Dementia imaging: A multimodality approach

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Learning objectives

1) To review the modalities available to the radiologist for imaging in dementia and normal imaging appearances.

2) To identify specific patterns on different modalities indicative of specific dementia sub-processes.

3) Review the various appearances of reversible and treatable intracranial pathologies that result in dementia.

Background

Dementia is a constellation of symptoms related to progressive decline in brain function, it is a symptom of disease rather than a disease entity, memory impairment is the cardinal feature. It is extremely common, particularly in the elderly with over 570,000 cases in the UK alone. It is one of the most expensive medical conditions to provide for with the estimated cost in 1998 to the UK NHS of £5.5 billion (1). Developments in new medical treatments have resulted in increasing utility of imaging services to categorize dementia subtypes in order to facilitate treatment where possible, specific guidance for treatment exists in the UK for a number of subtypes (2). Often radiographic features are non-specific and the role of imaging is frequently to exclude an unexpected but treatable cause for dementia such as that secondary to tumour, hydrocephalus or vascular disease.

Imaging findings OR Procedure details

Senile Dementia Alzheimer's Type (SDAT)

The disorders that result in dementia are often associated with supratentorial atrophy. The most common and notorious of which is Alzheimer's disease (properly known as senile dementia Alzheimer's type or SDAT). Memory is primarily affected but further dysfunction can be seen in personality and higher thought processes. Following diagnosis, current treatment consists of cholinesterase inhibitors, vitamin E, antioxidants.
and cognitive therapy. Gross examination of the brain substance reveals senile plaques and amorphous tangles.

At structural imaging (CT and MRI) the predominant finding is cortical atrophy with a temporal preponderance. Increases in ventricular and sulcal size, particular the temporal horns are seen in the majority of cases. The rate of atrophy is accelerated when compared to age-matched subjects (figs 1-3). Measures of the width of the temporal horn, width of choroid fissure, height of the hippocampus and the inter-uncle distance when taken together have an 86% sensitivity for diagnosing early SDAT, and subtle findings are best appreciated on coronal MR (fig 4). Tc-99m HMPAO SPECT may demonstrate relatively symmetrical reduced perfusion in the medial temporal lobes (fig 5), or if early in the disease, the parietal lobes (fig 6) (3). Serial Tc-99m HMPAO SPECT can be of value particularly to assess disease progression (figs 7,8) in early cases where the diagnosis may not be clinically apparent.

**Frontotemporal Dementia**

This term is used to describe patients who have focal cortical atrophy affecting the front and/or temporal lobes. There are frontal and semantic variations, and a third poorly understood subtype call progressive non-fluent aphasia. Patients with frontotemporal dementia typically have behavioural change and although differentiation from SDAT can sometimes be difficult, frontal atrophy is typically more pronounced (fig 9). Tc-99m HMPAO SPECT demonstrates reduced activity in the ventromedial frontal lobes (fig 10).

Pick's disease is a rare disease manifest by memory loss, confusion, cognitive and speech dysfunction, and is considered by some to be a frontal variant of frontotemporal dementia. There may be a temporal predominance to the volume loss, and associated caudate atrophy with sparing of the parietal cortex (fig 11). Histologically there are swollen nerve cells with spherical intracytoplasmic inclusions - Pick bodies.

**Vascular Dementia**

Ischaemic cerebrovascular disease is very common in the Western world, and seen in patients with long-standing atherosclerotic risk factors and/or hypertension. In addition to dementia patients may have personality change, incontinence and ataxia. The most common pattern is multi-infarct dementia where the clinical course typically demonstrates a stepwise deterioration in function. Structural (figs 12-14) and perfusion (figs 15,16) imaging shows multiple, patchy, often asymmetrical areas of white-matter change, with lacunar infarction of deep grey matter as a result of deep penetrating artery atherosclerosis.
Precipitating conditions that may result in presenile vascular dementia include genetic factors as seen in cerebral autosomal dominant arteriopathy with subcortical infarcts and leukoencephalopathy (CADASIL), inflammatory conditions with a vasculitic component (figs 17,18) and amyloid angiopathy (fig 19).

**Dementia with Lewy Bodies**

Dementia with Lewy bodies (DLB) is thought to be related to Parkinson's disease, it is distinguished clinically from Parkinson's disease dementia as the latter shows parkinsonism preceding the dementia by at least one year, and DLB is cortical whereas Parkinson's disease dementia is subcortical. Histologically they may appear the same and Lewy bodies are found diffusely in the brain. DLB patients may demonstrate a fluctuating course, and deficits are usually in memory, attention, visual abilities and executive function. Brainstem and substantia nigra atrophy may be evident in addition to cortical atrophy, and Tc-99m HMPAO SPECT demonstrates reduced perfusion in the occipital region (fig 20).

**Creutzfeldt-Jakob Disease**

Creutzfeldt-Jakob disease (CJD) is a rare disorder often occurring in a younger population than SDAT, prion proteins are considered to be the transmissible agent. Patients demonstrate a rapidly progressive decrease in function. CT is most often normal, although MR typically shows symmetrical increased T2/FLAIR signal intensity in the putamen and caudate nuclei. With time further basal ganglia and white-matter high signal change may develop along with cortical abnormalities. New variant CJD (nvCJD) is thought to have been transmitted to humans via infected cattle, that were infected by eating offal containing prions from infected sheep that were affected by scrapie. Again CT is typically normal and MRI characteristically shows symmetrical increased T2/FLAIR signal intensity in the posterior thalamus (pulvinar nucleus), a feature almost pathognomonic for nvCJD (figs 21,22).

**Reversible Causes - Tumours and Hydrocephalus**

Mental or behavioural changes occur in the majority of patients with brain tumours, the symptoms of dementia are associated with tumours of the frontal lobe, corpus callosum and third ventricle (due to hydrocephalus). Normal pressure hydrocephalus related to the clinical triad of dementia, urinary incontinence and gait disturbance with imaging evidence of enlarged ventricles with normal opening pressure at lumbar puncture. The significance of identifying these causes of dementia lies in their treatability and the potential for reversal of symptomatology (figs 23,24).
Fig. 1: Figure 1 - Axial CT of the brain demonstrating symmetrical volume loss predominantly in the temporal but also frontal regions in keeping with SDAT.

Fig. 2: Figure 2 - Axial CT of the brain demonstrating a severe case of SDAT with gross temporal atrophy, increased ventricular size and interuncal distance.
Fig. 3: Figure 3 - Axial T2W MRI of a different severe case of SDAT with marked temporal atrophy and compensatory dilatation of the lateral ventricle temporal horns.
**Fig. 4:** Figure 4 - Volume acquired T1W images allow reconstruction in the coronal plane to assess for enlargement of the parahippocampal fissures, here the choroid fissure is enlarged and there is reduced hippocampal height.
**Fig. 5:** Figure 5 - SPECT CT which shows structural changes of temporal atrophy with concordant reduced medial temporal perfusion on the nuclear medicine component of the study, both findings are in keeping with SDAT.
**Fig. 6:** Figure 6 - SPECT demonstrating biparietal reduced perfusion with preservation of temporal perfusion, this can be seen in early cases of SDAT and in young patients.
Fig. 7: Figure 7 - SPECT CT again showing early biparietal reduced perfusion only, the clinical picture was not clear therefore a 12 month follow up study was arranged.
Fig. 8: Figure 8 - SPECT CT of the same patient 12 months later demonstrated much more profound biparietal reduced perfusion in keeping with SDAT, the clinical picture has also progressed accordingly.
**Fig. 9:** Figure 9 - Axial CT of the brain demonstrating the structural changes of frontotemporal dementia, with atrophy seen predominantly affecting the frontal lobes bilaterally.
**Fig. 10:** Figure 10 - SPECT CT in frontotemporal dementia showing symmetrically reduced frontal perfusion with preservation of perfusion to the temporal and parietal regions to distinguish it from SDAT.
**Fig. 11:** Figure 11 - Pick's disease, a rare dementia that affects the frontal and temporal lobes in a focal rather than generalised way (as opposed to SDAT), CT of the brain shows profound frontal and associated caudate head atrophy.
**Fig. 12:** Figure 12 - Axial CT of the brain that demonstrated asymmetrical and patchy white matter low attenuation change typical of ischaemic small vessel cerebrovascular disease.
**Fig. 13:** Figure 13 - Axial T2W MRI in a different patient who demonstrates similar asymmetrical white matter high signal lesions secondary to small vessel disease.
Fig. 14: Figure 14 - Severe cerebrovascular disease with multiple areas of established cortical infarction, small vessel changes and resultant generalised brain atrophy.
**Fig. 15:** Figure 15 - SPECT CT of the brain that shows asymmetrical, sporadic areas of reduced perfusion in the left parietal and right temporal lobes. The distribution does not conform to a dementia process such as SDAT and strongly favours a vascular aetiology.
Fig. 16: Figure 16 - SPECT CT with a large perfusion deficit in the left fronto-temporo-parietal region due to established left MCA infarction that is confirmed on the CT component of the study.
Fig. 17: Confluent and severe changes of small vessel cerebrovascular disease in a young patient with confirmed systemic lupus erythematosus, the severe extend of the changes in the absence of significant risk factors is likely due to central nervous system vasculitis.
Fig. 18: Figure 18 - Bechet's disease, a multisystem vasculitis that affects the central nervous system in 5-10%. It typically affects the meso-diencephalon junction or pontobulbar region and may extend along tracts in the brain stem. It is associated with venous sinus thrombosis in more than a third of cases due to a venous vasculitic component.
Fig. 19: Figure 19 - Extensive changes of small vessel disease combined with haemorrhage (typically sporadic and of varying ages) should raise the suspicion of underlying amyloid angiopathy.
Fig. 20: Figure 20 - SPECT of the brain demonstrating bilateral reduction in tracer uptake of both occipital lobes with relative preservation of perfusion to the parietal, temporal and frontal regions. These features favour a diagnosis of DLB.
Fig. 21: Figure 21 - Axial FLAIR in a young, previously well adult male presented with several months of progressive personality change and dementia, initial CT at presentation was normal. FLAIR imaging revealed abnormal high signal returned from the posterior thalami (pulvinar nucleus) bilaterally in keeping with nvCJD.
Fig. 22: Figure 22 - Coronal FLAIR in the same patient confirms the abnormal signal returned from the pulvinar nuclei.
Fig. 23: Figure 23 - Axial CT of the brain in an elderly patient presenting with dementia-like symptoms. Images show obstructive hydrocephalus resulting from a tumour of the third ventricle, the patients clinical symptoms improved following treatment for the hydrocephalus.
Fig. 24: Figure 24 - A patient thought to have dementia was referred for SPECT CT for further characterisation. Images reveal a bifrontal tumour on the CT component of the study that corresponds to an area of abnormal perfusion on the radionuclide component.
Conclusion

Dementia is a huge economic and social burden on society and health care systems. Different dementia sub-types often affect the brain in typical patterns. In straightforward cases imaging of often not required, in difficult cases where the diagnosis is not clear clinically, prompt radiological classification facilitates early and appropriate treatment, thus improving patient quality of life and reducing the burden on health services.

Personal Information

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References
