

Predictive Utility of Apolipoprotein E Genotype for Alzheimer Disease in Outpatients With Mild Cognitive Impairment

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Background: In cognitively impaired patients without dementia, the utility of apolipoprotein E (APOE) genotyping is unclear.

Objective: To evaluate the predictive utility of the APOE $\epsilon 4$ genotype for conversion to probable Alzheimer disease (AD).

Design: Naturalistic, longitudinal study.

Setting: Memory disorders outpatient clinic.

Patients: A total of 136 patients with memory complaints were determined to have mild cognitive impairment and were evaluated every 6 months. Fifty-seven age- and sex-matched healthy controls were evaluated annually.

Main Outcome Measures: Primary outcome measures included conversion to AD. Secondary outcome measures included change over time in Mini-Mental State Examination (MMSE) score and Selective Reminding Test (SRT) delayed recall score.

Results: The APOE $\epsilon 4$ allele was present in 25% of patients and 21% of healthy controls. During a mean \pm SD

follow-up of 35.2 ± 24.3 months, 35 of 136 patients converted to AD. APOE $\epsilon 4$ carrier status did not differ between converters (31%) and nonconverters to AD (23%, $P = .3$) and did not affect the time trend in MMSE or SRT scores in the entire sample. Four of 5 APOE $\epsilon 4$ homozygotes converted to AD compared with 7 of 29 heterozygotes ($P = .02$). In a Cox proportional hazards model stratified by age quartiles, after controlling for sex, education, MMSE score, and SRT delayed recall score, APOE $\epsilon 4$ increased the risk of AD in patients 70 to 85 years old ($n = 57$; risk ratio, 2.77; 95% confidence interval, 1.1-7.3; $P = .03$) but not in patients 55 to 69 years old ($n = 79$; $P = .7$).

Conclusions: APOE $\epsilon 4$ carrier status was associated with conversion to AD in older outpatients after controlling for known demographic and clinical risk factors, and APOE $\epsilon 4$ homozygosity was associated with increased risk of conversion to AD. However, APOE $\epsilon 4$ carrier status by itself did not predict cognitive decline or conversion to AD, indicating that APOE genotyping in patients with mild cognitive impairment may have limited clinical applicability for prediction of outcome.

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THE GENE FOR APOLIPOPROTEIN E (APOE) IS ON THE long arm of chromosome 19 and exists in 3 allelic forms ($\epsilon 2$, $\epsilon 3$, and $\epsilon 4$).

APOE $\epsilon 4$ is associated with an increased risk of Alzheimer disease (AD).¹ In studies that compared patients who had AD with healthy controls, the mean odds ratio for heterozygotes was approximately 4 in clinical samples and approximately 2 in community samples, with considerable variability across studies.^{2,3} The APOE $\epsilon 4$ allele's association with AD is not influenced by sex, diminishes after the ninth decade of life,^{4,5} and may not hold in all ethnic groups.^{2,6}

In elderly patients without dementia, APOE $\epsilon 4$ carriers may show worse cognitive performance and greater cognitive decline over time compared with noncarriers,⁷⁻¹¹ particularly in homozygotes.¹² Several epidemiologic studies show that the APOE $\epsilon 4$ allele predicts cognitive decline¹³⁻¹⁶ and conversion to dementia,¹⁷ but it does not predict disease progression after the clinical diagnosis of AD is made.^{14,18} Other epidemiologic studies^{9,19,20} have shown that APOE $\epsilon 4$ is not associated with cognitive decline or the development of dementia, and its use as a screening test is not recommended.¹⁷ One report²¹ suggested that APOE $\epsilon 4$ carriers with AD may have a more benign disease course. APOE

genotyping does not provide sufficient sensitivity and specificity to be a diagnostic test for AD, but when combined with clinical criteria it may improve specificity.²²

The few longitudinal studies^{4,23} conducted in cognitively impaired outpatients without dementia have reported conflicting results regarding *APOE* genotyping in the prediction of AD, and physicians remain unclear about its utility in these patients. In a naturalistic, longitudinal study of cognitively impaired outpatients who did not meet clinical diagnostic criteria for dementia, the associations of the *APOE* $\epsilon 4$ genotype with baseline cognitive and functional measures and the predictive utility of the *APOE* $\epsilon 4$ genotype for cognitive decline and for the follow-up diagnosis of AD were examined.

METHODS

SUBJECTS

Patients who presented with memory complaints to a memory disorders center, which included a research clinic and affiliated neurologists' private offices, participated in a longitudinal study of putative early diagnostic markers of AD. Most (52%) were physician referred, 25% were self-referred, and 23% were referred by family, friends, or other sources. The research protocol was approved by the New York State Psychiatric Institute and Columbia Presbyterian Medical Center institutional review boards, and written informed consent was obtained from the patient and an informant (when available).

For patients, inclusion criteria were age of 40 years or older, intellectual impairment for 6 months or more but 10 years or less, and the diagnosis of "not demented" (Clinical Dementia Rating [CDR]=0) or "questionably demented" (CDR=0.5). Patients had a minimum modified Mini-Mental State Examination (MMSE) score of 40 or higher of 57 (Folstein MMSE score ≥ 22), but Spanish-speaking patients with 5 years or less of education and an MMSE score of 35 or higher (Folstein MMSE score ≥ 18) were included if they met all other inclusion and exclusion criteria. Neuropsychological testing screening guidelines were recall of 2 or fewer of 3 objects at 5 minutes on the MMSE, a delayed recall score more than 1 SD below norms on the Selective Reminding Test (SRT), or a Wechsler Adult Intelligence Scale-Revised (WAIS-R) performance IQ score of 10 points or more below the WAIS-R verbal IQ score. Patients without any of these deficits were eligible if they met all of the following criteria: subjective complaint of memory decline, informant's confirmation of decline, and functional impairment (positive score on at least 1 of the first 8 items of the modified Blessed Functional Activity Scale).²⁴

Exclusion criteria were a diagnosis of dementia, schizophrenia, schizoaffective disorder, or primary major affective disorder; electroconvulsive therapy within the past 6 months; current or recent (past 6 months) history of alcohol or other substance dependence (*Diagnostic and Statistical Manual of Mental Disorders, Fourth Revision* [DSM-IV] criteria); clinical or historical evidence of stroke; cortical stroke or an infarct 2 cm or greater in diameter on any magnetic resonance imaging slice; cognitive impairment rated as entirely caused by concomitant medications; and major neurologic illness. Patients who met these inclusion and exclusion criteria were defined as having mild cognitive impairment (MCI) and were followed up at 6-month intervals.

Healthy controls were recruited by advertisement. Inclusion criteria were the absence of memory complaints, score of 34 or higher of 41 on the Telephone Interview for Cognitive Status, score of 27 or higher of 30 on the MMSE with recall of 2 or more of 3 objects at 5 minutes, and SRT delayed recall score

not more than 1 SD below age-adjusted norms. Medical, neurologic, and psychiatric exclusion criteria were the same as for patients. Healthy controls were group matched to the patients with regard to age and sex and were followed up annually.

PROCEDURES

The study physician (neurologist or psychiatrist) completed a medical history and conducted a general physical, neurologic, and psychiatric examination. Laboratory tests included complete blood cell count with differential, serum electrolyte levels, liver and renal function tests, thyroid function tests, the VDRL test, serum B₁₂ and folate levels, and brain magnetic resonance imaging. A trained neuropsychology technician administered the following tests: WAIS-R, Wechsler Memory Scale, SRT (12-item), Rosen Drawing Test, Controlled Oral Word Association Test, category naming from the Boston Diagnostic Aphasia Evaluation, Boston Naming Test, Benton Visual Retention Test, and Target Finding (shape and letter cancellation tasks). For this report, to decrease type I error, the analyses of neuropsychological variables were restricted to the Folstein MMSE and a single measure of memory, SRT delayed recall, which is a well-established, strong predictor of AD.²⁵⁻²⁷

The neuropsychological scores were evaluated by an experienced neuropsychologist (Y.S.), and 2 expert clinical raters (D.P.D. and Y.S.) used these test results and all available clinical, laboratory, and magnetic resonance imaging information to make a consensus research diagnosis. A similar approach was used for follow-up evaluations, as previously described.^{28,29} The diagnosis of dementia was based on *DSM-IV* criteria, and the diagnosis of possible or probable AD was based on criteria of the National Institute of Neurological and Cognitive Disorders and Stroke—Alzheimer's Disease and Related Disorders Association.³⁰ The consensus diagnosis was the primary outcome variable. The raters were blind to *APOE* results at all time points.

Subjective Memory Complaints

The self-report Memory Functioning Questionnaire³¹ was administered at baseline and annually to all subjects. The overall subjective rating (single item) and 4 subscales were analyzed: general frequency of forgetting, seriousness of forgetting, retrospective functioning (functioning compared with prior times), and mnemonics use.³²

Functional Assessment Scale

The Pfeffer Functional Activities Questionnaire (FAQ)³³ was given at baseline to all patients and controls and separately to informants of patients. On the basis of our prior work showing that informant report of function and not patient report predicts AD, only the informant report was used in the analyses.²⁹ Each item was scored dichotomously (no difficulty or any difficulty), and the sum of items rated as "any difficulty" (range, 0-10) was analyzed. If a subject had never performed the task, the item was excluded from the total score.

Onset of Illness

In patients, the Onset of Illness interview was administered at baseline to an informant to determine the time of onset of memory decline and other deficits.³⁴

APOE Genotyping

APOE genotyping was conducted using standard methods by which DNA was amplified by the polymerase chain reaction.³⁵

Table 1. Sample Characteristics of Patients With MCI and Healthy Controls

Characteristic	Patients (n = 136)	Controls (n = 57)	P Value*
Female, No. (%)	75 (55)	32 (56)	.9
Age, mean ± SD, y	67.1 ± 9.9	65.9 ± 9.4	.4
Education, mean ± SD, y	15.1 ± 4.3	16.8 ± 2.6	.01
Ethnicity, %			
White	77	84	.5
Hispanic	19	7	.03
Black	2	7	.2
Other	2	2	.4
MMSE score, mean ± SD	27.6 ± 2.0	29.4 ± 0.7	<.001
SRT delayed recall score, mean ± SD	5.4 ± 3.0	9.0 ± 2.3	<.001
Apolipoprotein E ε4 positive, %	25	21	.56

Abbreviations: MCI, mild cognitive impairment; MMSE, Mini-Mental State Examination; SRT, Selective Reminding Test.

*A test of significance for χ^2 (categorical variables) or 2-tailed *t* test (continuous variables).

The genotypes were determined, blind to subject status, by the sizes of DNA fragments present and viewed and photographed under UV light after staining with 0.5 μ g of ethidium bromide.

STATISTICAL ANALYSES

The 2-tailed *t* test and χ^2 test (or Fisher exact test) were used to compare the features of patients and controls, APOE ε4 carriers (≥ 1 ε4 alleles) and noncarriers, and nonconverters and converters to AD (diagnosis of probable AD met at 2 consecutive 6-month intervals).

Survival analysis was used to examine the effect of APOE ε4 on the development of AD. The log-rank test was used without controlling for any variables, whereas the Cox proportional hazards model was used to control for specific baseline variables: age, sex, education in years, and baseline MMSE and SRT delayed recall scores. The time variable was the initial visit to the first follow-up time point at which AD was diagnosed.

Since baseline age played a role in sample selection and APOE ε4 interacted with age in tending to predict conversion to AD, a stratified proportional hazards regression model was used with stratification on baseline age quartiles (after excluding patients <55 years, none of whom converted to AD). The other demographic and cognitive covariates were included in the model. Similar analyses were conducted after restricting the sample to patients with a CDR of 0.5 or white patients only to evaluate APOE ε2 carrier status. The APOE ε4 carrier effect on the time trends for MMSE and SRT delayed recall scores was evaluated using a linear model with repeated measures, with and without controlling for sex, age, and education. The model parameters were estimated with generalized estimating equations (GEEs) that used all available data and took into account within-subject correlations.

RESULTS

BASELINE DEMOGRAPHIC AND CLINICAL FEATURES

Within 6 months of presentation, 2 patients with MCI were clinically diagnosed as having other neurologic disorders (corticobasal degeneration and amyotrophic lat-

Table 2. Characteristics of Apolipoprotein E ε4 Carriers and Noncarriers in Patients With MCI

Characteristic	ε4 Carriers (n = 34)	ε4 Noncarriers (n = 102)	P Value*
Female, No. %	18 (53)	57 (56)	.8
Age, mean ± SD, y	66.5 ± 9.8	67.3 ± 10.1	.7
Education, mean ± SD, y	15.5 ± 4.8	14.9 ± 4.2	.5
Ethnicity, %			
White	79.4	80.4	.9
Hispanic	8.9	15.6	.2
Black	2.9	2.0	.9
Other	8.8	2.0	.3
MMSE score, mean ± SD	27.7 ± 2.0	27.6 ± 2.0	.8
SRT delayed recall score, mean ± SD	5.3 ± 3.5	5.4 ± 2.8	.8
Pfeffer FAQ, mean ± SD	1.3 ± 2.2	1.7 ± 2.1	.3

Abbreviations: FAQ, Functional Activities Questionnaire; MCI, mild cognitive impairment; MMSE, Mini-Mental State Examination; SRT, Selective Reminding Test.

*Determined using χ^2 test (categorical variables) or 2-tailed *t* test (continuous variables).

eral sclerosis presenting with frontal lobe deficits), and they were excluded. Patients scored lower than controls on the MMSE and SRT delayed recall, as expected, but were similar in other features (**Table 1**). In the 136 patients with MCI, 57% had a CDR of 0.5 (questionable dementia) and 43% had a CDR of 0 (no dementia).

APOE GENOTYPE

The APOE genotype distribution in patients was as follows: 3,3, 67%; 2,3, 8%; 2,4, 0.7%; 3,4, 21%; and 4,4, 4%. The APOE genotype distribution in controls was as follows: 3,3, 60%; 2,3, 16%; 2,4, 2%; 2,2, 4%; 3,4, 18%; and 4,4, 2%. APOE ε4 carrier status did not differ between patients (25%) and controls (21%; *P* = .6) or between patients with a CDR of 0 (28%) and a CDR of 0.5 (23%; *P* = .5). In patients (and controls), the presence of APOE ε4 was not associated with age, sex, education, ethnicity, Pfeffer FAQ score, or baseline MMSE or SRT delayed recall score (**Table 2**). In patients, the global rating of subjective memory and the subscale scores for general frequency of forgetting, mnemonics use, and retrospective functioning were not related to APOE ε4 status. For the subscale of seriousness of forgetting, APOE ε4 noncarriers rated their memory as worse compared with APOE ε4 carriers ($t_{134} = 2.3$; *P* = .02).

FOLLOW-UP

Of the 136 patients who were followed up, 16 had dropped out by the 3-year follow-up time point: 11 patients had died and 5 patients had refused follow-up. There were 22 dropouts by the 5-year follow-up time point: 13 patients had died, 2 patients had lost contact, and 7 patients had refused further follow-up. In the 3 brain autopsy specimens obtained, neuropathologic analysis confirmed the clinical diagnosis. Four of the 35 patients with incident AD had other neurologic conditions (1 had parkinsonism, 1 had Lewy body disease, and 2 had cere-

Table 3. Characteristics of Converters and Nonconverters to Alzheimer Disease

Characteristic	Converters (n = 35)	Nonconverters (n = 101)	P Value*
Female, No. (%)	21 (60)	55 (54)	.5
Age, mean ± SD, y	73.0 ± 7.2	65.0 ± 10.0	<.001
Education, mean ± SD, y	14.0 ± 4.7	15.4 ± 4.1	.08
Ethnicity, %			
White	74	78	.7
Hispanic	17	13	.6
Black	3	6	.4
Other	6	3	.8
MMSE score, mean ± SD	26.4 ± 1.9	28.1 ± 1.8	<.001
SRT delayed recall score, mean ± SD	2.9 ± 2.0	6.2 ± 2.8	<.001
Apolipoprotein E ε4 carrier, %	31	23	.3

Abbreviations: MMSE, Mini-Mental State Examination; SRT, Selective Reminding Test.

*Determined using χ^2 test (categorical variables) or 2-tailed *t* test (continuous variables).

brovascular disease) that were deemed contributing factors. All 35 incident AD cases were retained for statistical analyses. Of the 57 controls, 2 progressed to a CDR of 0.5 but none converted to dementia during follow-up.

Thirty-four of 78 patients with a baseline CDR of 0.5 compared with 1 of 58 patients with a baseline CDR of 0 converted to AD during follow-up (Fisher exact test; $P < .001$). Converters were older and had lower baseline MMSE scores than nonconverters (**Table 3**). Mean ± SD duration of follow-up was 35.2 ± 24.3 months; converters (n = 35) were diagnosed as having AD a mean ± SD of 21.6 ± 15.6 months after initial evaluation, and nonconverters (n = 101) were followed up a mean ± SD of 46.9 ± 25.1 months. Controls were followed up a mean ± SD of 52.9 ± 24.9 months.

In patients, APOE ε4 carrier status did not differ between converters (31%) and nonconverters (23%; $\chi^2_1 = 1.0$; $P = .3$). Four of 5 APOE ε4 homozygotes converted to AD compared with 7 of 29 heterozygotes who converted to AD during follow-up (Fisher exact test; $P = .03$).

In the entire sample of 193 subjects (patients plus controls), APOE ε4 carrier status did not predict conversion to AD in survival analyses (log-rank test; $P = .2$). In a Cox proportional hazards model that controlled for sex ($P = .2$), age ($P = .04$), baseline MMSE score ($P < .001$), and SRT delayed recall score ($P < .001$), APOE ε4 status tended to predict conversion to AD (risk ratio, 2.0; 95% confidence interval [CI], 0.9-4.4; $P = .08$). Since no control converted to AD and the primary aim was to evaluate the predictive utility of APOE ε4 in patients with MCI, further analyses were restricted to patients.

In survival analyses conducted in the 136 patients, APOE ε4 status did not predict conversion to AD (log-rank test; $P = .2$). In a Cox proportional hazards model that controlled for sex ($P = .4$), age ($P = .02$), education ($P = .5$), baseline MMSE score ($P = .004$), and SRT delayed recall score ($P < .001$), APOE ε4 status tended to predict conversion to AD (risk ratio, 2.0; 95% CI, 0.9-4.4; $P = .08$). In a Cox model that included age, APOE ε4, and the age-by-APOE ε4 interaction, after control-

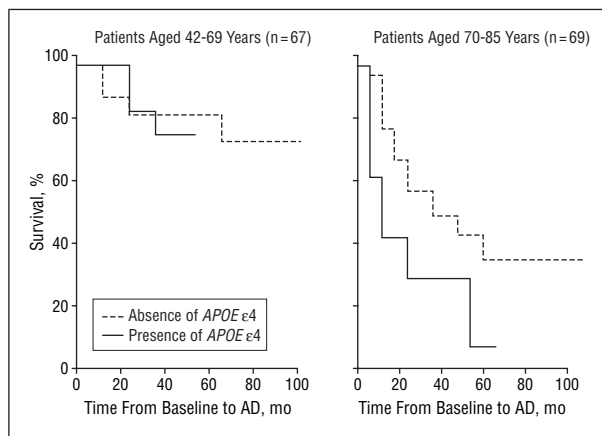


Figure. Effect of apolipoprotein E (APOE) ε4 carrier status on survival time (Kaplan-Meier curve) to Alzheimer disease (AD) in 136 outpatients with mild cognitive impairment. For patients with a baseline age of 55 to 69 years, the presence of APOE ε4 tended to reduce the time to AD (log-rank test; $\chi^2_1 = 2.98$; $P = .08$).

ling for sex, education, and baseline MMSE and SRT delayed recall scores, the age-by-APOE ε4 interaction tended to predict AD ($P = .06$), with the predictive effect of APOE increasing with baseline age.

To further assess the baseline age-dependent effect of APOE, patients younger than 55 years (n = 17) were excluded because none converted to AD. The remainder of the patient sample was dichotomized around the median age of 70 years. Without controlling for other variables, APOE ε4 status did not predict AD in patients 55 to 69 years old (log-rank test; $P = .55$) but tended to predict AD in patients 70 to 85 years old (log-rank test; $P = .08$) (**Figure**). In a Cox proportional hazards model stratified by age quartiles, after controlling for sex, education, and MMSE and SRT delayed recall scores, the presence of APOE ε4 significantly increased the risk of AD in patients 70 years or older (risk ratio, 2.77; 95% CI, 1.1-7.3; $P = .03$) but not in patients 55 to 69 years old ($P = .8$). When age at onset replaced age in these analyses, the results were essentially unchanged.

In another set of Cox models in the patient sample, APOE ε4 status was not a significant predictor of AD after including the covariates of baseline subjective memory complaints global score, Pfeffer FAQ score, or baseline SRT delayed recall score in each model. Restricting the sample to white patients (n = 109) and controlling for age, sex, education, and MMSE and SRT delayed recall scores, the presence of APOE ε4 tended to predict conversion to AD (risk ratio, 2.5; 95% CI, 1.0-6.3; $P = .06$) in another Cox model. In similar Cox analyses with the same covariates in older (≥ 70 years) white patients, APOE ε4 significantly increased the risk of AD (risk ratio, 3.5; 95% CI, 1.1-11.2; $P = .04$). Restricting the patient sample to a baseline CDR of 0.5 (n = 78) and controlling for age, sex, education, MMSE score, and SRT delayed recall score in another Cox model, APOE ε4 status was not a significant predictor of AD (risk ratio, 1.8; 95% CI, 0.8-4.0; $P = .15$). In the subsample with a CDR of 0.5, APOE ε4 homozygosity (3 homozygotes; thus, power was limited) was not a significant predictor ($P = .4$) in Cox analyses that controlled for the same covariates.

Table 4. Product-Limit Estimates of Cumulative Proportion of Conversion to AD Within 2 or 3 Years of Follow-up in APOE ε4 Carriers and Noncarriers With MCI Classified by Baseline Age Group

Age Group, y	No. of Patients		Conversion in 2 y*		Conversion in 3 y*	
	APOE ε4-	APOE ε4+	APOE ε4-	APOE ε4+	APOE ε4-	APOE ε4+
42-54	11	6	0	0	0	0
55-69	45	13	0.14	0.17	0.14	0.25
70-85	46	15	0.30	0.51	0.36	0.51

Abbreviations: AD, Alzheimer disease; APOE, apolipoprotein E; ε4+, APOE ε4 carriers; ε4-, APOE ε4 noncarriers; MCI, mild cognitive impairment.

*Data are presented as proportion of subjects.

The main analyses were performed again by classifying the sample into APOE ε2 carriers and noncarriers instead of APOE ε4 carriers and noncarriers. APOE ε2 was not significant in any analysis for the prediction of or protection against AD.

In GEE analyses with repeated measures in the entire patient sample, there was no time trend in MMSE or SRT delayed recall scores, with and without controlling for age, sex, and education. In the subsample of 35 converters to AD, with the analyses restricted to the 3 years of follow-up before diagnostic conversion to AD, APOE ε4 status did not affect the decreasing linear time trend in MMSE scores, with and without controlling for age, sex, and education. In these 35 converters, patients with APOE ε4 showed a greater decline ($P=.03$) in the decreasing linear time trend for SRT delayed recall scores ($P<.001$) after controlling for age, sex, and education.

COMMENT

The prevalence of APOE ε4 carrier status did not differ between patients and controls. In patients, APOE ε4 carrier status was not associated with measures of subjective memory, in contrast to some reports.^{8,16,36} APOE ε4 carrier status by itself predicted neither conversion to AD nor decline in memory or global cognition in the patient sample.^{37,38} These results are consistent with some but not all studies of this type.^{4,23,39} Although APOE ε4 carrier status did not predict cognitive decline in the patient sample, it was associated with the declining linear trend in SRT delayed recall score in the subsample that converted to AD. However, APOE ε4 status did not add significantly to the prediction obtained from the SRT delayed recall score, in contrast to another report.²³

The APOE ε4 effect on conversion to AD appeared to increase with age (Table 4), and the analyses indicated that this effect remained after controlling for relevant covariates in the entire patient sample and in white patients only. The literature on APOE ε4 and age is complex, and recent epidemiologic data suggest that APOE ε4 is associated with an earlier age at onset but that this association is absent after the ninth decade of life.^{5,40} In our sample, the oldest patient was aged 85 years at baseline, thus limiting the evaluation of APOE ε4 effects in the very old.^{5,40}

Study limitations included the moderate sample size and the paucity of minorities (n=27) to evaluate this subgroup separately or to assess ethnic differences.⁶ Au-

topsy was performed on only 3 of 13 patients who died; APOE ε4 appears to provide moderate to strong sensitivity and specificity for the autopsy diagnosis of definite AD.⁴¹ Therefore, the primary outcome of AD may have contained classification error, and some current nonconverters may convert to AD with longer follow-up. This limitation was tempered by using expert raters who used strict diagnostic methods and by using repeated-measures analyses (GEEs) on cognitive scores that were statistically powerful and eliminated the subjective element in diagnosis. The setting of the outpatient academic center limits generalizability to other types of settings, but to improve clinical relevance, the inclusion and exclusion criteria identified a broad group of patients with MCI. However, these differ from the narrower criteria for MCI used in other longitudinal clinical studies.^{4,23} Nonetheless, the number of converters to AD (n=35) was large enough to assess predictors of conversion to AD.

Four of 5 patients with APOE ε4 homozygosity converted to AD, consistent with the literature on AD and in samples without dementia.^{4,7,9,10} The APOE ε4 homozygotes were important determinants of the overall effects in survival analyses, since the APOE ε4 carrier effect became less significant after homozygotes were excluded. There was no APOE ε2 effect, and data about the possible protective role of APOE ε2 against AD are conflicting.^{13,16}

In summary, APOE ε4 carrier status by itself did not predict cognitive decline or conversion to AD, indicating that APOE genotyping in patients with MCI may have limited clinical applicability. However, APOE ε4 carrier status was associated with conversion to AD in older outpatients after controlling for known demographic and clinical risk factors, and APOE ε4 homozygosity was associated with increased risk of conversion to AD. Overall, the results indicate that assessment of the APOE genotype should remain an important research tool in the investigation of patients with MCI and AD.

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