Title

Subcortical Abnormalities Detected in Bipolar Affective Disorder Using Magnetic Resonance Imaging: Clinical and Neuropsychological Significance

Journal

JAMA Psychiatry, 47(1)

ISSN

2168-622X

Authors

Dupont, RM
Jernigan, TL
Butters, N
et al.

Publication Date

1990

DOI

10.1001/archpsyc.1990.01810130057008

Peer reviewed

Subcortical Abnormalities Detected in Bipolar Affective Disorder Using Magnetic Resonance Imaging

Clinical and Neuropsychological Significance

Renee M. Dupont, MD; Terry L. Jernigan, PhD; Nelson Butters, PhD; Dean Delis, PhD; John R. Hesselink, MD; William Heindel; J. Christian Gillin, MD

• **Magnetic resonance imaging was utilized to determine the nature and rate of subcortical abnormalities in bipolar affective disorder. Nine of 19 bipolar patients and no controls demonstrated subcortical signal hyperintensities on blind evaluation of the images. There was no apparent change in the appearance of the hyperintensities in 7 of 7 subjects with abnormal magnetic resonance images who underwent repeated imaging at 1 year. Bipolar patients with abnormalities had a history of more hospitalizations and appeared more impaired on tests of fluency and recall when compared with bipolar patients without abnormalities or with controls. The possible etiology and significance of signal hyperintensities in bipolar affective disorder is discussed.**

(*Arch Gen Psychiatry.* **1990;47:55-59)**

Abnormalities in brain structure and function have been observed in some patients with affective disorders. Ventricular enlargement demonstrated using computed tomography has been reported by some investigators in bipolar disorder,[1-5] unipolar depression,[6-8] and mixed affective disorders.[9-13] Cerebellar atrophy[14-16] and altered x-ray attenuation[17,18] were also shown in some patients with bipolar affective disorder. The latter measurements may reflect abnormalities in white matter that are beneath the limits of spatial resolution using computed tomography. In the first study using magnetic resonance imaging (MRI) to look at brain structure in carefully screened bipolar subjects and normal controls, we described the presence of subcortical signal hyperintensities in relatively young bipolar depressives but not in similarly matched control subjects.[19] In two later studies using MRI,[20,21] subcortical signal abnormalities in older depressed patients were reported. Since such abnormalities have been noted frequently in asymptomatic as well as ill elderly individuals,[22-35] the significance of these observations is ambiguous without the inclusion of demographically matched control subjects.

The neuropsychological profiles of depressed patients and of patients with so-called subcortical dementias (eg, Huntington's disease [HD], progressive supranuclear palsy) have both been characterized by psychomotor slowing, lack of initiation (ie, bradyphrenia), and attentional deficits combined with intact language function and praxis.[36-39] In a study designed to compare the memory disorders of unipolar and bipolar patients with those of patients with HD (ie, a genetically transmitted, progressive basal ganglia disorder), Wolfe and her colleagues[40] found that bipolar patients and patients with HD performed more poorly than did unipolar patients and normal controls on tasks placing maximum demands on retrieval from long-term memory. It is important to emphasize that despite the similarity in cognitive profiles between subcortical dementias and affective disorders, there is no evidence to indicate that the latter disorder demonstrates a similarly progressive course.

Other behavioral studies in bipolar illness,[41-45] reporting that the cognitive impairments of depressed patients[46-48] may persist when their mood disorders are in remission, also lend support to the possibility of a persistent cognitive syndrome in these patients. In a series of case reports, McCallister and Price[49] demonstrated that reversible cognitive deficits associated with depression may be superimposed over an irreversible dementia, and Reding et al[50] have reported that more than 50% of a group of elderly patients with a diagnosis of pseudodementia eventually became demented within a 3-year follow-up period. All of these studies suggest that some underlying pathophysiological condition, rather than the state of depression itself, may be responsible for the cognitive deficits reported in some patients with affective disorders.

The present study represents a further assessment of subcortical structural abnormalities in patients with bipolar affective disorder. Twenty bipolar patients and 10 age-matched controls, carefully screened to minimize the presence of confounding historical and medical factors, were examined with MRI and a battery of cognitive tests previously shown to be sensitive to basal ganglia dysfunction. Magnetic resonance imaging was chosen because of its demonstrated sensitivity for detecting small subcortical abnormalities. The inclusion of appropriately matched control subjects provided an opportunity to compare the incidence of any noted abnormalities in the two groups and thereby control for the increased sensitivity of MRI to structural changes. A previous report of a subset of patients included in this study has been published.[19]

PATIENTS AND METHODS

Patients

Patients with bipolar affective disorder were recruited from the University of California, San Diego, Clinical Mental Health Research Center (MHCRC) clinical inpatient wards, and from outpatient clinics at the San Diego Veterans Administration Medical Center, the University of California, San Diego Medical Center inpatient service, a community mental health center, and community mental health activist groups. Controls were recruited from the normal control pool of the MHCRC. All subjects were willing and able to give informed consent for participation in this study.

Accepted for publication August 14, 1989.

From the San Diego Veterans Administration Medical Center and the Department of Psychiatry, University of California, San Diego.

Reprint requests to Department of Psychiatry, M-003, School of Medicine, University of California, San Diego, La Jolla, CA 92093 (Dr Dupont).

All patients and controls were screened using the following procedures: Schedule for Affective Disorders and Schizophrenia- Lifetime version (SADS-L) interview,[51] history and physical examination, and laboratory examination. All bipolar patients met Research Diagnostic Criteria for bipolar affective disorder, type I; patients were allowed entry without regard to medication status with the exceptions of benzodiazepines or antihypertensives with known central nervous system effects. Because we were interested in exploring persistent structural and cognitive alterations, all patients were studied regardless of mood state if they met entrance criteria, could complete the protocol, and were capable of giving informed consent.

Patients and controls were excluded if they were over 55 years of age, had a history of head injury with loss of consciousness for more than 5 minutes or with any neurological sequelae, had poorly controlled hypertension, or gave a history of alcohol abuse of 5 years' duration or more or for any duration within 5 years of the study. No subject with a history of intravenous drug abuse was included in the study. No subject showed any clinical evidence of tardive dyskinesia. All controls and their first-degree relatives had no history of major psychiatric illness or substance abuse.

Approximately 160 bipolar patients were screened to select the final 20 who met entrance criteria. Major grounds for exclusion were alcoholism, drug abuse, history of head injury, and age. The final study sample comprised 20 bipolar patients (19 men, 1 woman) and 10 controls (all men). Of the bipolar patients studied initially, 8 were taking lithium carbonate alone; 1 was taking lithium carbonate plus desipramine; 1 was taking lithium carbonate, benztropine, and fluphenazine; 1 was taking lithium carbonate plus a diuretic; 1 was taking lithium carbonate plus mesoridazine; 2 were taking lithium carbonate plus carbamazepine; 1 was taking lithium carbonate plus thiothixene; 1 was taking lithium carbonate, perphenazine, and carbamazepine; 1 was taking carbamazepine; and 3 were taking no medication. None of the patients had ever received bilateral electroconvulsive therapy. One patient, who was the only left-handed subject in the study, had a history of treatment with unilateral electroconvulsive therapy. Control and bipolar subjects used in the final analysis (see "Results" section) did not differ in age or years of education.

Neuropsychological Test Battery

The test battery (Table 1) was part of a larger battery administered at one 2- to 3-hour sitting. Two subjects (one control and one patient) did not complete the California Verbal Learning Test.[52] In these cases, partial test battery results were entered into the analyses. The test battery utilized for this report was designed to evaluate whether impairments in the initiation of retrieval (eg, poor recall and fluency, intact recognition) are evident in bipolar patients and to place such findings in the context of other cognitive performances. Accordingly, indexes of language function, visuospatial capacity, and verbal and figural memory and two tests highly sensitive to cerebral dysfunction in general were all included in the test battery.

Imaging Protocol

All images were obtained on a 1.5-T superconducting magnet (Signa, General Electric, Milwaukee, Wis) at the University of California, San Diego–American Medical International Medical Center Magnetic Resonance Institute. Images were obtained using the standard MRI protocol of the Image Analysis Laboratory of the Department of Psychiatry: proton density and T_2-weighted coronal and axial images are obtained using an asymmetrical, multiple-echo sequence (TR 2000, TE 25,70). T_1-weighted sagittal images (TR 600, TE 25) are also collected. All sections are 5 mm thick with a 2.5-mm gap between sections. A 256×256 matrix with a 24-cm field of view is used. The 20-section series extends from the apex to the brain stem in the axial plane but does not extend fully through the frontal and occipital poles in the coronal plane. Nine T_1-weighted sagittal images are centered at the midsagittal plane and are acquired to visualize medial structures, the corpus callosum, and the brain stem.

A senior neuroradiologist (J.R.H.) blind to group membership and demographic data evaluated all images for structural abnormalities. Particular attention was paid to subcortical regions, with careful notation of all signal hyperintensities. Signal hyperintensities were diagnosed when regions of high signal were present on both the balanced and T_2-weighted images. Lesions were defined on both the transaxial and coronal views when locations were within the extent of the partial coronal series. Because high-signal "caps" immediately adjacent to the frontal or occipital horns of the lateral ventricle are normal, hyperintensities in these areas were not considered to represent focal abnormalities. Regions of high signal in the vicinity of slowly flowing vessels were not included if their appearance could be accounted for by the phenomenon of flow enhancement, nor were penetrating cortical vessels or thalamostriate vessels with their linear high-intensity T_2 signal considered abnormal.

RESULTS

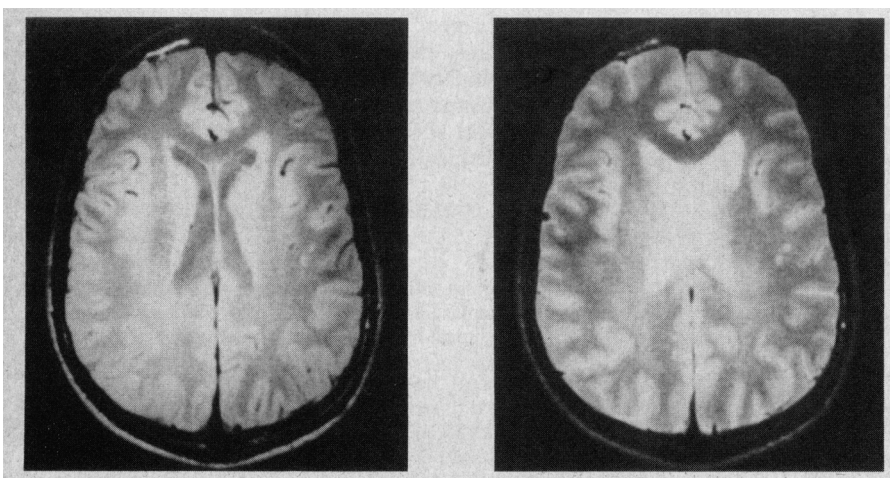
Ten of the 20 bipolar subjects and none of the controls had abnormal MRI images based on the blind examination. One bipolar subject, excluded from further analysis, demonstrated a previously undiagnosed arachnoid cyst displacing the left temporal lobe posteriorly. The subject groups did not differ significantly in age or education (Table 2). Nine of the 19 remaining bipolar patients but none of the 10 controls exhibited the presence of subcortical signal hyperintensities involving the white matter ($P<.001$, Fischer's Exact Test; Figure).

Distribution of Signal Abnormalities

The distribution of signal hyperintensities was varied. Seven of the nine patients had abnormalities involving the frontal lobes. Only two

Table 1.—Neuropsychological Test Battery

Vocabulary Test[53]
Confrontation Naming Test[54]
Controlled Oral Word Association Test[53]
Judgement of Line Orientation Task[53]
Embedded Figures Test[53]
California Verbal Learning Test[52]
Digit Symbol Substitution[54]
Trailmaking Test, part B[53]



The proton density–weighted image (left) and T_2-weighted image (right) of a 30-year-old bipolar man are displayed. Two regions of signal hyperintensity are demonstrated: anterolateral to the frontal horn of the left lateral ventricle, and in the left subcortical temporoparietal area. In contrast to cerebrospinal fluid and brain, these regions show high signal on both images.

Table 2.—Description of Clinical Variables in Bipolar Patients and Normal Subjects*

	Bipolar With Normal MRI	Bipolar With Abnormal MRI	Control
Age, y	37±10	36±10	41±10
Education, y	14.6±2.5	14.7±2.9	16.0±2.8
Age at onset, y	25±7.5	26±6.9	...
Marital status, %	60	67	80
No. of hospitalizations	2.0±2.0	3.7±1.2†	...
No. with history of psychosis, %	70±48	78±44	...
Neuroleptic use	0.8±0.8	1.2±1.0	...
Hamilton Rating Scale for Depression	8.3±7.2	13.8±6.9‡	0.7±0.7‡

*MRI indicates magnetic resonance imaging. Values are mean±SD, except for marital status, which is percentage married or divorced at the time of the study. For neuroleptic use, 0 indicates no use at all; 1, used 6 months or less; 2, used more than 6 months but not long-term use; 3, long-term use.
†$P \leq .05$ compared with bipolar patients with normal MRI scan.
‡$P \leq .10$ compared with bipolar patients with normal MRI scan.

patients had no apparent right-hemisphere hyperintensities at all. Bilateral hemisphere involvement was seen in four patients, unilateral right hemisphere involvement in three, and unilateral left hemisphere involvement in two subjects. All hyperintensities except 1 in the thalamus were located in subcortical white matter regions. One patient had involvement of the corpus callosum posteriorly; one patient had a lesion directly adjacent to the left caudate nucleus. The number of hyperintensities per patient ranged from 1 to 12. In two patients, both in their 40s, moderate to marked cortical atrophy was noted; both of these individuals had scans demonstrating hyperintensities. One of those patients had diffuse increase in perivascular spaces with resultant linear hyperintensities on T_2-weighted but not balanced images. No patient displayed evidence of focal cortical abnormalities.

We recontacted all subjects with abnormalities after 1 year for repeated imaging to examine the persistence of these signal abnormalities. We were able to restudy seven of the nine patients with hyperintensities (one subject refused, one subject had moved). Six of these seven patients were found to have abnormalities that were unchanged on visual examination compared with the previous study. The one individual who appeared to demonstrate no abnormality on repeated scan underwent scanning a third time with contiguous sections, to eliminate the possibility that the abnormality had been missed because of the 2.5-mm gap between sections on the second scan. In this third scan, the hyperintensity was again detected, unchanged compared with the first scan. Thus, no individual studied demonstrated visually evident resolution or worsening of the abnormalities in this short follow-up period. In addition, four patients who underwent repeated scanning were in affective states clinically different from their initial scan (two depressed individuals no longer met Research Diagnostic Criteria for major depression, though some residual symptoms remained; one manic individual now met criteria for major depression; one depressed individual was now in remission). Thus, these MRI abnormalities are apparently not reversible state markers.

Clinical Correlates of Signal Hyperintensities

As shown in Table 2, bipolar patients with lesions had more psychiatric hospitalizations than those without lesions ($P<.05$), although no significant differences were found between the groups with respect to age at onset, duration of illness, or current age. Family history of psychiatric disorder, and history of psychosis, were not associated with the presence of these lesions. Although duration of neuroleptic use did not appear to differ between these groups, this insensitive, retrospective measure does not take into account type of neuroleptic used, dosage, compliance, or exposure to side effects.

Table 3.—Summary of Neuropsychological Test Results*

Test	Bipolar Patients (n=19)	Controls (n=10)	t	Bipolar MRI− (n=10)	Bipolar MRI+ (n=9)	t
Language						
Vocabulary	20.3	21.2	0.6	19.5	21.1	0.8
Naming test	26.7	24.9	2.2†	27.0	26.3	1.1
Letter fluency	40.7	41.5	0.2	46.0	34.8	2.1†
Visuospatial						
Line Orientation (No. correct)	17.4	17.8	0.3	18.9	15.8	1.9‡
Embedded Figures (time)	585	487	0.7	484	698	1.2
Memory measures						
CVLT Recall, trials I-V T-score	39.4	45.1	1.1	45.1	33.7	1.8‡
CVLT Recognition (discriminability)	93.0	95.7	1.6	92.8	93.2	0.2
General measures						
Trailmaking Test B (s)	84.9	90.7	0.2	77.8	92.9	1.2
Digit Symbol (scaled score)	10.8	14.0	3.4§	11.9	9.6	2.3†

*MRI indicates magnetic resonance imaging (plus and minus indicate abnormal and normal, respectively); CVLT, California Verbal Learning Test. One control subject and one bipolar patient (with normal MRI) did not complete the CVLT. Thus, the numbers were reduced for the two CVLT measures in the relevant groups.
†$P<.05$.
‡$P<.10$.
§$P<.01$.

Neuropsychological Test Results

Table 3 gives the performances of the bipolar patients and control subjects on the neuropsychological test battery. Little evidence of a general cognitive impairment was found in the bipolar patients as a group (n=19) compared with the control group (n=10). Although a single significant comparison in this context is not substantially above chance expectations, it is of interest that on the Digit Symbol Substitution Test, a measure highly sensitive to cerebral dysfunction in general,[53] the bipolar patients as a group performed significantly worse than the control subjects. In contrast, on the Naming Test,[54] the control subjects actually performed significantly more poorly than did the bipolar patients.

Comparisons of the performances of bipolar patients with and without MRI abnormalities did yield significant differences. Patients with abnormalities had significantly lower verbal fluency and Digit Symbol scores than did patients without abnormalities. In addition, the difference between the two bipolar subgroups on the recall measures of the California Verbal Learning Test, and on the Line Orientation task,[54] approached statistical significance.

COMMENT

The major finding of this investigation is the unusually high incidence of signal hyperintensities in the brain MRIs of the bipolar patients. These abnormalities appear to be persistent, remaining unchanged for a year in all patients who underwent repeated scanning. Although the significance and histopathological nature of white matter hyperintensities remain controversial, these lesions have been shown in the normal elderly and in patients with a variety of medical and neurological disorders to be strongly associated with ischemic brain disease and various risk factors for atherosclerotic vascular disorders (eg, smoking, hypertension).[22-35] In younger individuals, Awad et al[22] report that in a study of a large number of clinical scans, no individual without brain disease and under 40 years of age demonstrated these abnormalities. Signal hyperintensities with unique distributions may be indicative

of disease states such as multiple sclerosis and subacute arteriosclerotic encephalopathy (Binswanger's disease). It seems unlikely that the positive MRI findings for the bipolar patients are attributable either to their age (which was relatively young) or to undiagnosed neurological disorders since our similarly screened and age-matched controls had none.

This study does not establish either the etiology or clinical significance of the bipolar patients' signal hyperintensities. However, three general hypotheses concerning the relationship between bipolar illness and the MRI abnormalities should be considered. (1) The MRI abnormalities precede and predispose to or cause bipolar illness. (2) The MRI abnormalities follow the onset of the bipolar condition and reflect damage associated with treatment or repeated affective episodes. (3) The MRI abnormalities and bipolar illness arise from a common cause but are not directly linked. Finally, in all of these cases it may be possible that the MRI abnormality is a nonspecific finding in neuropsychiatric illnesses.

With regard to the first possibility, the signal hyperintensities could be due to posttraumatic, viral, toxic, or genetic factors or to some combination of these and other factors that also predispose individuals to affective disturbances. It is noteworthy in this regard that Robinson et al[55] and Starkstein et al[56] have reported that patients who develop bipolar illness following brain injury are more likely to have a positive family history of affective illness than are those who manifest depression. These findings suggest that structural lesions may lead to bipolar illness in individuals with a genetic predisposition for affective illness. Although our sample of bipolar patients was limited, the incidence of a positive family history for affective illness was not greater in patients with MRI abnormalities than without.

Second, the possibility that the noted hyperintensities might be associated with treatment or severity of illness demands consideration of a number of factors. For instance, hypotension induced by the α-blocking action of numerous psychotropic drugs may result in ischemic lesions. Also, brain dysfunction (and associated hyperintensities) may be related to frequency of bipolar episodes.

Third, the logical possibility must be considered that the MRI abnormalities and bipolar illness are not directly related to one another in an etiological sense but reflect the effect of some common processes. For example, if bipolar illness results from a diffuse alteration in membrane physiology, as some have hypothesized, it is possible that this could result in detectable MRI hyperintensities through an alteration in protein-water relationships. Consistent with this possibility, Ranguel-Guerra et al[57] have reported that altered T_1-weighted relaxation times in bipolar patients are normalized after lithium carbonate treatment, while such values in normal controls showed no change with lithium carbonate treatment.

Finally, to address the nonspecificity of these abnormalities, it is possible that the signal hyperintensities will prove to be present in some but not all neuropsychiatric illnesses. They might be similar to decreased rapid eye movement latency, which has been reported in depression, schizophrenia, borderline personality disorder, and obsessive-compulsive disorder, among others.[58-62] Magnetic resonance imaging studies in other disorders are clearly needed to determine the diagnostic specificity of this abnormality.

In addition to the noted MRI abnormalities, the neuropsychological results provide further evidence of subcortical dysfunction in our bipolar patients. The 9 patients with signal hyperintensities encountered more difficulty with the letter fluency and verbal recall tests than did the 10 patients with no MRI abnormalities. On the other language tests and the verbal recognition task, the two subgroups of bipolar patients performed almost identically. Deficient verbal fluency (Letter Category Test) with normal naming and vocabulary performance (Naming Test, Vocabulary) suggests impairment in the initiation of systematic retrieval strategies. Similarly, free recall of words presented on the California Verbal Learning Test places more demands on patients' retrieval capacities than does recognition of whether a given word was or was not on the to-be-remembered list.

The present neuropsychological results are consistent with those reported recently by Wolfe and colleagues.[40] When these investigators compared the neuropsychological profiles of patients with HD and bipolar and unipolar affective disorders, they found that only the patients with HD and bipolar disorder were significantly more impaired than unipolar patients and normal controls on verbal fluency, recall, and recognition tests. These noted similarities in the performances of patients with HD and bipolar disorder do not necessarily prove identity in underlying neurological and/or cognitive disorders. However, the combination of these behavioral parallels and of the high incidence of MRI subcortical abnormalities suggests that damage to some subcortical structures may play a role in the etiology, pathophysiology, or clinical presentation of some bipolar patients.

It should be emphasized that MRI hyperintensities were not observed in 10 of 19 bipolar patients in this study. One question is whether MRI could have missed the lesions in some subjects or artifactually created them in others. If a bias exists in the detection of signal hyperintensities by MRI, it is in the direction of an underestimation of their rate of occurrence. First, 2.5-mm gaps exist between sections in our protocol. In our follow-up study, the abnormality in 1 of 7 subjects appeared initially to have resolved but was found in a subsequent scan to be present in the nonimaged gap. Second, some of these "lesions" may be missed because they are small or diffuse. Finally, it is unlikely that artifacts in MRI result in the apparent creation de novo of these lesions. Awad et al[24] reported no false positives on MRI detection of signal hyperintensities in their study of postmortem imaging and pathological evaluation. In any case, if it is shown that these MRI abnormalities are found only in a subset of bipolar patients, their etiological role will have to be assessed accordingly.

It is not yet possible to report whether the lesions seen on MRI are related to the ventricular enlargement seen by others in bipolar illness. In a later report we will present quantitative structural information with respect to diagnosis and lesion presence. We plan to follow up these patients longitudinally with MRI, neuropsychological testing, and clinical measures.

A major stumbling block in our understanding of the significance of these lesions has been the lack of adequate neuropathological data for correlation. We know of no histological studies that could help us understand the nature of these lesions in the bipolar patients. Specifically, since similar signal characteristics may be indicative of very diverse disease processes, it is hazardous to extrapolate from studies in disorders such as multiple sclerosis or ischemic brain disease. The sensitivity of MRI and the variety of imaging planes available using this modality will yield a wealth of information about structural abnormalities not previously available. It is probable that the neuropsychiatric symptoms and the MRI abnormalities reflect a more widespread pattern of parenchymal injury, only some of which is visible with MRI. Magnetic resonance imaging also affords the chance to characterize changes in tissue through determination of relaxation times and MRI spectroscopy. This study and others that demonstrate the existence of structural abnormalities in bipolar patients raise the possibility that biological markers for phenotypes of bipolar illness may exist.

This study was supported by Mental Health Clinical Research Center Grant MH 30914, grant MH 42575, and fellowship training grant MH 18399 from the National Institute of Mental Health; by a Veterans Administration research training grant for psychiatrists; and by the San Diego Veterans Administration Research Service.

References

1. Pearlson GD, Garbacz DJ, Breakey WR, Ahn HS, DePaulo JR. Lateral ventricular enlargement associated with persistent unemployment and negative symptoms in both schizophrenia and bipolar disorder. *Psychiatry Res.* 1984; 12:1-9.

2. Pearlson GD, Garbacz DJ, Moberg PJ, Ahn HS, DePaulo JR. Symptomatic, familial, perinatal and social correlates of computerized axial tomography changes in schizophrenics and bipolars. *J Nerv Ment Dis.* 1985;173:42-50.

3. Pearlson GD, Garbacz DJ, Tompkins RT, Ahn HS, Gutterman DF, Veroff AE, DePaulo JR. Clinical correlates of lateral ventricular enlargement in bipolar affective disorder. *Am J Psychiatry.* 1984;141:253-256.

4. Nasrallah HA, McCalley-Whitters M, Pfohl B. Clinical significance of large cerebral ventricles in manic males. *Psychiatry Res.* 1984;13:151-156.

5. Schlegal S, Kretzschmar K. Computed tomography in affective disorder, I. *Biol Psychiatry.* 1987;22:4-14.

6. Scott ML, Golden CJ, Ruedrich SL, Bishop RJ. Ventricular enlargement in major depression. *Psychiatry Res.* 1983;8:91-93.

7. Shima S, Shikano T, Kitamura T, Masuda Y, Tsukumo T, Kanba S, Asai M. Depression and ventricular enlargement. *Acta Psychiatr Scand.* 1984;70:275-277.

8. Targum SD, Rosen LN, DeLisi LE, Weinberger DR, Citrin CM. Cerebral ventricular size in major depressive disorder: association with delusional symptoms. *Biol Psychiatry.* 1983;18:329-336.

9. Dolan RJ, Calloway P, Mann AH. Cerebral ventricular size in depressed subjects. *Psychol Med.* 1985;15:873-878.

10. Jacoby RF, Levy R, Bird JM. Computed tomography and the outcome of affective disorder: a follow-up study of elderly patients. *Br J Psychiatry.* 1981; 139:288-292.

11. Luchins DJ, Lewine RRJ, Meltzer HY. Lateral ventricular size, psychopathology, and medication response in psychoses. *Biol Psychiatry.* 1984;19:29-44.

12. Standish-Berry HMAS, Hale AS, Honig A, Bouras N, Bridges PK, Bartlett R. Ventricular size, the dexamethasone suppression test and outcome of severe endogenous depression following psychosurgery. *Acta Psychiatr Scand.* 1985; 72:166-171.

13. Standish-Barry HMAS, Bouras N, Bridges PK, Bartlett JR. Pneumoencephalographic and computerized axial tomography scan changes in affective disorder. *Br J Psychiatry.* 1982;141:614-617.

14. Coffman JA, Nasrallah HA. Relationships between brain density, cortical atrophy and ventriculomegaly in schizophrenia and mania. *Acta Psychiatr Scand.* 1985;72:126-132.

15. Nasrallah HA, McCalley-Whitters M, Jacoby CG. Cortical atrophy in schizophrenic and bipolar patients. *Am J Psychiatry.* 1982;139:667-668.

16. Lippman S, Manshadi M, Baldwin H, Drasin G, Rice J, Alrajeh S. Cerebellar vermis dimensions on computerized tomographic scan of schizophrenic and bipolar patients. *Am J Psychiatry.* 1982:139:667-668.

17. Coffman JA, Nasrallah HA. Brain density patterns in schizophrenia and mania. *J Affective Disord.* 1984;6:307-315.

18. Schlegal S, Kretzschmar K. Computed tomography in affective disorders, II. *Biol Psychiatry.* 1987;22:15-23.

19. Dupont RM, Jernigan TL, Gillin JC, Butters N, Delis DC, Hesselink JR. Presence of subcortical signal hyperintensities in bipolar patients detected by MRI. *Psychiatry Res.* 1987;21:357-358.

20. Coffey CE, Figiel GS, Djang WT, Cress M, Saunders WB, Weiner RD. Leukoencephalopathy in elderly depressed patients referred for ECT. *Biol Psychiatry.* 1988;24:143-161.

21. Krishnan KRR, Goli B, Ellinwood EH, France RD, Blazer DG, Nermeroff CB. Leukoencephalopathy in patients diagnosed as major depressive. *Biol Psychiatry.* 1988;23:519-522.

22. Awad IA, Spetzler RF, Hodak JA, Awad CA, Carey R. Incidental subcortical lesions identified on magnetic resonance imaging in the elderly, I: correlation with age and cerebrovascular risk factors. *Stroke.* 1986;17:1084-1089.

23. Awad IA, Johnson PC, Spetzler RF, Hodak JA. Incidental subcortical lesions identified on magnetic resonance imaging in the elderly, II: postmortem pathological correlations. *Stroke.* 1986;17:1090-1097.

24. Brant-Zawadzki M, Fein G, Dyke CV, Kiernan R, Davenport L, de Groot J. MR imaging of the aging brain: patchy white-matter lesions and dementia. *Am J Neuroradiol.* 1985;6:675-682.

25. Challa VR. White matter lesions in MR imaging of elderly subjects. *Radiology.* 1987;164:874-875.

26. Gerard G, Weisberg LA. MRI periventricular lesions in adults. *Neurology.* 1986;36:998-1001.

27. Goto K, Nobuyoshi I, Fukasawa H. Diffuse white-matter disease in the geriatric population. *Radiology.* 1981;141:687-695.

28. Hachinski BC, Potter P, Merskey H. Leuko-araisosis. *Arch Neurol.* 1987;44:21-23.

29. Inzitari D, Diaz F, Fox A, Hachinski BC, Steingart A, Lau C, Donald A, Wade J, Mulic H, Merskey H. Vascular risk factors and leuko-araiosis. *Arch Neurol.* 1987;44:42-47.

30. Johnson KA, Buonanno FS, Davis KR, Rosen TJ, Brady TJ, Growdon JH. Clinical correlates of hemisphere white matter MR signal abnormality. *Neurology.* March 1987;37(suppl):230.

31. Kirkpatrick JB, Hayman LA. White-matter lesions in MR imaging of clinically healthy brains of elderly subjects: possible pathologic basis. *Neuroradiology.* 1987;162:509-511.

32. Sarpet G, Chaudry R, Hindo W. Magnetic resonance imaging of periventricular hyperintensity in a Veterans Administration hospital population. *Arch Neurol.* 1987;44:725-728.

33. Steingart A, Hachinski BC, Lau C, Fox AJ, Fox H, Lee D, Inzitari D, Merskey H. Cognitive and neurologic findings in demented patients with diffuse white matter lucencies on computed tomographic scan (leukoaraiosis). *Arch Neurol.* 1987;44:36-39.

34. Sze G, De Armond SJ, Brant-Zawadzki M, Davis RL, Norman D, Newton TH. Foci of MRI signal anterior to the frontal horns: histologic

35. Zimmerman RD, Fleming CA, Lee BCP, Saint-Louis LA, Deck MDF. Periventricular hyperintensity as seen by magnetic resonance: prevalence and significance. *AJNR.* 1986;7:13-20.

36. Caine E, Hunt R, Weingartner H, Ebert M. Huntington's dementia: clinical neuropsychological features. *Arch Gen Psychiatry.* 1978;35:377-384.

37. Cummings JL. Subcortical dementia: neuropsychology, neuropsychiatry, and pathophysiology. *Br J Psychiatry.* 1986;149:682-697.

38. Feinberg T, Goodman B. Affective illness, dementia, and pseudodementia. *J Clin Psychiatry.* 1984;45:99-103.

39. Mayeux R. Behavioral manifestations of movement disorders. *Neurol Clin.* 1984:2.

40. Wolfe J, Granholm E, Butters N, Saunders E, Janowsky D. Verbal memory deficits associated with major affective disorders: a comparison of unipolar and bipolar patients. *J Affective Disord.* July-August 1987;13:83-92.

41. Friedman MJ, Culver CM, Ferrell RB. On the safety of long-term treatment with lithium. *Am J Psychiatry.* 1977;134:1123-1126

42. Grossman LS, Harrow M, Sands JR. Features associated with thought disorder in manic patients at 2-4 year follow-up. *Am J Psychiatry.* 1986;143:306-311.

43. Harrow M, Grossman LS, Silberstein ML, Meltzer HY, Kettering RL. A longitudinal study of thought disorder in manic patients. *Arch Gen Psychiatry.* 1986;43:781-785.

44. Reus VI, Targum SD, Weingartner H, Post RM. Effect of lithium carbonate on memory processes of bipolar affectively ill patients. *Psychopharmacology.* 1979;63:39-42.

45. Sapin LR, Berrettini WH, Nurnberger JI, Rothblat LA. Mediational factors underlying cognitive changes in affective illness. *Biol Psychiatry.* 1987;22:979-986.

46. Feinberg T, Goodman B. Affective illness, dementia, and pseudodementia. *J Clin Psychiatry.* 1984;45:99-103.

47. Kiloh LG. Pseudo-dementia. *Acta Psychiatr Scand.* 1961;37:336-351.

48. Wells CE. Pseudodementia. *Am J Psychiatry.* 1979;136:895-900.

49. McAllister TW, Price TRP. Severe depressive pseudodementia with and without dementia. *Am J Psychiatry.* 1982;139:626-629.

50. Reding M, Haycox J, Blass J. Depression in patients referred to a dementia clinic: a three-year prospective study. *Arch Neurol.* 1985;42:894-896.

51. Spitzer RL, Endicott J, Robins E. Research Diagnostic Criteria: rationale and reliability. *Arch Gen Psychiatry.* 1978;35:773-782.

52. Delis DC, Kramer JH, Kaplan E, Ober BA. *The California Verbal Learning Test.* New York, NY: Psychological Corp; 1987.

53. Lezak M. *Neuropsychological Assessment.* 2nd ed. New York, NY: Oxford University Press Inc; 1983.

54. Kaplan E, Goodglass H, Weintraub S. *Boston Naming Test.* Philadelphia, Pa: Lea & Febiger; 1983.

55. Robinson RG, Kubos KL, Starr LB. Mood disorders in stroke patients: importance of location of lesion. *Brain.* 1984;107:81-93.

56. Starkstein SE, Pearlson GD, Boston J, Robinson RG. Mania after brain injury: a controlled study of causative factors. *Arch Neurol.* 1987;44:1069-1073.

57. Ranguel-Guerra RA, Perez-Payan H, Minkoff L, Todd LE. Nuclear magnetic resonance in bipolar affective disorders. *AJNR.* 1983;4:229-231.

58. Hiatt J, Floyd TC, Katz PH, Feinberg I. Further evidence of abnormal non–rapid eye movement sleep in schizophrenia. *Arch Gen Psychiatry.* 1985;42:797-802.

59. Insel TR, Gillin JC, Moore A, Mendelson WB, Loewenstien RJ, Murphy DL. The sleep of patients with obsessive-compulsive disorder. *Arch Gen Psychiatry.* 1982;39:1372-1377.

60. Jus K, Bouchard M, Jus AK, Villeneuve A, Lachance R. Sleep EEG studies in untreated, long-term schizophrenic patients. *Arch Gen Psychiatry.* 1973;29:386-390.

61. McNamara E, Reynolds CF, Soloff PH, Mathias R, Rossi A, Spiker D, Coble PA, Kupfer DJ. EEG sleep evaluation of depression in borderline patients. *Am J Psychiatry.* 1984;141:182-186.

62. Uhde TW, Roy-Byrne P, Gillin JC, Mendelson WB, Boulenger JP, Vittone BJ, Post RM. The sleep of patients with panic disorder: a preliminary report. *Psychiatry Res.* 1984;12:251-259.

63. Witkin H, Oltman PK, Raskin E, Karp S. *A Manual for the Embedded Figures Tests.* Palo Alto, Calif: Consulting Psychologists Press; 1971.

64. Lewis RF, Rennick PM. *Manual for the Repeatable Cognitive Perceptual Motor Battery.* Gross Pointe Park, Mich: Axon Publishing Co; 1979.