy and had no specific somatic complaints were included in our study. All the participants were informed about the study, and their volunteer consents were received. Complete blood counts, routine biochemical examinations, thyroid function tests, serum B12 and folate levels, and The Venereal Disease Research Laboratory (VDRL) test were performed in all the participants to exclude those diseases that could lead to cognitive impairment. Subjects with pathological examination or laboratory findings, neurodegenerative disease findings on MRI, intracranial space-occupying lesions, head trauma or other neurological diseases (including Parkinson’s disease), a history of alcohol or other psychoactive substance addiction were excluded from the study. The dominant hand of all subjects was the right hand. All the 25 patients with appropriate characteristics and the 25 healthy volunteers who agreed to participate in the study were evaluated prospectively. Approval was received from the ethics committee of our hospital prior to the conduct of the study.

**Neuropsychological Assessment**

The participants were neurologically examined in detail by two neurologists. Information was obtained regarding the cognitive status of the patient and at least one of his/her relatives. The SMMT was applied to all participants (10). Those who did not have any complaint of forgetfulness reported by themselves or their relatives, who had normal neurological examination, and who had SMMT score of ≥28 were evaluated as the control group.

On the same day, the MoCA test was applied to the patients who were considered to have MCI and whose SMMT score was between 23 and 26 as assessed by an experienced psychologist. MoCA is evaluated as follows: recall from short-term memory, five-word learning exercises (two times), and delayed recall (5 points) after 5 min; clock-drawing test (3 points) that measures visual–spatial functions and cube copying (1 point); trail-making test that measures the executive functions –combining consecutive figures and letters adapted from the form B (1 point); verbal fluency (1 point) and two-object similarities (2 points) that evaluate abstract thinking; subtraction test (3 points) that comprises tasks of attention functions and working memory and forward and backward digit span test (1 point each) and naming three animal pictures that measures language functions (3 points); and syntactic repetition of two complex sentences (2 points), orientation (6 points), and tapping the desk when he/she hears the letter A (1 point), which requires inhibition. The highest score that can be obtained from the scale is 30 and the lowest score is 0. The cut-off score of MoCA was determined as 21 in those who were normal.

In our study, the patients whose cognitive functions were found to be impaired but who did not fulfill the DSM-V criteria for dementia based on the result of clinical assessment and neuropsychometric examinations and the patients who had a MoCA scale score of 17–21 were diagnosed with MCI according to Petersen criteria (6). All the patients were evaluated as having amnestic MCI.

**Magnetic Resonance Imaging**

MRI examinations were performed in the MR unit with 1.5 T (Signa Hdx; GE Medical Systems, Milwaukee, WI, USA). Gradient-weighted Fast Spoiled Gradient-Recalled-Echo (FSPGR) 3D T1 inversion recovery (IR) sequence, which allowed multplanar reformation and volume measurement, was added to the routine brain MRI of the patients and the control group. No contrast material was used in the examinations. A total of 450 consecutive coronal T1-weighted gradient echo images were obtained (Figure 1a). Cross-sectional thickness was determined as 0.8 mm, TR as 13.7, TE as 5.8, TI as 400 ms, flip angle as 11°, field of view (FOV) as 22 cm, number of excitations (NEX) as 1, and pixel matrix was determined as 288×288.

The obtained T1-weighted three-dimensional coronal sections were processed volumetrically. The volumes of bilateral hippocampus areas were calculated in mm³ using the method of marking-extracting with the automatic image analysis software AW Volume-viewer 3, accompanied by axial and sagittal reformat images, on the GE Advantage (AW4.4) workstation (Figure 1b). The researcher who made the volume calculation was blind to the clinical information of the subjects.

**Statistical Analysis**

SPSS 15.0 for Windows (SPSS Inc.; Chicago, Illinois, USA) was used for the statistical analysis. The chi-square test was used to assess the relationships between categorical variables, and the Student’s t-test was used to evaluate the difference between the averages of the continuous variables of the two groups. The relationship of numerical variables was examined through Spearman’s correlation analysis.

**Results**

The mean ages of the patients and the control subjects were 69.1±6.2 and 67.4±5.9 years, respectively. No statistically significant difference was observed between the groups in terms of age and gender (p=0.320 and p=0.777, respectively).
The SMMT and MoCA scores and the hippocampal volume averages are shown in Table 1.

The SMMT scores and the right and left hippocampal volume averages were statistically significantly lower (p<0.001, p=0.011, and p=0.014, respectively) in the patient group than in the control group.

The hippocampal volume averages of the patient and control groups are shown graphically in Figure 2.

A statistically significant positive correlation was found between the MoCA scores and the left hippocampal volume (p=0.013). There was no statistically significant relationship among the right hippocampal volume, age, and SMMT scores (Table 2).

Discussion

Elderliness is a natural stage of human life. Human lifespan has prolonged along with improved living conditions and treatment or control of diseases. This causes an increase in the prevalence of diseases related to elderliness.

Alzheimer’s disease has a separate place and importance in geriatric diseases because the deterioration in cognitive ability directly affects the quality of life of individuals.

Mild cognitive disorder is an interim period that should be recognized and should not be overlooked, because it has a high risk of progression to Alzheimer-type dementia (11). Although this risk is reported at different rates in various series, it is 6%-40% per annum (12). In amnestic MCI, which is the most common subtype, the risk of conversion to Alzheimer-type dementia is especially apparent. This ratio is about 1%-2% in healthy people over 65 years of age (13).

Today, different examination methods are used for the diagnosis of MCI and Alzheimer-type dementia. In the study of Ge et al. (14) in which 129 healthy controls were monitored for 42 months, the participants who had increased tau/A β 1-42 ratios in the cerebrospinal fluid (CSF) and who had an increased frequency of the apolipoprotein E ε4 allele were reported to have been diagnosed...
with MCI at the end of the study. In voxel-based positron emission tomography (PET) that was performed using the BF 227 ligand, patients with AD and MCI were reported to have an abnormal distribution pattern in the field of posterior association (15). It has been reported that changes in latency and amplitudes of movement-related cortical potentials (MRCP) can indicate the presence of frontal dysfunction electrophysiologically in cases with MCI (16). These are difficult and expensive examinations to access and implement.

The inability to perform subunit analyses such as memory, visual-spatial, language, and other complex functions are moderately affected in MCI. This moderate decrease in cognitive function capacity and hippocampal volume, which can be demonstrated by the MoCA test, which should fulfill more requirements accumulating in the hippocampus and with the disease burden (18).

In our study, the MoCA test was performed in the patients who were clinically and radiologically diagnosed with MCI. In our opinion, the fact that amnestic type is the most common type and the patients who have complaints of forgetfulness were included in the study can explain the amnestic MCI diagnosis in all patients. Several features in the design of the MoCA test allow it to detect MCI with greater sensitivity. When compared with SMMT, the memory test contains more words, fewer learning trials are administered, and it has a longer delayed recall duration. Executive functions, high language functions, and complex visual-spatial functions are moderately affected in MCI. This moderate decrease can be demonstrated by the MoCA test, which should fulfill more tasks in comparison to the SMMT (7).

In our study, there was a significant difference between the right and left hippocampal volumes (p=0.011 and p=0.014, respectively) when subjects with MCI and healthy controls were compared. The severity of hippocampal atrophy in MCI determines the progression to dementia. The severity of atrophy in the hippocampus and the entorhinal cortex was found to correlate especially with the subunits of memory tests involving recall and new learning (23).

In our study, we found a significant association in the correlation analysis between the MoCA scale scores and the left hippocampal volume averages (p=0.013). We believe that this indicates a close relationship between cognitive function capacity and hippocampal volume, which can be demonstrated by the MoCA scale.

The inability to perform clinical follow-ups of patients, the inability to determine whether Alzheimer-type dementia developed, and the inability to perform subunit analyses such as memory, visual-spatial functions, attention, and volumetric index on MRI can be considered among the limitations of our study.

To summarize, we observed in our study that the hippocampal volume in subjects with MCI was significantly reduced compared to that in the healthy control group. We found that the hippocampal volume reduction was directly proportional to the MoCA scale. When compared with SMMT, the memory test contains more words, fewer learning trials are administered, and it has a longer delayed recall duration. Executive functions, high language functions, and complex visual-spatial functions are moderately affected in MCI. This moderate decrease can be demonstrated by the MoCA test, which should fulfill more tasks in comparison to the SMMT (7).

In our study, the MoCA test was performed in the patients who were clinically and radiologically diagnosed with MCI. In our opinion, the fact that amnestic type is the most common type and the patients who have complaints of forgetfulness were included in the study can explain the amnestic MCI diagnosis in all patients. Several features in the design of the MoCA test allow it to detect MCI with greater sensitivity. When compared with SMMT, the memory test contains more words, fewer learning trials are administered, and it has a longer delayed recall duration. Executive functions, high language functions, and complex visual-spatial functions are moderately affected in MCI. This moderate decrease can be demonstrated by the MoCA test, which should fulfill more tasks in comparison to the SMMT (7).

In our study, there was a significant difference between the right and left hippocampal volumes (p=0.011 and p=0.014, respectively) when subjects with MCI and healthy controls were compared. The severity of hippocampal atrophy in MCI determines the progression to dementia. The severity of atrophy in the hippocampus and the entorhinal cortex was found to correlate especially with the subunits of memory tests involving recall and new learning (23).

In our study, we found a significant association in the correlation analysis between the MoCA scale scores and the left hippocampal volume averages (p=0.013). We believe that this indicates a close relationship between cognitive function capacity and hippocampal volume, which can be demonstrated by the MoCA scale.

The inability to perform clinical follow-ups of patients, the inability to determine whether Alzheimer-type dementia developed, and the inability to perform subunit analyses such as memory, visual-spatial functions, attention, and volumetric index on MRI can be considered among the limitations of our study.

To summarize, we observed in our study that the hippocampal volume in subjects with MCI was significantly reduced compared to that in the healthy control group. We found that the hippocampal volume reduction was directly proportional to the MoCA scale. These findings suggest that the cognitive level correlates with the MoCA scale scores in MCI, and these tests that are inexpensive and easy to access can be used for the diagnosis.

**Ethics Committee Approval:** Ethics committee approval was received for this study.

**Informed Consent:** Informed consent was obtained from patients who participated in this study.

**Peer-review:** Externally peer-reviewed.

---

**Table 1. The comparison of SMMT and MoCA scale scores with the hippocampal volume averages of the patient and control groups**

<table>
<thead>
<tr>
<th></th>
<th>Patient Avg±SD</th>
<th>Min-Max</th>
<th>Control Avg±SD</th>
<th>Min-Max</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MoCA</td>
<td>18,3±1,1</td>
<td>17-21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMMT</td>
<td>23,1±1,2</td>
<td>23-26</td>
<td>28,5±0,6</td>
<td>28-30</td>
<td>&lt;0,001</td>
</tr>
<tr>
<td>Hippocampal volume (mm³)</td>
<td>Right 2357,8±543,8</td>
<td>1581-3526</td>
<td>2748,8±499,0</td>
<td>2025-3820</td>
<td>0,011</td>
</tr>
<tr>
<td></td>
<td>Left 2323,5±541,7</td>
<td>1506-3428</td>
<td>2692,4±479,8</td>
<td>2010-3756</td>
<td>0,014</td>
</tr>
</tbody>
</table>

SMMT: Standardized Mini Mental Test; MoCA: The Montreal Cognitive Assessment Scale

**Table 2. The comparison of MoCA test scores with the right and left hippocampal volumes, age, and SMMT score averages in the patient group**

<table>
<thead>
<tr>
<th></th>
<th>MoCA Rho</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Age</td>
<td>0,128</td>
<td>0,542</td>
</tr>
<tr>
<td>SMMT</td>
<td>0,027</td>
<td>0,900</td>
</tr>
<tr>
<td>Right hippocampal volume (mm³)</td>
<td>0,357</td>
<td>0,080</td>
</tr>
<tr>
<td>Left hippocampal volume (mm³)</td>
<td>0,488</td>
<td>0,013</td>
</tr>
</tbody>
</table>

SMMT: Standardized Mini Mental Test; MoCA: The Montreal Cognitive Assessment Scale

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

References

17. Anstey KJ, Maller JL. The role of volumetric MRI in understanding mild cognitive impairment and similar classifications. Aging Ment Health 2003; 7: 238-50. [CrossRef]