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Original Article

Radiology Section

Imaging Approaches in Dementia: A Retrospective Cohort Study of Cross-sectional Imaging in the Indian Population

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ABSTRACT

Introduction: Dementia is a broad medical term that describes the progressive cognitive decline of brain function due to disease or impairment, resulting in interference with daily activities. Magnetic Resonance Imaging (MRI) is commonly used for the clinical diagnosis of dementia by identifying cerebral atrophy and structural alterations. Furthermore, Magnetic Resonance Spectroscopy (MRS) can detect biochemical abnormalities in dementia patients, which may be beneficial for early diagnosis and treatment.

Aim: To provide a comprehensive protocol and a guidance tool for radiologists to effectively diagnose dementia and its subtypes {Alzheimer's Disease (AD), frontotemporal lobe dementia, etc.} based on radiological findings coupled with volumetry, spectroscopy, and Arterial Spin Labelling (ASL) findings.

Materials and Methods: A retrospective observational study was conducted in the Department of Radiology, Nanavati Max Superspeciality Hospital, Mumbai, Maharashtra, India, between June 2022 and June 2023. A total of 125 patients were analysed to observe the correlation between whole brain volume, Intracranial Volume (ICV) of different cortical regions, hippocampal atrophy, and MRS findings. Descriptive statistics were used, and results were expressed as means and standard deviations for continuous variables, and as frequencies and percentages for categorical variables.

Results: Out of 125 patients, 71 (56.8%) were males, and 54 (43.2%) were females, with ages ranging from 41 to 96 years. The majority presented with Mild Cognitive Impairment (MCI) 36 patients (28.8%) and Vascular Dementia (VaD) (18 patients - 14.4%). Some clinical features and imaging findings overlapped, resulting in some cases being a combination of different types of dementia. MRI, MRS, and Medial Temporal Atrophy (MTA) played a crucial role in allowing clinicians to perform a differential diagnosis.

Conclusion: The use of MR volumetry and spectroscopy aids in classifying the type of dementia, which, in turn, gives treating clinicians a better perspective for further treatment and its outcomes.

Keywords: Alzheimer's disease, Arterial spin labelling, Frontotemporal lobe dementia, Magnetic resonance imaging, Magnetic resonance spectroscopy

INTRODUCTION

Dementia is a clinical syndrome characterised by cognitive impairment, often involving difficulties with patients' thoughts, behaviour, mood, and memory, which worsen over time [1-3]. It primarily affects the older population (>65 years), but approximately 9% of cases occur in younger individuals. According to the latest World Health Organisation (WHO) report, the number of patients suffering from dementia is expected to increase from 55 million to 139 million by 2050 [4,5]. Distinguishing between the characteristics of typical ageing and dementia is crucial for an accurate diagnosis. Individuals experiencing normal ageing maintain independent functioning and may only occasionally report memory problems. In contrast, patients with dementia depend on others for daily tasks and have significantly impaired memory, often unable to recall events when asked. Moreover, patients with dementia may exhibit socially unacceptable behaviours, whereas those aging normally typically retain social skills [5-7].

Alzheimer's disease is the most common form of dementia, accounting for about 60-70% of cases worldwide [8]. Other less common forms include VaD, Frontotemporal Dementia (FTD), MCI, and Dementia with Lewy Bodies (DLB). Accurate classification of different dementias remains a challenge for clinicians, as histopathologic examination alone cannot determine the underlying cause, often revealing mixed pathologies in the patient's brain [1].

Neuroimaging techniques have been widely used for the diagnosis of dementia by ruling out cognitive impairment due to intracranial haemorrhage or space-occupying lesions. These techniques have become reliable for accurately diagnosing distinct types of dementia [9]. Fluorodeoxyglucose (FDG) Positron Emission Tomography (PET) combined with MRI is beneficial for confirming findings and identifying abnormalities at an early stage [10].

The aim of the present study was to diagnose the different subtypes of dementia using volume analysis, MRS findings, morphologic factors, and ASL results. A differential diagnosis can enable the development of an effective treatment plan, thereby providing symptomatic relief to patients.

MATERIALS AND METHODS

This retrospective observational study included all adult patients (confirmed cases of dementia) between June 2022 and June 2023 at the Department of Radiology, Nanavati Max Superspeciality Hospital, Mumbai, Maharashtra, India.

Inclusion and Exclusion criteria: Data were collected retrospectively from 125 cognitively impaired participants. These individuals underwent imaging based on complaints such as memory loss, forgetfulness, gait disorders (imbalance, visual disturbances, etc.), and clinical/cognitive function assessment tests such as the finger tapping test, Mini-mental State Examination (MMSE) total score, and Montreal Cognitive Assessment (MoCA). Participants with memory

complaints and a diagnosis of schizophrenia were excluded from the study.

Study Procedure

Patients were scanned using a GE 3.0 Tesla MRI Scanner, and the protocols used are illustrated in [Table/Fig-1]. To analyse the variation in head size, the authors also calculated the total ICV for each participant using Neuroshield, an artificial intelligence-based clinical tool [11,12]. MRI has been used for decades to measure structural changes in the brain associated with dementia. It is an imaging modality that provides detailed anatomical information due to its excellent tissue contrast, spatial resolution, and levels of image resolution [1,13]. These studies assist in evaluation of neurodegenerative diseases by quantifying the volume of brain structures. Brain volume measurements are a known biomarkers for diagnosing different types of dementia [14]. This volumetric analysis serves as a valuable clinical diagnostic support tool, aiding clinicians in calculating volumetric changes, tracking the clinical progression of the disease, and monitoring the percentage of ICV [11].

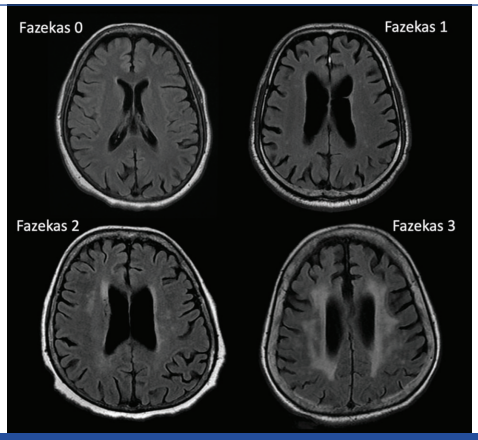
Type of sequence	Target areas	Planes	Protocol		Use
Diffusion weighted imaging	Whole brain	Axial	FOV-24 Slice thickness-5×0 Matrix-128×128 Nex-2		To detect acute infarct
FLAIR		Axial	FOV-24 Slice thickness-5×0 (spacing) Matrix-288×224 Nex-1		To visualise the old infarcts and white matter changes
Susceptibility-Weighted Angiography (SWAN) (1 mm)		Axial	FOV-24 Slice thickness-2.4 Matrix-384×224		To detect haemorrhages
T2-weighted		Sagittal	FOV-16 Slice thickness-3×0 (spacing) Matrix-384×384 Nex-3		To detect Normal Pressure Hydrocephalus (NPH)
3D Spoiled gradient recalled acquisition in steady state (3D-SPGR)	Whole brain and hippocampal volumetry	4 mm sections in Sagittal plane	FOV- 25.6 Slice thickness-2.2 Matrix-256×256 Nex-1		To calculate volumes
MR angiogram (Optional)-3DTOF sequence	Brain and neck	NA	Brain FOV-22 Slice thickness-1.2 Matrix-512×288 Nex-1	Neck FOV-28 Slice thickness-2.8 Matrix-416×224 Nex-1	To detect narrowing of the arteries, clot or bulge
Single Voxel Spectroscopy-TE PRESS sequences (35 ms)	Gray and White Matter in the brain	NA	2×2×2 cm sized voxels placed in the gray and white matter		To measure biochemical changes in the brain with a focus on NAA/Cr and mL/Cr levels
Arterial Spin Labelling (ASL)	Whole brain	NA	FOV-24 Slice thickness-4 Points-512 Arms-8 Nex-3		To assess the Cerebral blood flow

[Table/Fig-1]: Brain MRI protocol.
FOV: Field of view

The MRS is a widely available, non invasive technique that measures biochemical changes in brain tissue [15]. N-Acetyl-L-Aspartate (NAA) is a neuronal marker found in neurons, neuroglial precursors, and immature oligodendrocytes, while myo-inositol (ml) is a glial marker present in the frontal, parietal, temporal, and temporoparietal lobes [1]. A decrease in the NAA/Creatinine (Cr) ratio correlates with the severity of dementia and cognitive decline [16]. Klunk WE et al., demonstrated that a decrease in NAA is linked to neuronal loss [17].

MRI studies aid in identifying the type of dementia based on visual rating scales such as the MTA score, Fazekas scale, and Koedam score. The MTA and Koedam scores assist in identifying AD, while the Fazekas scale helps in determining VaD and normal aging [18]. The MTA is a visual score performed on coronal T1-weighted MRI images based on hippocampal height and the width of the choroid fissure and temporal horn [19,20]. The Fazekas scale is used to quantify the amount of white matter hyperintensities on Fluid-attenuated Inversion Recovery (FLAIR) or T2-weighted images [21,22]. [Table/Fig-2] shows the Fazekas score scale. The Koedam score provides a scale for analysing parietal atrophy in sagittal, coronal, and axial planes and has proven to have a positive predictive value in the diagnosis of AD [23].

ACR appropriateness criteria: Imaging findings in structural MRI studies are non specific and have limited potential to differentiate between types of dementia. Advanced imaging techniques like functional neuroimaging with MRI and MRS can provide a better understanding of neurodegenerative disorders. The American College of Radiology Appropriateness Criteria (ACR) offers evidence-based guidelines for clinical conditions that are annually reviewed by an interdisciplinary expert panel. The guideline development and revision involve an extensive analysis of existing medical literature from peer-reviewed journals and the application of well-established methodologies (RAND/UCLA Appropriateness Method and Grading of Recommendations Assessment, Development, and Evaluation or GRADE) to rate the appropriateness of imaging and treatment



[Table/Fig-2]: MRI brain scans demonstrate the scale of Fazekas score by showing white matter hyperintensities.

procedures. In instances where the evidence is not unequivocal, expert opinion may be used to recommend imaging or treatment [24,25].

The PET with FDG is most commonly used to identify neurodegenerative processes [10]. FDG PET scans serve as an in-vivo clinical assessment of the autoradiographic technique. These scans are utilised to visualise cerebral glucose metabolism, which is instrumental in the differential diagnosis of dementia and the prediction of cognitive decline by analysing neural degeneration. Glucose is the primary metabolic substrate for energy production in the brain. FDG leverages deoxyglucose as a tracer to detect the exchange of glucose between plasma and the brain [26]. Given that glucose is the sole source of energy for the brain, the loss of neurons in neurodegenerative brain diseases may result in decreased glucose consumption in specific brain regions [27]. It is important to note that molecular imaging, such as FDG PET, was not utilised in the diagnosis of dementia types in our study.

STATISTICAL ANALYSIS

Descriptive statistics were used, and results were expressed as means and standard deviations for continuous variables, and as frequencies and percentages for categorical variables.

RESULTS

[Table/Fig-3] summarises the statistical analysis of the dataset, detailing whole brain volume and hippocampal volume with respect to gender. The majority of patients were aged between 71-80 years, with 52 (41.6%) falling within this age range [Table/Fig-4].

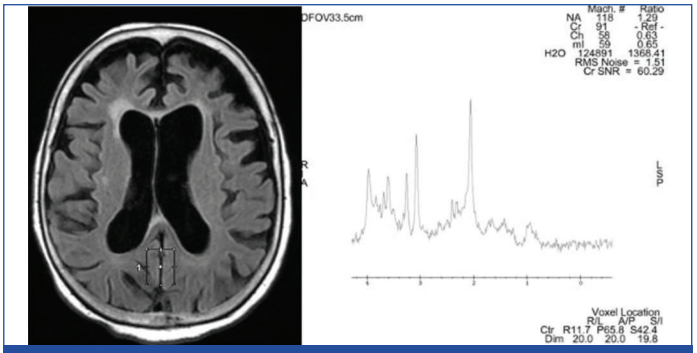
Variables	Mean	Standard deviation	Minimum	Maximum
Age (Overall)	72.58	9.86	43	96
Male	72.8	9.86	50	93
Female	72.3	9.86	43	96
Whole brain volume (cc) (Overall)	895.08	107.06	688.27	1257.08
Male	915.38	107.07	717	1164
Female	871.41	107.07	688.27	1257.1
Left hippocampal volume (cc) (Overall)	2.54	0.48	1.22	3.45
Male	2.59	0.48	1.22	3.45
Female	2.48	0.48	1.61	3.33
Right hippocampal volume (cc) (Overall)	2.67	0.55	0.7	3.58
Male	2.77	0.55	1.19	3.58
Female	2.56	0.55	0.7	3.3

[Table/Fig-3]: Descriptive statistics illustrating the age, whole brain volume and hippocampal volume.

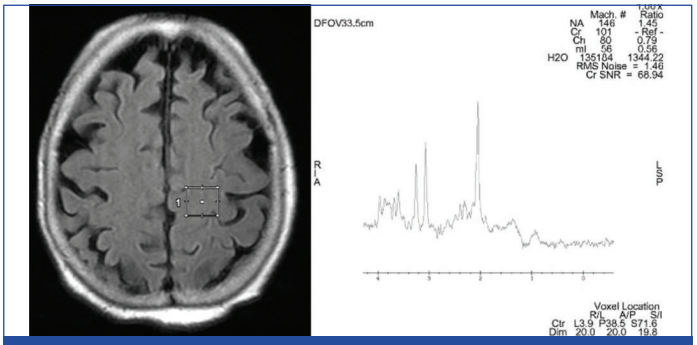
Age group (years)	Male	Female	Total	Percentage
40-50	2	1	3	2.4
51-60	8	5	13	10.4
61-70	15	15	30	24
71-80	31	21	52	41.6
81-90	13	11	24	19.2
91-100	2	1	3	2.4
Total	71	54	125	100

[Table/Fig-4]: Age distribution of the cohort.

In the present study, from a cohort of 125 patients, only 10 patients (8%) were diagnosed with AD. Brain volumetry performed on AD patients revealed a mild to moderate reduction in whole brain volume (mean=877.78 cc), and a moderate to severe reduction in hippocampal volumes (mean value of right hippocampal volume: 2.38 cc; mean value of left hippocampal volume: 2.21 cc). MRI scans showed white matter changes in these patients. Magnetic Resonance Spectroscopy (MRS) indicated a decrease in the N-acetylaspartate to creatinine (NAA/Cr) ratio and an increase in the myo-inositol to creatinine (mI/Cr) ratio, further supporting an AD pathology. [Table/Fig-5] presents a moderate reduction in the NAA/Cr ratio, indicative of neuronal loss, and an elevation in the mL/Cr ratio in the grey matter as observed in AD (in a 78-year-old female patient). [Table/Fig-6] shows a similar reduction in the NAA/Cr ratio within the white matter of the same patient.



[Table/Fig-5]: Grey matter spectroscopy of 78-year-old woman with AD; MR spectroscopy with short TR and TE sequence showing mild elevation of myo-inositol and moderate reduction of NAA.



[Table/Fig-6]: White Matter Spectroscopy of 78-year-old woman with AD; MR spectroscopy with short TR and TE sequence showing moderate reduction of NAA.

The MCI cases accounted for 29% of the total sample (n=36), with an average age of approximately 67 years. Compared to AD patients, those with MCI exhibited a mild reduction in whole brain volume (mean=926.43 cc±107.26) and hippocampal volumes (mean value of right hippocampal volume=2.78 cc±0.422; mean value of left hippocampal volume=2.61 cc±0.382) with a MTA score ranging from 1 to 2.

The number of infarcts and the Fazekas score contributed to the diagnosis of VaD. A multi-infarct etiology was most common among the patients. In individuals with VaD, white matter NAA/Cr levels were lower when compared to AD patients. FTD cases (n=10) were diagnosed based on cerebral atrophy and the specific morphological features of the atrophy, particularly in the frontal and temporal lobes.

Additionally, Normal Pressure Hydrocephalus (NPH) was identified in the present cohort and was diagnosed based on cerebral atrophy, aqueductal or fourth ventricular flow void, the disproportion of ventricular dilatation to the degree of cortical atrophy, and the callosal angle.

[Table/Fig-7] illustrates the total number of patients diagnosed with different subtypes of dementia within the cohort.

Types of dementia	Number of patients	Percentage (%)
Alzheimer's Dementia	10	8
Frontotemporal Dementia (FTD)	10	8
Mild Cognitive Impairment (MCI)	36	28.8
Vascular Dementia (VaD)	18	14.4
Normal Pressure Hydrocephalus (NPH)	15	12
Combination	29	23.2
Others	7	5.6
Total	125	

[Table/Fig-7]: Types of patients and their individual count in the study population.

While the cases of dementia discussed represent a broad classification, clinical features and imaging findings may sometimes overlap, resulting in various combinations of dementia. The most common mixed type found was AD with FTD, each with an overlay of multi-infarct status (VaD). MRS is a valuable tool in the diagnosis of different dementias. [Table/Fig-8] summarises the diagnostic factors used by clinicians for differential diagnosis. The NAA/Cr ratio in the white and grey matter, as shown in [Table/Fig-9], is frequently employed to classify the various subtypes of dementia. AD patients exhibited an NAA/Cr ratio below 1.4 in the grey matter spectrum, which is a strong indicator of neuronal loss. Alongside an increased ml/Cr ratio, this could potentially assist radiologists in confirming a diagnosis of AD, although further exploration is needed. In contrast, the NAA/Cr ratio in the grey matter of FTD patients was approximately 1.5. However, for diagnosing VaD, the NAA/Cr ratio in the white matter spectrum is considered.

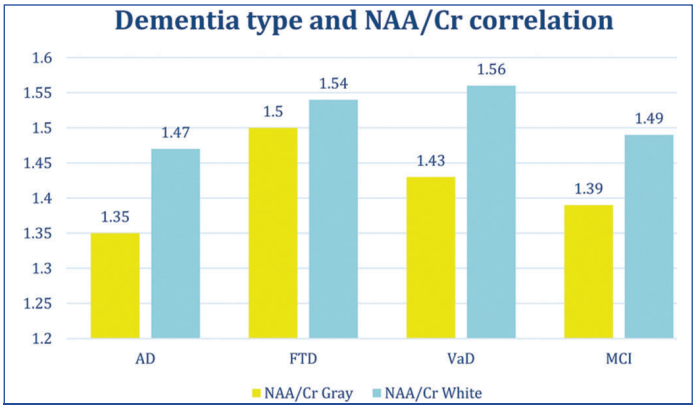
DISCUSSION

Alzheimer's Disease (AD)

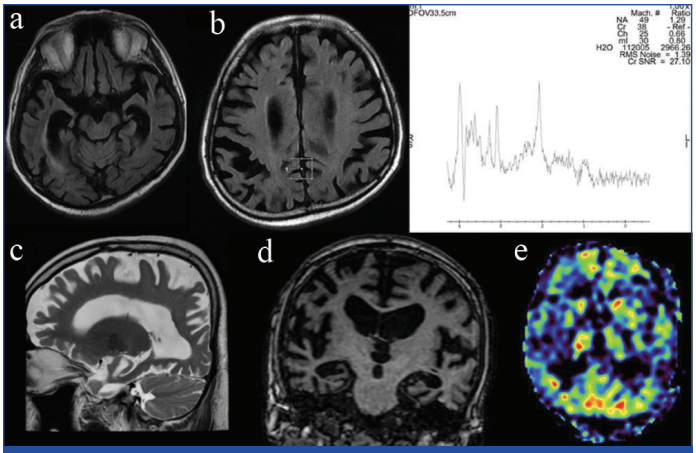
MRI is more sensitive than Computed Tomography (CT) scans to patterns of cortical atrophy and can better exclude other causes of dementia. It plays a crucial role in the diagnosis of AD by assessing volume changes in characteristic locations of the medial temporal lobe (including the hippocampus, entorhinal cortex, and perirhinal cortex) and the temporoparietal cortical region. [Table/Fig-10] shows MRI images of two patients diagnosed with AD. Medial temporal lobe atrophy can be determined directly or indirectly. Direct assessment depends on the volume loss of the hippocampus or the parahippocampus, while indirect assessment relies on the enlargement of the parahippocampal fissures. Direct assessment is comparatively more sensitive and specific and has been shown to predict the progression of MCI to dementia [28]. The MTA scale is a commonly used visual assessment scale that has been clinically and neuropathologically validated. The MTA score has demonstrated significant ability to distinguish AD patients from those with vascular cognitive impairment or DLB [29]. Clinically, AD is characterised by a cognitive decline in the form of episodic memory deficits. As the disease progresses, patients may also experience psychological and behavioural problems such as mood disorders, aphasia, visuospatial difficulties, executive dysfunction, and sleep disorders [28,30]. A decrease in the concentration of NAA in the frontal, parietal, temporal lobes, and the hippocampi is commonly seen in AD patients. Various neurodegenerative conditions feature reduced levels of NAA [15]. Studies have shown that elevated glial metabolite, myo-inositol/creatine (mL/Cr) levels, and decreased NAA/Cr levels are associated with AD patients [17]. Thus, the combination of high ml and low NAA in MRS assists in the early diagnosis of AD [18].

Type of dementia	Clinical symptoms	MRI modality specifications	Imaging findings	MR spectroscopy	Morphologic factors	ASL findings
Alzheimer's disease	• Insidious onset and slow progressive decline • Short-term memory impairment in early stage	• Atrophy best seen in TI-weighted volumetric sequences • Vascular damage correlated with/precedes cognitive impairment illustrated in the form of white matter hyperintensities on T2-weighted and FLAIR images MRI	• Atrophy of medial temporal lobe • Parietal lobe atrophy	• Elevated myo-inositol to creatinine (mL/Cr) levels • Decreased N- acetyl-L-asparatate to crearinine (NAA/Cr) levels linked to neuronal loss	High MTA (3-4)	Relative symmetric hypoperfusion
Vascular dementia	• Sudden or gradual onset • Usually correlated with cerebrovascular disease (stroke, lacunar infarcts) and atherosclerotic co-morbidities • Possible gait difficulties and falls (depending on the extent of the stroke)	• T2-weighted and FLAIR images show vascular infarcts in both small and large vessel diseases in the form of hyperintense signals • Increasing white matter lesions on imaging correlate with increasing cognitive decline	• Global atrophy • White matter lesions • In some cases, strategic infarcts affecting the cognitive regions are observed	Decreased NAA/Cr levels in the white matter spectrum linked with neuronal loss	Moderate MTA (I-2)	Symmetric and maintained cerebral perfusion
Frontotemporal dementia	More prominent personality changes (disinhibition) and behavioural disturbances (apathy, aggression, agitation with less memory impairment in early stage)	Volumetric MRI	Cerebellar atrophy of the frontal and temporal lobe	• Elevated mL/Cr in the frontal cortex • Decreased NAA/Cr levels in the frontal cortex linked to neuronal loss	• Moderate MTA (2-3) • Fazekas score (1-2)	Symmetric and maintained cerebral perfusion
Mild cognitive impairment	• Cognitive impairment related to memory, executive function/ attention, language, or visuospatial skills • Essentially normal functional activities • Absence of dementia	TI-signal decay for measuring white matter damage	Atrophy of the entorhinal cortex and hippocampus	Decreased NANCr levels in the posterior cingulatc gyrus linked to neuronal loss	• Moderate MTA (1-2) • Fazekas score (1)	Symmetric and maintained cerebral perfusion
Normal pressure hydrocephalus	• Progressive gait impairments • Cognitive deficits • Urinary urgency and/or incontinence	• Sagittal TI-weighted images help in assessing the aqueductal flow • T2/FLAIR signal on MRI indicative of changes in brain water content	• Peri ventricular hyperintensities and widening of temporal horns of the lateral ventricles • Narrowing of sulci and subarachnoid spaces over the midline surface of the brain	NAA/Cr levels reduced in white matter spectrum linked to neuronal loss	• MTA score (2) • Fazekas score (3)	NA

[Table/Fig-8]: Comprehensive features to differentiate the subtypes of dementia based on clinical, radiological, morphological and spectroscopic findings.



[Table/Fig-9]: Bar graph shows the correlation of NAA/Cr ratio of the grey and white matter in the subtypes of dementia.

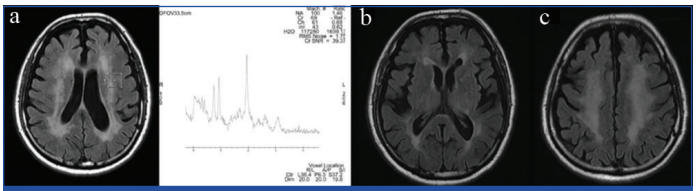


[Table/Fig-10]: A 72-year-old man and 78-year-old woman with AD: a) Axial FLAIR image showing moderate dilatation of both temporal horns and temporoparietal atrophy with an MTA score of 4; b) Sagittal T2-weighted image showing severe atrophy of left frontal and parietal lobes with resultant dilatation of overlying sulci; c) MR spectroscopy with short TR and TE sequence showing mild elevation of myo-inositol and moderate reduction of NAA; d) Coronal T1-weighted image showing MTA score of 4; e) Another patient with AD showing generalised reduction in CBF with predominantly affecting both temporal and parietal lobes.

Vascular Dementia (VaD)

The VaD is the second most common type of dementia, and MR images of VaD patients show periventricular white matter hyperintensities [31]. Multi-infarct dementia, a subtype of VaD, results from a series of small strokes that lead to permanent brain damage. These patients develop early symptoms such as mood changes and difficulties in understanding, concentrating, and planning. As the disease progresses, patients may show signs of confusion, difficulty following instructions, and inappropriate laughing or crying, along with loss of bladder or bowel control [32]. Some symptoms of VaD are similar to those of AD [33,34].

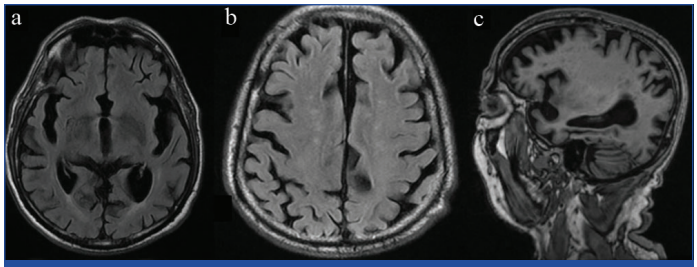
Binswanger's disease, another subtype of VaD, arises due to arteriosclerosis and thromboembolism, affecting blood vessels that impact white matter and other subcortical structures. [Table/Fig-11] highlights an example of this rare type of VaD. Most patients experience progressive memory loss, urinary urgency, and an unsteady walking pattern [35,36]. Hyperintense signals on T2-weighted images and Fluid-attenuated Inversion Recovery (FLAIR) images aid in the distinct visualisation of both small and large vessel diseases and in identifying microhaemorrhages [37]. Additionally, there is a variable appearance with multifocal asymmetrical abnormalities in affected brain regions [10].



[Table/Fig-11]: A 78-year-old man with VaD; a) Axial FLAIR image showing multiple discrete and confluent lacunar infarcts in both frontal and parietal lobes and single-voxel white matter spectroscopy showing reduction in NAA/Cr ratio (1.46), suggestive of neuronal loss; b) Showing similar lesions in the parieto-occipital periventricular white matter as seen in Binswanger's disease; c) Showing confluence of these infarcts with pattern resembling subcortical arteriosclerotic encephalopathy.

Frontotemporal Dementia (FTD)

The FTD consists of three subtypes: behavioural variant, primary progressive aphasia, and motor disorder [31]. MRI helps to determine the region and extent of atrophy, which enables the diagnosis of FTD. [Table/Fig-12] is an example of a patient who was diagnosed with FTD [38]. The various FTD subtypes seen in literature are the behavioural and semantic variants of FTD, corticobasal syndrome, non fluent agrammatic variant of FTD, and FTD-associated motor neuron disease. Moreover, some patients with FTD present progressive supranuclear palsy in combination, primarily affecting movement. However, in the scope of the present study, only the behavioural variant of FTD and semantic variant of FTD will be discussed [39]. [Table/Fig-13] describes the clinical and radiological findings of these two subtypes of FTD.



[Table/Fig-12]: An 84-year-old man with FTD; a) Axial FLAIR image showing significant dilatation of left Sylvian fissure with moderate atrophy of left temporal and both frontal lobes; b) Showing moderate dilatation of cortical sulci in both frontal lobes (left more than right); c) Showing moderate dilatation of sulci in the frontal lobe with relative sparing of left parietal lobe. Volumetric studies in this patient revealed moderate reduction in hippocampal (left more than right) complete and whole brain volume consistent with semantic variant of FTD.

FTD subtypes	Clinical findings	Imaging findings
Behavioural variant FTD	• Disinhibition and loss of apathy and empathy • Hyperorality and preservative or compulsive behaviours	Bifrontal and anterior temporal atrophy seen in T2-weighted axial MRI
Semantic variant FTD	• Loss of word meaning • Visual agnosia and prosopagnosia as disease progresses	• Atrophy in dominant anterior temporal lobe demonstrated by (FLAIR) MRI • Posterior temporal and visual temporal association areas affected with disease progression

[Table/Fig-13]: FTD subtypes, their clinical and imaging findings.

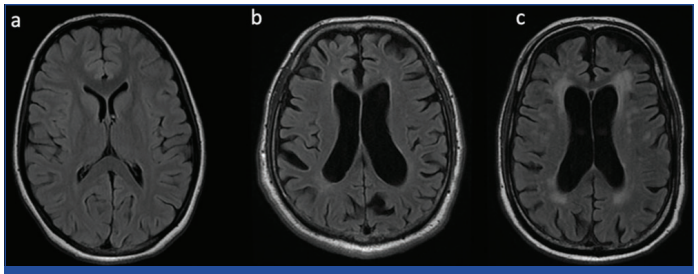
There is an overlap between the cortical regions affected by atrophy in FTD and AD. FTD shows relatively more atrophy in the frontal lobes, whereas AD shows more atrophy in the lateral, parietal, and occipital cortices [29]. This type of dementia is diagnosed in patients within the age group of the 40s to early 60s. The behavioural variant of FTD typically shows asymmetrical frontal and temporal cortical atrophy [31]. The semantic variant of FTD typically shows anterior temporal and ventral temporal association area atrophy, in turn, affecting the patient's ability to use and understand language, whereas progressive non fluent aphasia affects the patient's ability to speak. Some of the common symptoms of FTD are behavioural changes, impaired judgement, decreased self-awareness, and frequent mood changes, while physical symptoms involve tremors, poor coordination, muscle weakness, etc., [40].

Mild Cognitive Impairment (MCI)

The MCI is an early stage of loss in cognitive abilities, such as memory, language, or judgement. The symptoms of people diagnosed with MCI are not severe enough to interfere significantly with daily activities [41,42]. The level of memory deficit may remain stable in MCI patients for years, which is unlikely in the case of AD, where cognitive abilities decline gradually [43]. A person diagnosed with MCI may be at risk of developing AD or other related dementias [42]. The MTA score gives a strong indication of the progression of MCI to Alzheimer's dementia [23]. MRI is extensively used to diagnose MCI and to differentiate it from AD.

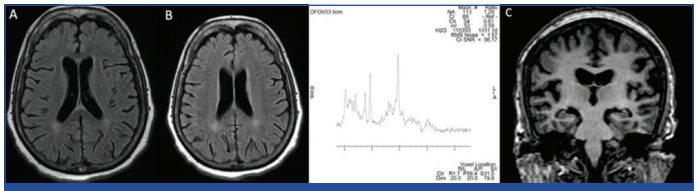
The hippocampal T2 prolongation serves as a unique marker to distinguish MCI from AD. Apart from this, MRI T2 signal decay has been used to measure white matter damage in patients with MCI, owing to its sensitivity to water content. Moreover, patients with MCI have a smaller entorhinal cortex and hippocampus compared to healthy subjects. According to many recent studies, hippocampal volume predicts the transformation of MCI to AD [44].

[Table/Fig-14] is a comparative illustration of the MRI scans of a control, an MCI patient, and an AD patient. In the present study,



[Table/Fig-14]: MRI brain scans of patients; a) FLAIR image of control patient; b) FLAIR image of patient diagnosed with Mild Cognitive Impairment (MCI); c) FLAIR image of patient diagnosed with Alzheimer's Disease (AD).

The MR volumetry showed a mild reduction in the whole brain and hippocampal volume. MRS exhibited a slight to moderate reduction in NAA, which is suggestive of neuronal loss. In most patients, a symmetric and maintained cerebral perfusion was identified. [Table/Fig-15] is an example of a female patient diagnosed with MCI.

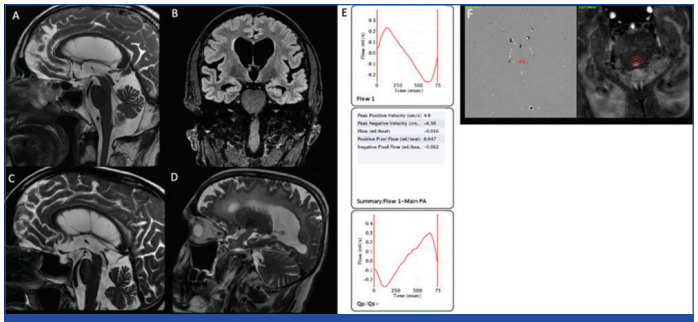


[Table/Fig-15]: A 69-year-old woman with MCI; a) Showing few, old lacunar infarcts in bilateral frontal and parietal white matter on FLAIR image corresponding to Fazekas score of 1; b) Single-voxel spectroscopy with short TR and TE through occipital cortex showing mild reduction in NAA without any changes in other metabolites, suggestive of neuronal loss; c) Coronal T2-weighted image showing MTA score of 2 and mild cerebral atrophy involving grey and white matter almost equally, with predilection for both frontal and temporal lobes. Volumetric studies for this patient revealed mild reduction in whole brain and hippocampal volumes.

Normal Pressure Hydrocephalus (NPH)

The NPH is one of the few dementias that is potentially reversible, and its timely diagnosis can result in the reversal of symptoms [45]. This syndrome can occur in people of any age but is most common in the elderly and may result from head trauma, infection, subarachnoid haemorrhage, tumour, etc., [46]. MRI is the best modality to image the morphological changes observed in NPH, and this can be further supported by CSF flow studies, MRS, and CT scans [47].

Radiographic features demonstrate periventricular hyperintensities, thinning of the corpus callosum, widening of temporal horns without hippocampal atrophy, enlarged Sylvian fissures, and basal cisterns [48]. In NPH, changes in brain water content are observed as high T2-FLAIR signals on MRI scans and as periventricular hypodensity on CT scans [47]. [Table/Fig-16] shows examples of two of the present study NPH patients.



[Table/Fig-16]: A 75-year-old man and 69-year-old man with NPH; a) Sagittal T2 image showing exaggerated flow void in the cerebral aqueduct; b) Showing ventricular dilatation disproportionate to cortical atrophy with periventricular T2 hyperintensities; c) Sagittal T2 image showing hyperdynamic aqueductal flow with thinning of the corpus callosum; d) Sagittal T2 of another patient showing periventricular hyperintensities; e) Showing CSF flow study report; f) CSF flow image showing stroke volume of 150 µL per cycle suggestive of shunt responsive status (D) Sagittal T2 of another patient showing periventricular hyperintensities.

Dementia with Lewy Bodies (DLB)

The DLB is a form of progressive dementia that affects an individual's ability to reason, think, and process information, ultimately leading to a decline in independent function [49]. People with DLB have characteristic features, including recurrent visual hallucinations, changes in attention and alertness, and confusion [50]. DLB typically presents in older adults (50-70 years of age) and is usually sporadic [51]. Structural studies measuring cortical thickness demonstrate that DLB patients show lower levels of volume loss in the amygdala, temporal lobe (including less pronounced grey matter loss in the temporal lobe), and hippocampus when compared to AD patients [52]. Generally, DLB patients do not show deterioration in the formation of episodic memory, as observed in AD. However, impairments in visuospatial and attention tasks have been reported. The midbrain, particularly the substantia innominata and putamen, exhibit greater decline in volume and atrophy in DLB compared to AD [53].

Other Dementias

Apart from the types mentioned in this paper, other dementias or conditions that cause dementia-like symptoms include behavioural variant FTD, brain tumours causing dementia, Creutzfeldt-Jakob disease, dementia with Lewy bodies, Huntington's disease, chronic traumatic encephalopathy, Human Immunodeficiency Virus (HIV)-associated dementia, and Parkinson-like disease. MRI is used to characterise these dementias at the structural level to guide the diagnosis of the patient and direct them towards appropriate management [10].

Limitation(s)

Although the present study of 125 patients underscores the importance of brain volumetry and MRS in differentiating types of dementia, a more detailed evaluation with a larger study group should be conducted to establish these methods as a gold standard for diagnosis. Molecular imaging was not included in the present study due to the low volume of available data. Compared to existing literature, the present study noted some differences, which may be attributed to demographic, environmental, and genetic factors.

CONCLUSION(S)

Neuroimaging modalities are enabling healthcare practitioners to diagnose dementia using biomarkers. MR volumetry is yet another tool that assists in the differential diagnosis of dementia types.

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