Chapter 9
Brain imaging using CT and MRI

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Key points

- Head magnetic resonance imaging (MRI) or computed tomography (CT) should be considered as part of the initial laboratory evaluation of dementia.
- Structural imaging serves primarily to rule out treatable causes of dementia.
- Structural imaging MRI provide insights regarding the underlying causes of dementia.

This is a chapter of the *World Alzheimer Report 2021, Journey to a Diagnosis of Dementia* which can be accessed in full at: https://www.alzint.org/resource/world-alzheimer-report-2021/

General background

In people older than 65 years of age, memory and thinking problems are frequently associated with dementia. However, several brain diseases can also cause memory problems. As a result, doctors perform brain scans, such as computed tomography (CT), and/or magnetic resonance imaging (MRI), to rule out other treatable causes for memory and thinking problems. A CT scan uses X-rays to take pictures of the brain. Using powerful magnets, an MRI can provide more detailed brain pictures. Both the CT and MRI are useful in identifying brain tumours, strokes or other problems that might cause memory and thinking problems.

Brain imaging using head CT or MRI

Structural imaging findings assist in the diagnosis of typical dementia by ruling out the comorbidities of treatable dementias or suggest the presence of comorbidities that may exacerbate dementia symptoms, such as cerebrovascular disease. In addition, specific patterns of brain atrophy, ventricular enlargement and change on the MRI signal may suggest the underlying cause of dementia.

CTs are widely available, less costly, and more convenient for assessing people with claustrophobia, agitation or carriers of pacemakers or ferromagnetic devices. Investigation of individuals with dementia symptoms seldom needs contrast agents. The preferred MRI sequences for dementia assessment are a global T1 sagittal to assess atrophy, T2-weighted and fluid-attenuated inversion recovery (FLAIR) images to detect white matter alterations; conventional T2*-weighted gradient recall-echo or susceptibility-weighted imaging to detect signal alterations derived from microbleeds. Finally, diffusion-weighted Imaging, which provides information regarding water restriction associated with inflammation, is particularly useful for Creutzfeldt-Jakob disease (1).

Reduced cerebral volume or atrophy is invariably described in dementia. While brain loss may be a feature of the ageing brain, the term atrophy implies an underlying pathological process. Structurally, atrophy refers to a wide range of findings, including widening of cerebral sulci, gyri volume or grey matter thickness reduction, or the enlargement of the cerebral ventricles or subarachnoid spaces. Even

Table 1. Methods for semi-quantitative description of brain abnormalities in dementia

	Cortical atrophy	Hippocampus atrophy	Deep white matter abnormalities	Periventricular white matter abnormalities
Range	0–3	0–4	0–3	0–3
Preferred MRI sequence	T1	T1	FLAIR	FLAIR

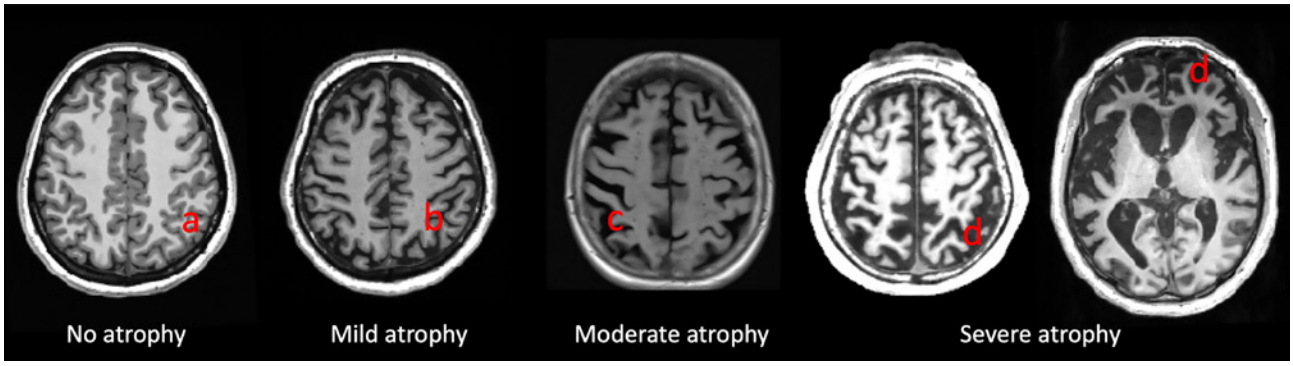

Figure 1. Representation of a series of T1 weighted MRI showing cortical atrophy depicting normal (a), mild (b), moderate (c), and severe (d) cortical atrophy, respectively.

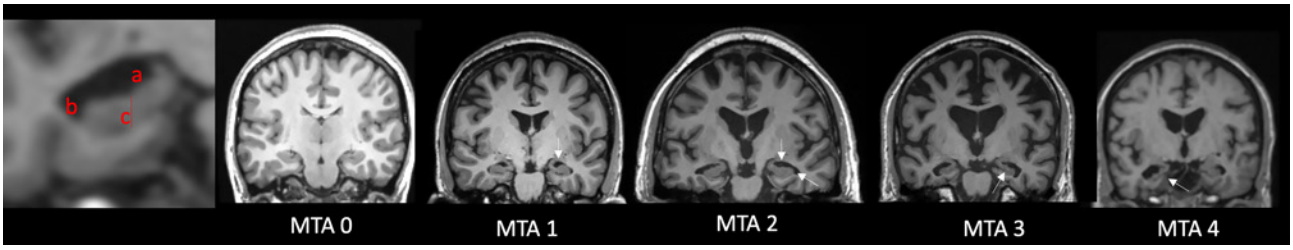

Figure 2. Medial temporal atrophy scores 0–4 indicate medial temporal volume loss. Medial temporal lobe atrophy (MTA) is assessed using a 5-point scale, with scores deduced through assessment of the hippocampal height (c) and width of the choroid fissure (a) and temporal horn (b). For individuals younger than 75 years of age, an MTA score of 2 or more is abnormal, while for subjects older than 75 years of age, an MTA score of 3 or more is abnormal.

though quantitative volumetric measures of global and focal atrophy can be obtained in specialised centres, dementia specialists frequently describe brain atrophy by referring to traditional semi-quantitative visual rating scales (Table 1).

The global cortical atrophy score serves to report mild (opening of sulci), moderate (gyral volume loss), and severe (knife blade) levels of cortical atrophy across cortical regions. The same scale is also useful for reporting various ventricular segments as mild, moderate, and severely enlarged (2,3).

Ventricular enlargement in typical cases is global and proportional to cortical atrophy. When ventricular enlargement seems disproportional to cortical atrophy, one should suspect normal pressure hydrocephalus, particularly in dementia cases associated with incontinence and gait disturbance.

Hippocampal atrophy is part of the repertoire of structural changes observed in typical and atypical dementias. A medial temporal lobe atrophy (MTA) score, also known as Scheltens scale, describes the progression of hippocampal atrophy observed in typical dementia cases based on the coronal T1 weighted MRI reconstructed according to the hippocampal plane. As such, the widening of the choroidal fissure characterises score 1, the widening of the temporal horn characterises score 2, moderate and severe volume loss of hippocampus body characterises scores

3 and 4, respectively. Hippocampal atrophy is associated with a tau load, TDP-43 load, neuronal depletion and other pathophysiological events in the mesial temporal lobe (3,4).

Frontal and temporal lobe atrophy is a hallmark of the frontotemporal dementias, which is a condition associated with multiple pathophysiological processes, including tauopathies (3R, 4R, 3/4R), TDP43 and FUS inclusions. The variability across atrophy patterns seems to be dependent on genetic factors and underlying pathology. Recently, it has been proposed that patterns of brain atrophy observed in frontotemporal dementias and other neurodegenerative conditions follow patterns dictated by physiological brain networks. Methods for assessing frontal lobe atrophy using semi-quantitative visual methods have been summarised elsewhere and are out of the scope of this report (3).

Atrophy in people with the diagnosis of primary progressive aphasia predominates in the left hemisphere. In semantic aphasia, the pattern of atrophy encompasses the anterior ventral and basal temporal lobe, the hippocampus amygdala, and fusiform gyrus. In individuals with non-fluent aphasia, atrophy includes the left inferior frontal, opercular, and insular regions with as well as motor and premotor regions. Atrophy in the basal ganglia, thalamus, and amygdala is frequently observed. The right temporal variant of frontotemporal dementia associated with the behavioural variant of frontotemporal dementia has also been recognised as a distinct syndrome.

Central atrophy – In corticobasal syndrome, atrophy encompass perirolandic regions asymmetrically. Superior frontal, pre-and post- central atrophy are typically accompanied by ipsilateral dilation of the lateral ventricles and basal ganglia atrophy. Corpus callosum atrophy has also been described in corticobasal syndrome (5,6).

Brainstem atrophy and increase signal on T2 – Brainstem atrophy is present in individuals with progressive supranuclear palsy or multiple system atrophy. In progressive supranuclear palsy, an MRI reveals brainstem atrophy, particularly involving the midbrain. Such midbrain atrophy on the midsagittal T1 weighted MRI resembles a hummingbird or a penguin silhouette. On an axial T2-weighted MRI, midbrain atrophy resembles the morning glory flower silhouette. On T1 weighted images, multiple system atrophy individuals show putamen, pons, and middle cerebellar

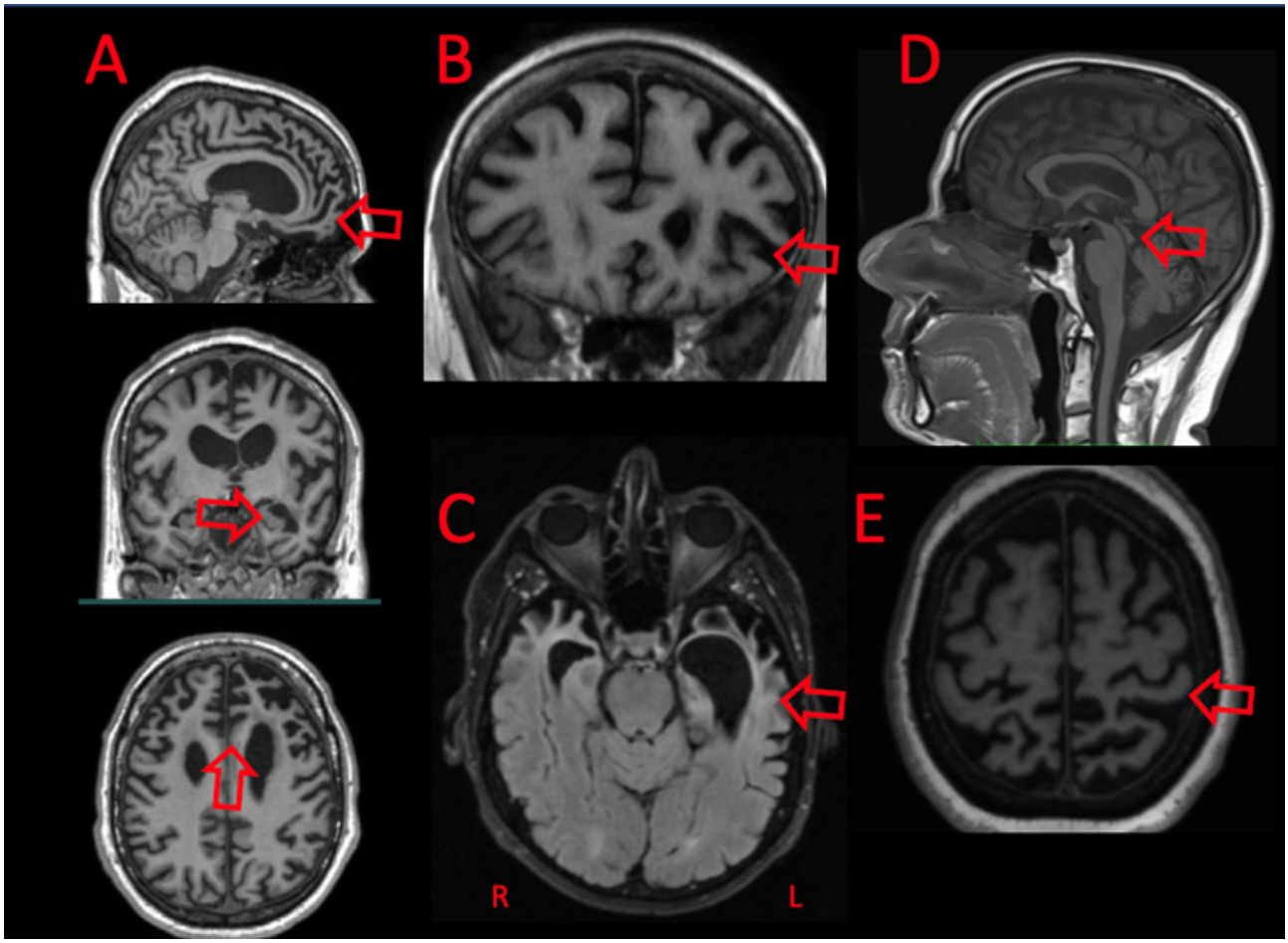

Figure 3. Representative patterns of brain atrophy from a behavioural frontotemporal dementia case (A), non-fluent primary progressive aphasia (B), semantic primary progressive aphasia (C), progressive supranuclear palsy (D) and corticobasal syndrome (E). Arrows represent areas with clinically significant atrophy.

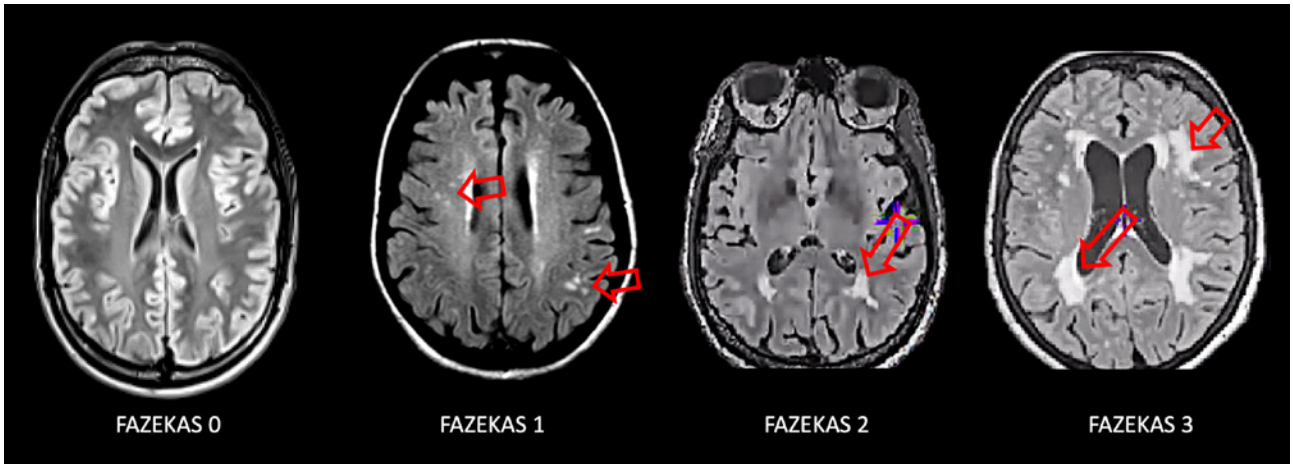

Figure 4. Typical example of Fazekas deep score.

peduncles atrophy. On T2 MRI sequences, the lateral putamen and middle cerebellar peduncles may show hyperintensities. The hyperintense T2 signal in the shape of a cross within the pons of multiple system atrophy patients is called the 'hot cross bun sign'.

T2 and FLAIR hypersignal – Cortical with white matter hyperintensities in T2 and FLAIR can be observed in corticobasal syndrome, posterior cortical atrophy and frontotemporal dementias.

Cerebrovascular disease is a common cause of cognitive impairment and dementia. Imaging manifestations of cerebrovascular disease found in people with dementia include focal areas of infarction or diffuse ischemic changes in the white matter also designates as leukoaraiosis.

T2 weighted imaging and FLAIR MRI have better sensitivity for detecting chronic cerebrovascular abnormalities in dementia. MRI findings associated with vascular cognitive impairment and dementia include cortical and subcortical infarctions and periventricular white matter lesions (see chapter related to cerebrovascular disease) (7).

White matter hyperintensities are lesions on T2-weighted images, mainly in the periventricular regions and in the centrum semiovale. They are the most common abnormalities seen on MRI scans, identified as risk factors for stroke (8). The Fazekas scores provide a semiquantitative reading of the white matter hyperintense lesions attributed to chronic small vessel disease. The Fazekas score is a 4-point score system for assessing periventricular lesions and deep white matter hyperintensities. The absence of a periventricular signal defines score 0, while a periventricular cap of pencil-thin characterises score 1, and a smooth halo illustrates score 2. Periventricular score 3 indicates irregular hyperintensities extending into the deep white matter. The absence of deep periventricular hyperintensities defines the Fazekas score 0, while punctate focal deep hyperintensity characterises score one, and the confluence of hyperintensities illustrates score 2. Large confluent areas of deep white matter hyperintensities describe the score 3.

Lacunes are focal small infarcts with less than 1.5 mm, caused by the atherosclerotic occlusion of deep small vessels. They are the second most common neuroradiological finding associated with vascular brain pathology. On CT scans, lacunar infarcts appear as a small ovoid hypodensity, while on MRI scans, they appear as an ovoid cavity, filled with fluid and hyperintense in T2-weighted images (9,10)

Perivascular spaces, also called Virchow-Robin spaces, are subpial interstitial spaces surrounding the penetrating arteries and arterioles and filled with fluid that follows the course of a vessel through the grey or white matter. Perivascular spaces in the basal ganglia are particularly prominent, with a diameter up to 3–5 mm (11,12).

Gradient echo MRI pulse sequences and susceptibility-weighted imaging show cortical and subcortical microhaemorrhages. They constitute an incidental finding in older individuals. While microhaemorrhages associated with cerebral amyloid angiopathy are observed in cortical areas, those associated with hypertension typically occur in the basal ganglia, thalamus, or pons (13,14).

Diffusion-weighted imaging is mandatory for the care of rapidly progressive dementias. MRI findings in sporadic Creutzfeldt-Jakob disease feature hyperintense signal on DWI, FLAIR, and T2-weighted in the topography of the frontal, parietal and cingulate and insular cortices, head of caudate and putamen. Thalamic hyperintensity resembling a double hockey stick, also called the pulvinar sign, suggests the variant Creutzfeldt-Jakob disease (15–17).

Survey results

Of the 2,327 people with dementia and their carers who completed the survey, neuroimaging with either CT or MRI was an integral part of their dementia patient assessment (Chart 1). However, as indicated by the responses from the 1,111 clinicians, accessibility and costs remain challenges to overcome, particularly in low- and middle-income countries (Chart 2).

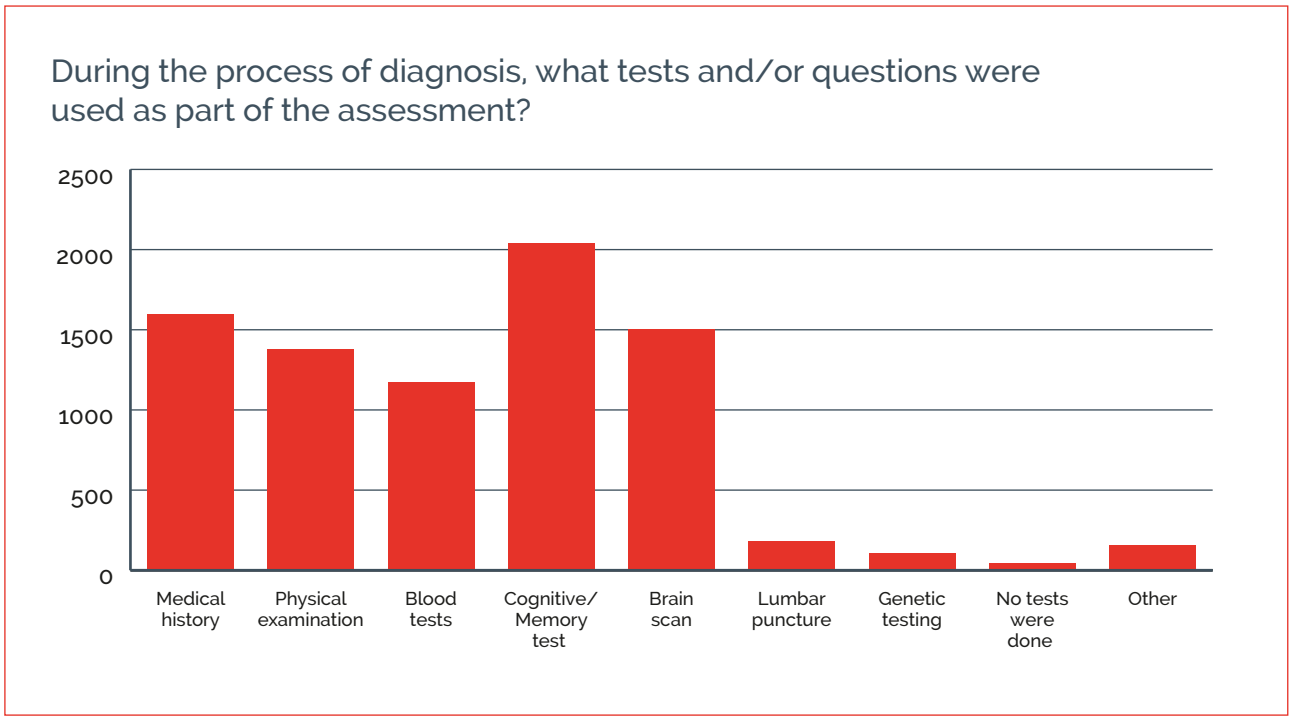

Chart 1. People with dementia and carer responses (multiple answers selected).

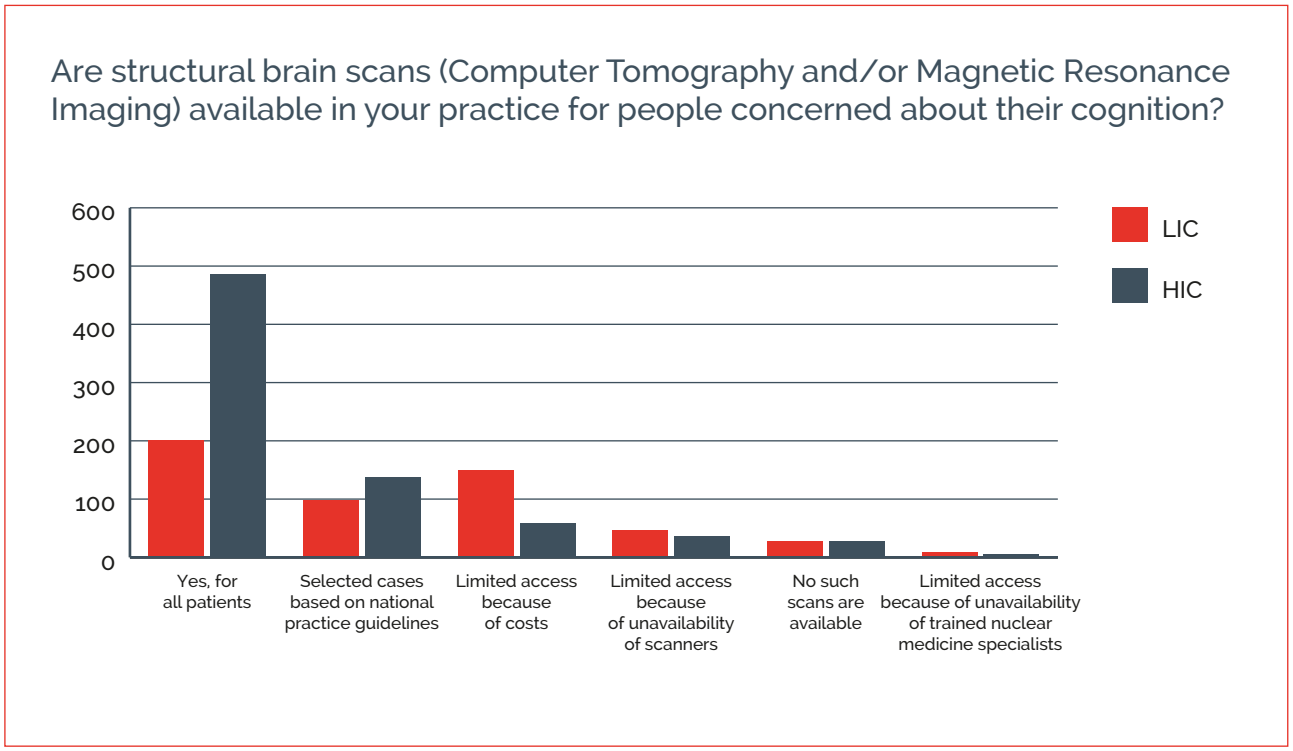

Chart 2. Clinician responses.

Conclusions

As people near the age of 65, instances of memory and thinking problems are often associated with the onset of dementia. Hence the reason doctors order brain scans to confirm such a diagnosis, as well as to rule out other potential causes of the memory or thinking problems experienced by an individual.

Many medical guidelines suggest the superiority of magnetic resonance imaging (MRI) in assessing individuals with dementia. However, neuroimaging with computed tomography or magnetic resonance unequivocally benefits dementia patients with acute onset of cognitive impairment, rapid neurologic deterioration, seizures, or findings on physical examination suggestive of vascular disease, tumour, or other brain focal abnormalities. It should be noted that these tests are costly, and accessibility is not universal.

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