# Temporal lobe atrophy on MRI in Parkinson disease with dementia

## A comparison with Alzheimer disease and dementia with Lewy bodies

C.W.C. Tam, MRCPsych; E.J. Burton, PhD; I.G. McKeith, MD; D.J. Burn, MD; and J.T. O'Brien, DM

**Abstract—***Objective:* To investigate the extent of medial temporal lobe atrophy (MTA) on MRI in Parkinson disease (PD) with and without dementia compared with Alzheimer disease (AD) and dementia with Lewy bodies (DLB) and to determine whether MTA correlates with cognitive impairment in PD and PD dementia (PDD). *Methods:* Coronal T1-weighted MRI scans were acquired from control subjects (n = 39) and patients with PD (n = 33), PDD (n = 31), DLB (n = 25), and AD (n = 31), diagnosed according to standardized clinical diagnostic criteria. Cognitive function was assessed using the Cambridge Cognitive Examination (CAMCOG), and MTA was rated visually using a standardized (Scheltens) scale. *Results:* More severe MTA was seen in PDD ($p = 0.007$), DLB ($p < 0.001$), and AD ($p < 0.001$) vs control subjects. PD subjects had greater hippocampal atrophy than control subjects ($p = 0.015$) but less than subjects with DLB and AD, though not with PDD. MTA correlated with CAMCOG score and memory scores in the DLB group and with age in control, PDD, and AD groups. There were no correlations between MTA and cognitive impairment in PD, PDD, and AD. PDD and DLB had a similar profile of cognitive impairment and MTA. *Conclusions:* Medial temporal lobe atrophy (MTA) was seen in cognitively intact older subjects with Parkinson disease (PD) and was not more pronounced in Parkinson disease dementia (PDD). Alzheimer disease (AD) and, to a lesser extent, dementia with Lewy bodies (DLB) showed more pronounced MTA. Results suggest early hippocampal involvement in PD and that when dementia develops in PD, anatomic structures apart from the hippocampus are predominantly implicated. Greater hippocampal involvement in AD vs PDD and DLB is consistent with clinical, cognitive, and pathologic differences between the disorders.

NEUROLOGY 2005;64:861–865

A prospective incidence study reported that more than three-quarters of an older cohort with Parkinson disease (PD) developed dementia (PDD) during an 8-year follow-up.[1] Early intervention in patients with PD who are at risk for dementia is important for future disease-modifying therapies. Structural neuroimaging has the potential to play an important role.

Atrophy of the medial temporal lobe (MTA) is a well-recognized feature of Alzheimer disease (AD) and can discriminate patients with AD from age-matched control subjects.[2-4] However, hippocampal atrophy may not be specific to AD and has been reported in vascular dementia.[5] Studies have shown medial temporal lobe structures on MRI to be relatively preserved in dementia with Lewy bodies (DLB) vs AD.[6-8] There have been few studies in PDD, and inconsistencies have emerged. One study reported hippocampal atrophy in PDD to be even greater than in AD,[9] whereas others have found hippocampal atrophy in nondemented PD that correlated with impaired episodic memory.[10,11]

Studies using more sensitive serial MRI methods have shown significantly greater annual brain volume loss in nondemented PD patients vs control subjects.[12,13] We have previously used voxel-based morphometry to demonstrate atrophy of the frontal lobe in PD that extends to temporal, occipital, and parietal lobes in PDD.[14]

We sought to compare the extent of MTA assessed visually from MRI scans in subjects with PD with and without dementia and those with DLB and AD and control subjects and to examine the relationship between MTA and cognitive and noncognitive symptoms. We hypothesized that MTA would be less common in PDD and DLB than in AD and that MTA would be more frequent in PD than control subjects.

**Methods.** *Subjects.* The sample consisted of 159 subjects (33 with PD, 31 with PDD, 25 with DLB, 31 with AD, and 39 healthy elderly control subjects). Subjects underwent MRI scans as part of a baseline assessment in a prospective longitudinal study of dementia. Patients were recruited from hospital and community-dwelling populations under the care of old age psychiatrists, geriatricians, and neurologists. Control subjects were recruited from friends and spouses of patients or caregivers. The Newcastle and North Tyneside Ethics Committee approved the study. All subjects gave written informed consent to participate.

From the Department of Psychiatry (Dr. Tam), Tai Po Hospital, Hong Kong; and Institute for Ageing and Health (Drs. Burton, McKeith, and O'Brien), University of Newcastle upon Tyne, and Department of Neurology (Dr. Burn), Regional Neurosciences Centre, Newcastle General Hospital, UK.

Supported by a program grant from the Medical Research Council UK.

Received July 30, 2004. Accepted in final form November 11, 2004.

Address correspondence and reprint requests to Dr. J.T. O'Brien, Wolfson Research Centre, Newcastle General Hospital, Newcastle, NE4 6BE, UK; e-mail: j.t.o'brien@ncl.ac.uk

 

*Assessment and diagnosis.* Subjects underwent detailed physical, neurologic, and neuropsychiatric examinations, which included clinical history and mental state and physical examination and, for demented subjects, a standardized blood screen with thyroid function tests, vitamin $B_{12}$, folate, and syphilis serology. Standardized schedules administered included the Mini-Mental State Examination (MMSE),[15] Cambridge Cognitive Examination (CAMCOG),[16] and Neuropsychiatric Inventory.[17] Diagnosis was made by consensus between experienced clinicians using the National Institute of Neurologic and Communicative Disorders and Stoke/Alzheimer's Disease and Related Disorders Association criteria for AD,[18] the consensus criteria for DLB and PDD,[19] and the UK Parkinson's Disease Society Brain Bank criteria for PD.[20] Twenty-seven patients with AD met criteria for probable AD and 4 for possible AD, 22 DLB patients fulfilled probable and 3 fulfilled possible DLB criteria, whereas all PD and PDD patients met the clinical diagnostic criteria for PD. The distinction between DLB and PDD was made on the basis of the duration of the parkinsonism, as recommended by the consensus diagnostic criteria for DLB.[19] Patients whose dementia developed either before or within 12 months of the onset of parkinsonism were classified as DLB. Those whose dementia developed 12 months or later after the onset of PD were classified as PDD.

Exclusion criteria for normal subjects were evidence of dementia (either from history, mental state examination, or score of <80 on the CAMCOG) or any other major psychiatric, neurologic, or physical disorder including drug and alcohol abuse.

*MRI procedure.* All scans were performed on a 1.5 T GE Signa scanner (General Electric, Milwaukee, WI). Whole-brain T1-weighed three-dimensional fast spin echo spoiled gradient echo data sets were acquired in the coronal plane (repetition time = 12.4 milliseconds, echo time = 4.2 milliseconds, inversion time = 650 milliseconds, matrix = 256 × 256, slice thickness = 1.6 mm, flip angle = 15°, field of view = 20 cm, in-plane resolution = 0.78 × 0.78 mm), yielding 124 contiguous slices through the head. Standard head positioning was used throughout.

*MTA rating.* A widely used standardized scale (Scheltens Scale) was used to rate left and right MTA from hard copies of T1-weighted coronal images.[3] This scale rates atrophy as 0 (absent), 1 (minimal), 2 (mild), 3 (moderate), and 4 (severe) based on the width of the surrounding CSF spaces (temporal horn and choroid fissure) and the height of the hippocampal formation (which includes the hippocampus proper, subiculum, and parahippocampal and dentate gyri). An example of the different severities of MTA is shown in figure 1. For the purpose of analysis, left and right scores were summed to give an overall combined MTA score, ranging from 0 to 8. All scans were rated by the same trained rater blinded to clinical diagnosis. Interrater reliability was assessed between the trained rater and an experienced rater by measuring 20 subjects. Intrarater reliability was assessed by measuring 20 subjects on two occasions.

*Statistical analysis.* The statistical package SPSS for Windows (version 11; Chicago, IL) was used for data analysis. Differences between groups on continuous variables were assessed using analysis of variance with post-hoc Tukey tests to determine group differences. For nonparametric data, Kruskal–Wallis analysis of variance was used followed by a post-hoc Mann–Whitney *U* test or Pearson $\chi^2$ statistic as appropriate. Correlations between MTA scores, age, and cognitive function were examined using the Spearman rank order correlation coefficient. All statistical tests were two tailed and were regarded as significant at $p < 0.05$. Interrater reliability for visual ratings of scans was assessed using weighted κ that controls for chance agreement between raters.

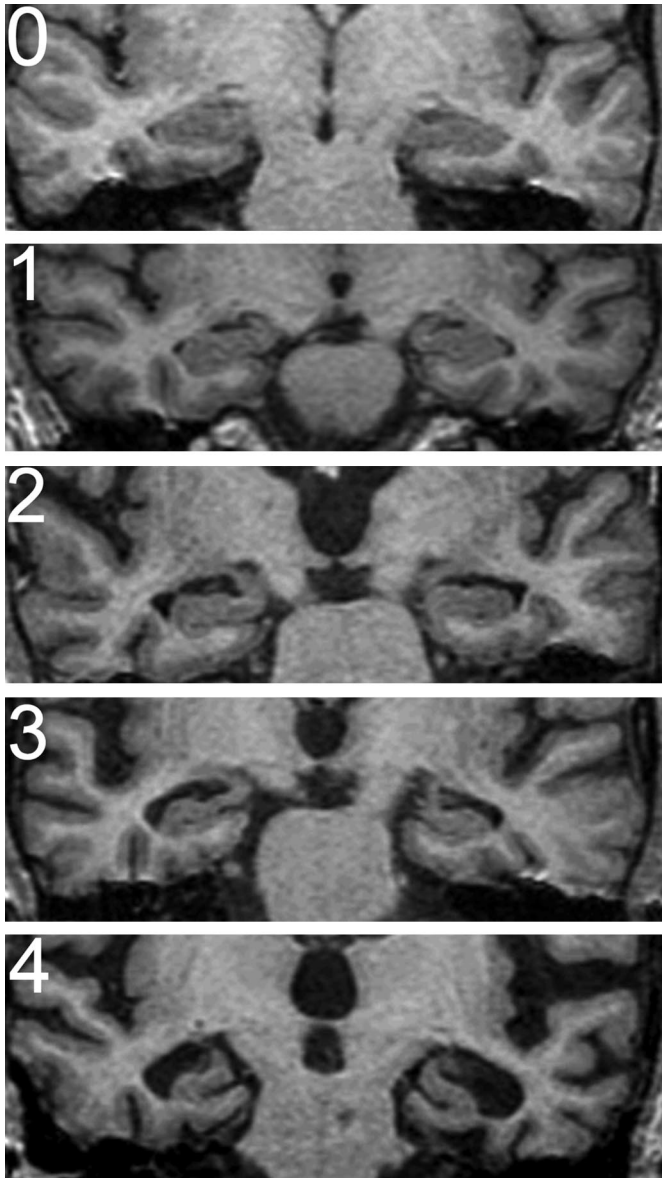


*Figure 1. Example coronal images of medial temporal lobe atrophy scores (0 to 4), showing increasing atrophy, loss of height of the hippocampus, and widening of the temporal horn.*

**Results.** *Reliability.* Interrater reliability was regarded as satisfactory. Weighted κ values for visual ratings of atrophy were as follows: right MTA 0.60 and left MTA 0.57. Intrarater reliability was excellent with weighed κ values for visual ratings of atrophy as follows: right MTA 0.90 and left MTA 0.86.

*Demographic and cognitive characteristics.* The demographic and clinical characteristics of all groups are summarized in table 1. Groups were matched for sex and broadly matched for age, although the AD group was older than the PDD group ($p < 0.001$). Educational level did not differ between PD and all dementia groups ($\chi 2$ [3] = 3.13, $p = 0.37$). The three dementia groups had similar duration of cognitive symptoms and severity of cognitive impairment as measured by MMSE ($\chi^2$ [2] = 0.77, $p = 0.68$) and total CAMCOG ($\chi^2$ [2] = 0.52, $p = 0.68$) scores. Unified Parkinson's Disease Rating Scale scores were higher in subjects with PD, PDD, and DLB than control subjects and those with AD ($p < 0.001$), with AD patients having higher scores than control subjects ($p < 0.001$).

At the time of MRI scan, 25 (76%) patients with PD, 27 (87%) with PDD, and 2 (8%) with DLB were receiving levodopa. Those patients taking cholinesterase inhibitors included seven (23%) with PDD, eight (26%) with AD, and eight (32%) with DLB. All patients underwent assessments and MRI scans while receiving their medication.

*Neuropsychological characteristics in different dementia groups.* Table 2 summarizes the neuropsychological char-

***Table 1*** *Demographic and neuropsychological data of subjects studied with MRI*

| | Control, n = 39 | PD, n = 33 | PDD, n = 31 | DLB, n = 25 | AD, n = 31 | Differences between groups |
|---|---|---|---|---|---|---|
| Sex, M/F | 21/18 | 25/8 | 19/12 | 15/10 | 15/16 | NS |
| Age, y | 75.20 ± 6.71 | 75.44 ± 5.18 | 71.88 ± 5.75 | 75.38 ± 1.59 | 78.73 ± 5.07 | AD > PDD, $p < 0.001$* |
| MMSE, max 30 | 28.13 ± 1.53 | 26.79 ± 1.80 | 18.90 ± 5.30 | 17.16 ± 5.76 | 18.00 ± 4.58 | Control > PD > PDD, AD, DLB, $p < 0.001$† |
| CAMCOG, max 107 | 93.77 ± 3.92 | 88.88 ± 7.29 | 64.13 ± 15.64 | 63.52 ± 14.53 | 62.06 ± 13.79 | Control > PD > PDD, AD, DLB, $p < 0.001$† |
| CAMCOG memory, max 30 | 22.21 ± 1.70 | 21.64 ± 2.52 | 15.73 ± 4.84 | 15.25 ± 4.24 | 10.19 ± 4.41 | Control, PD > PDD, DLB > AD, $p < 0.001$† |
| UPDRS III, max 108 | 1.31 ± 2.0 | 25.4 ± 10.4 | 35.3 ± 9.3 | 27.3 ± 16.5 | 4.5 ± 3.8 | DLB, PDD, PD > control and AD, AD > control, $p < 0.001$† |
| Duration of cognitive symptoms, y | NA | NA | 3.22 ± 2.44 | 2.38 ± 1.82 | 2.91 ± 1.54 | NS |
| Age at onset of cognitive impairment, y | NA | NA | 68.29 ± 5.37 | 73.47 ± 6.12 | 75.40 ± 5.71 | AD, DLB > PDD, $p < 0.05$* |

Values are mean ± SD.

* One way analysis of variance and Tukey post-hoc tests.
† Kruskal–Wallis and post-hoc Mann–Whitney test.

PD = Parkinson disease; PDD = Parkinson disease dementia; DLB = dementia with Lewy bodies; AD = Alzheimer disease; MMSE = Mini-Mental State Examination; CAMCOG = Cambridge Cognitive Examination; UPDRS = Unified Parkinson's Disease Rating Scale.

acteristics of different diagnostic groups. All dementia groups had lower scores than the control and PD groups on all CAMCOG subscales ($p < 0.05$). The PD group had lower scores than the control group in language expression ($p = 0.014$), perception ($p = 0.05$), and executive function ($p < 0.001$) subscales. The AD group had lower scores than the PDD and DLB groups in memory (PDD, $p = 0.003$; DLB, $p = 0.009$) and orientation (PDD, $p = 0.006$) subscales. PDD and DLB groups had lower scores than the AD group in attention (PDD, $p = 0.012$; DLB, $p = 0.038$), praxis (PDD, $p < 0.001$; DLB, $p = 0.002$), and executive function (PDD, $p = 0.039$) subscales. There were no differences between the PDD and DLB groups in any of the cognitive assessments (i.e., memory, $p = 0.092$; orientation, $p = 0.228$).

*Differences in MTA.* Table 3 summarizes the combined scores of MTA in each group. MTA was greater on the left in all groups except the AD group. However, the asymmetry was not significant (control, $p = 0.302$; PD, $p = 0.593$; PDD, $p = 0.197$). There were differences in the combined MTA scores in different diagnostic groups ($\chi^2$ [4] = 61.08, $p < 0.001$). MTA of the control group was less than that of PD, PDD, AD, and DLB groups ($p = 0.015$ for PD and $p = 0.007$ for PDD, $p < 0.001$ for AD and DLB). The AD group had more MTA vs PD, PDD, and DLB groups ($p < 0.001$). DLB had more MTA vs PD ($p = 0.01$). Differences in MTA between PD and PDD ($p = 0.267$) or between PDD and DLB ($p = 0.203$) were not significant. MTA showed a pattern (control < PD ~ PDD ~ DLB < AD) (tables 3 and 4). There is some overlap between groups on combined MTA rating (figure 2). Ratings of ≥5 were unusual in control subjects (only 6/39 cases), whereas ratings of <5 were unusual in AD (2/31 cases).

*Correlation of MTA ratings with age and cognitive impairment.* Age was associated with combined MTA score in the control ($\rho = 0.41$, $p = 0.009$), PDD ($\rho = 0.39$, $p = 0.032$), and AD ($\rho = 0.44$, $p = 0.013$) groups but not in PD ($\rho = 0.34$, $p = 0.054$). In normal control subjects, language comprehension and total scores of CAMCOG inversely correlated with combined MTA rating ($\rho = -0.36$, $p = 0.023$; $\rho = -0.35$, $p = 0.029$). In subjects with DLB, language expression ($\rho = -0.53$, $p = 0.008$), orientation ($\rho = -0.60$, $p = 0.002$), memory (remote: $\rho = -0.60$, $p = 0.002$; recent: $\rho = -0.44$, $p = 0.027$; total: $\rho = -0.48$, $p = 0.017$), MMSE ($\rho = -0.49$, $p = 0.014$), and total CAMCOG ($\rho = -0.51$, $p = 0.014$) scores inversely correlated with combined MTA ratings. There were no correlations between MTA rating and cognitive impairment in PD, PDD, and AD groups. There were no correlations between frequency or severity of neuropsychiatric symptoms and MTA ratings in any dementia groups.

**Discussion.** Our data confirm previous reports that patients with PD without dementia have more MTA than age-matched control subjects. This implies that older PD subjects have progressive MTA before the onset of dementia. In our study, PD subjects had more impairment in language expression (including verbal fluency) and executive function than the control subjects. These findings are consistent with reports from community-based studies in early PD, showing cognitive impairments in 36% of newly diagnosed and nondemented PD cases, with a profile and associated imaging changes indicative of frontostriatal dysfunction.[21,22] Mild cognitive impairments of this type in a PD patient in conjunction with concomitant hippocampal atrophy might provide a presymptomatic marker for dementia risk. Previously reported risk factors for developing de-

***Table 2*** *CAMCOG total and subscale scores*

| | Control (39) | PD (33) | PDD (30) | DLB (25) | AD (31) | Differences between dementia groups |
|---|---|---|---|---|---|---|
| Abstract thinking (8) | 7 | 6 | 4 | 4 | 5 | NS |
| Attention (7) | 7 | 6 | 2 | 2 | 4 | AD > PDD,* AD > DLB* |
| Calculation (2) | 2 | 2 | 1 | 1 | 1 | NS |
| Language comprehension (9) | 9 | 9 | 7 | 7 | 8 | NS |
| Language expression (21) | 19 | 13 | 15.5 | 14 | 15 | NS |
| Memory: recent (4) | 4 | 4 | 3.5 | 3 | 2 | PDD > AD,‡ DLB > AD† |
| Memory: learning (17) | 13 | 13 | 8 | 8.5 | 5 | PDD > AD,‡ DLB > AD‡ |
| Memory: remote (6) | 6 | 5 | 5 | 4 | 3 | PDD > AD† |
| Orientation (10) | 10 | 10 | 7 | 6 | 5 | PDD > AD† |
| Perception (11) | 8 | 8 | 5 | 5 | 6 | NS |
| Praxis (12) | 11 | 11 | 6.5 | 6 | 9 | AD > PDD,† AD > DLB† |
| Executive function | 21 | 16 | 9 | 9 | 11 | AD > PDD* |
| Memory: total | 22 | 22 | 16 | 16 | 10 | PDD > AD,‡ DLB > AD‡ |

Values are medians. Values in parentheses represent maximum scores for each test.

* $p < 0.05$.
† $p < 0.01$.
‡ $p < 0.001$.

CAMCOG = Cambridge Cognitive Examination; PD = Parkinson disease; PDD = Parkinson disease dementia; DLB = dementia with Lewy bodies; AD = Alzheimer disease.

***Table 4*** *Comparison of medial temporal lobe atrophy between subjects with PD and different dementia subjects*

| | PD vs PDD | PD vs DLB | PDD vs DLB | PD vs AD | PDD vs AD | DLB vs AD |
|---|---|---|---|---|---|---|
| Combined hippocampal atrophy | 0.27 | ↓* | 0.20 | ↓† | ↓† | ↓† |

Post-hoc Mann–Whitney *U* test: * $p < 0.01$, † $p < 0.001$.

PD = Parkinson disease; PDD = Parkinson disease dementia; DLB = dementia with Lewy bodies; AD = Alzheimer disease.

mentia in PD include older age, older age at onset of PD, male sex, longer duration of symptoms, decreased verbal fluency, and axial motor impairment. Prospective study is needed to further clarify these associations.

MTA in PDD was less severe than in AD, more closely resembling that seen in DLB. These findings are in agreement with previous volumetric[10] and autopsy[23] studies and consistent with previous observations using voxel-based morphometry of gray matter loss in temporal lobes in the same sample.[14] Differences in MTA between the demented groups could not be explained by different durations of cognitive symptoms or severity of global cognitive impairment. All three demented groups had more extensive MTA than age-matched control subjects. Previous studies have also reported increased atrophy of temporal lobe structures in both PDD and DLB, and neuropathologic studies find the CA2 to CA3 region of the hippocampus to be mainly affected in DLB, whereas AD is characterized by involvement of CA1 hippocampus and entorhinal cortex.[24]

The profiles of cognitive impairment in PDD, DLB, and AD groups were consistent with previous studies.[25] AD subjects had more memory impairment and less impairment in attention, visuospatial, and executive function vs PDD and DLB subjects. Only the DLB group had correlations between memory, global cognitive function, and MTA. Recent studies have found memory and MMSE score correlated with hippocampal volume in DLB,[7] AD,[26] and also PD and PDD.[10] The absence of correlation could be due to the relatively simple visual scale, which is a global rating including hippocampus, parahippocampal gyrus, and ventricles, which may not match onto a cognitive task in such a way as a single measurement (e.g., of hippocampus). Also possible were floor effects in AD subjects on the MTA rating, as most AD cases scored 6 or 8 out of 8 on the combined score.

The major strength of this study is the recruitment of a large number of community-based elderly patients with late-life dementia, with comparable age, sex, education, and duration of dementia. MR images were acquired using a standardized protocol, and atrophy was assessed blind to diagnosis using an established scale with satisfactory reliability. A potential criticism of this study is the reliance on clinical, rather than pathologic, diagnoses. However, clinical diagnoses were made after detailed assessment and in accordance with standardized criteria in a center with a proven track record of high accuracy as judged by autopsy confirmation.[27]

***Table 3*** *Medial temporal lobe atrophy on MRI*

| Medial temporal lobe atrophy | Control | PD | PDD | DLB | AD |
|---|---|---|---|---|---|
| Right | 1.46 ± 0.94* | 1.88 ± 0.49 | 2.03 ± 0.66 | 2.36 ± 0.81 | 3.06 ± 0.81 |
| Left | 1.33 ± 0.93* | 1.82 ± 0.64 | 1.87 ± 0.99 | 2.20 ± 0.76 | 3.06 ± 0.85 |

Values are means ± SD.

* Control < PD, PDD, DLB, AD, post-hoc Mann–Whitney *U* test.

PD = Parkinson disease; PDD = Parkinson disease dementia; DLB = dementia with Lewy bodies; AD = Alzheimer disease.

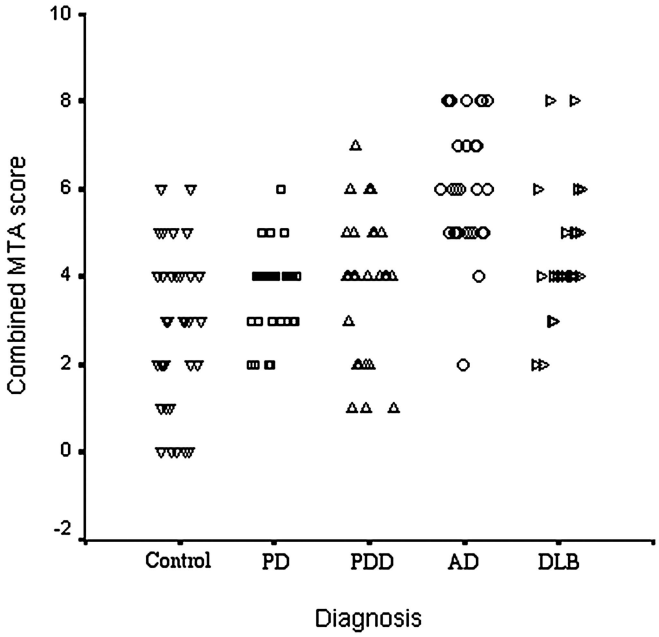


*Figure 2. Scatterplot of combined medial temporal lobe atrophy (MTA) score by diagnostic group. PD = Parkinson disease; PDD = Parkinson disease dementia; AD = Alzheimer disease; DLB = dementia with Lewy bodies.*


## Acknowledgment

The authors thank Elise Rowan and the Lewy Body Team for help with recruitment, clinical assessment, and database.


## References


1. Aarsland D, Andersen K, Larsen JP, Lolk A, Kragh-Sorensen P. Prevalence and characteristics of dementia in Parkinson's disease. An eight-year prospective study. Arch Neurol 2003;60:387–392.
2. Jack CR Jr, Petersen RC, O'Brien PC, Tangalos EG. MR-based hippocampal volumetry in the diagnosis of Alzheimer's disease. Neurology 1992;42:183–188.
3. Scheltens P, Leys D, Barkhof F, et al. Atrophy of medial temporal lobes on MRI in "probable" Alzheimer's disease and normal aging: diagnostic value and neuropsychological correlates. J Neurol Neurosurg Psychiatry 1992;55:967–972.
4. Jack CR Jr, Petersen RC, Xu YC, et al. Medial temporal atrophy on MRI in normal aging and very mild Alzheimer's disease. Neurology 1997;49:786–794.
5. Barber R, Ballard C, McKeith IG, Gholkar A, O'Brien JT. MRI volumetric study of dementia with Lewy bodies: a comparison with AD and vascular dementia. Neurology 2000;54:1304–1309.
6. Barber R, Gholkar A, Scheltens P, Ballard C, McKeith IG, O'Brien JT. Medial temporal lobe atrophy on MRI in dementia with Lewy bodies. Neurology 1999;52:1153–1158.
7. Barber R, McKeith IG, Ballard C, Gholkar A, O'Brien JT. A comparison of medial and lateral temporal lobe atrophy in dementia with Lewy bodies and Alzheimer's disease: magnetic resonance imaging volumetric study. Dement Geriatr Cogn Disord 2000;12:198–205.
8. Burton EJ, Karas GK, Paling SM, et al. Patterns of cerebral atrophy in dementia with Lewy bodies using voxel based morphometry. Neuroimage 2002;17:618–630.
9. Laakso MP, Partanen K, Riekkinen P, et al. Hippocampal volumes in Alzheimer's disease, Parkinson's disease with and without dementia, and in vascular dementia: an MRI study. Neurology 1996;46:678–681.
10. Camicioli R, Moore MM, Kinney A, Corbridge E, Glassberg K, Kaye JA. Parkinson's disease is associated with hippocampal atrophy. Mov Disord 2003;18:784–790.
11. Riekkinen P Jr, Kejonen K, Laakso MP, Soininen H, Partanen K, Riekkinen M. Hippocampal atrophy is related to impaired memory, but not frontal functions in non-demented Parkinson's disease patients. Neuroreport 1998;9:1507–1511.
12. Double KL, Halliday GM, McRitchie DA, Reid WG, Hely MA, Morris JG. Regional brain atrophy in idiopathic Parkinson's disease and diffuse Lewy body disease. Dementia 1996;7:304–313.
13. Hu MT, White SJ, Chaudhuri KR, et al. Correlating rates of cerebral atrophy in Parkinson's disease with measures of cognitive decline. J Neural Transm 2001;108:571–580.
14. Burton EJ, McKeith IG, Burn DJ, Williams ED, O'Brien JT. Cerebral atrophy in Parkinson's disease with and without dementia: a comparison with Alzheimer's disease, dementia with Lewy bodies and controls. Brain 2004;127:791–800.
15. Folstein MF, Folstein SE, McHugh PR. Mini-Mental State. A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12:189–198.
16. Roth M, Tym E, Mountjoy CQ, et al. CAMDEX: a standardized instrument for the diagnosis of mental disorder in the elderly with special reference to the early detection of dementia. Br J Psychiatry 1986;149:698–709.
17. Cummings JL, Mega M, Gray K, Rosenberg-Thompson S, Carusi DA, Gornbein J. The Neuropsychiatric Inventory: comprehensive assessment of psychopathology in dementia. Neurology 1994;44:2308–2314.
18. McKhann G, Drachman D, Folstein M, Katzman R, Price D, Stadlan EM. Clinical diagnosis of Alzheimer's disease: report of the NINCDS-ADRDA Work Group under the auspices of Department of Health and Human Services Task Force on Alzheimer's Disease. Neurology 1984;34:939–944.
19. McKeith IG, Galasko D, Kosaka K, et al. Consensus guidelines for the clinical and pathologic diagnosis of dementia with Lewy bodies (DLB): report of the Consortium on DLB International Workshop. Neurology 1996;47:1113–1124.
20. Gibb WR, Lees AJ. The relevance of the Lewy body to the pathogenesis of idiopathic Parkinson's disease. J Neurol Neurosurg Psychiatry 1988;5:745–752.
21. Lewis SJ, Dove A, Robbins TW, Barker RA, Owen AM. Cognitive impairments in early Parkinson's disease are accompanied by reductions in activity in frontostriatal neural circuitry. J Neurosci 2003;23:6351–6356.
22. Foltynie T, Brayne CE, Robbins TW, Barker RA. The cognitive ability of an incident cohort of Parkinson's patients in the UK. The CamPaIGN study. Brain 2004;127:550–560.
23. Lippa CF, Johnson R, Smith TW. The medial temporal lobe in dementia with Lewy bodies: a comparative study with Alzheimer's disease. Ann Neurol 1998;43:102–106.
24. Dickson DW, Ruan D, Crystal H, et al. Hippocampal degeneration differentiates diffuse Lewy body disease from Alzheimer's disease: light and electron microscopic immunocytochemistry of CA2–3 neurites specific to DLBD. Neurology 1991;41:1402–1409.
25. Noe E, Marder K, Bell KL, Jacobs DM, Manly JJ, Stern Y. Comparison of dementia with Lewy bodies to Alzheimer's disease and Parkinson's disease with dementia. Mov Disord 2004;19:60–67.
26. Petersen RC, Jack CR Jr, Xu Y-C, et al. Memory and MRI-based hippocampal volumes in aging and AD. Neurology 2000;54:581–587.
27. McKeith IG, Ballard CG, Perry RH, et al. Prospective validation of consensus criteria for the diagnosis of dementia with Lewy bodies. Neurology 2000;54:1050–1058.

# Temporal lobe atrophy on MRI in Parkinson disease with dementia: A comparison with Alzheimer disease and dementia with Lewy bodies

C. W.C. Tam, E. J. Burton, I. G. McKeith, et al.

*Neurology* 2005;64;861-865
DOI 10.1212/01.WNL.0000153070.82309.D4