An investigation of ACE as a risk factor for dementia and cognitive decline in the general population

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METHODS

The MRC Cognitive Function and Ageing Study is a multicentre prospective study into the functional and cognitive status of the elderly in England and Wales. The centres used for the present analyses are set in two rural (Cambridgeshire and Gwynedd) and two urban (Nottingham and Newcastle) locations. A detailed description of the design of the study has been published elsewhere. Briefly, a two phase sampling design was used, where stratification for probability sampling for assessment was based on age and performance on dementia screening tests (automated geriatric examination for computer assisted taxonomy (AGECAT) organicity items6 and the Mini Mental Status Examination7). A total of 2034 subjects out of 10 264 screened were sampled for assessment in this way. The assessed respondents then underwent two further follow up interviews to ascertain incident cases. Those not sampled in the first (prevalence) wave were screened during the second wave (two years later), and were selected for assessment using the same probability sampling scheme (5618 screened, 1151 assessed). At the third wave (approximately six years into the study), a combined screen and assessment was completed on 1730 of this cohort who were still alive, accessible, and who had consented to remain in the study. Of this number, 1070 consented to give a blood sample or buccal swab for genetic studies.

Respondents were assessed by trained interviewers from professions allied to medicine. The assessment interview provides information processed by the computer algorithm AGECAT, which generates a diagnosis of dementia (as well as affective and anxiety disorders) on the basis of criteria compatible with those of the International Classification of Diseases, 9th revision (ICD-9) and the Diagnostic and Statistical Manual (DSM-III-R).11 Dementia is diagnosed if a person has an AGECAT organicity rating of O3 or above, which is highly correlated with clinical assessment of dementia status.5 Cases comprised all blood/saliva contributing participants who had been assigned an AGECAT organicity level of O3 or higher at any point during the three assessment waves and an MMSE score of 21 or less at the third assessment wave. The control group comprised subjects with AGECAT organicity level below O3 and an MMSE score of 26 or greater at the third assessment wave. Cases and controls were drawn from the 913 subjects who had both APOE (a known genetic risk factor for dementia) and ACE genotypes.

There were 118 cases (male=33; median age at wave 3=81, 25th centile=78, 75th centile=85; female=85; median age=86, 25th centile=82, 75th centile=89) and 433 controls (male=208; median age at wave 3=75, 25th centile=72, 75th centile=83).
centile=79.5; female=225; median age at wave 3=76, 25th centile=72, 75th centile=81).

APOE genotyping was performed as described by Wenham et al,12 and ACE genotypes were determined using the method described by Evans et al.13 All genotyping was carried out by the first author (AY), and genotype assignments double checked for accuracy by the corresponding author (DCR). Samples with ambiguous genotypes were rerun. Three genotyping attempts were performed for each sample, after which the APOE/ACE status of unsuccessfully typed samples were recorded as unknown/failed. APOE genotype was successfully determined in 1030 subjects and ACE genotype in 922. There are 913 subjects whose APOE and ACE genotypes are both known.

The association between ACE and dementia risk was examined by unconditional logistic regression. The analyses were conducted using third wave data only, to examine the cross sectional association between ACE and dementia risk, adjusting for age, sex, education, and APOE e4 carrier status. Separate analyses for men and women, controlling for age and years in full time education were also carried out. The categorical variable ACE was classified by genotype: DD (reference group), DI, and II. Additionally, an odds ratio was calculated for allele I relative to D. This analysis assumes that the maternal and paternal alleles act multiplicatively on risk, so that, for example, the odds ratio associated with DI relative to DD is the product of the odds ratios of D and I (that is, the same as the odds ratio of I). Under this model the two alleles

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Allele and genotype frequencies at the ACE locus among demented and non-demented CFAS subjects — overall</th>
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<tbody>
<tr>
<td></td>
<td>Cases (%)</td>
</tr>
<tr>
<td>Allele</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>103 (43.6)</td>
</tr>
<tr>
<td>I</td>
<td>133 (56.4)</td>
</tr>
<tr>
<td>Genotype</td>
<td></td>
</tr>
<tr>
<td>DD</td>
<td>28 (23.7)</td>
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<tr>
<td>DI</td>
<td>47 (39.8)</td>
</tr>
<tr>
<td>II</td>
<td>43 (36.4)</td>
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</tbody>
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*Adjusted for age, sex, years in full time education, and APOE e4 carrier status (for genotype).
†Pooled estimate OR (95% CI) for Alzheimer’s disease.
genotype was back transformed \[\text{MMSE}_{\text{original}} = 31 - \exp(\text{mean education})\]. The mean transformed MMSE score of each ACE genotype, age, sex, and number of years in full time education was then compared using analysis of variance (cross adjusting for \[\text{MMSE}_{\text{transformed}} = \log_e(31 - \text{MMSE})\], pooled by genotype, and stratified by wave 3 MMSE score). The Kruskall Wallis test was used to compare the distributions of MMSE differences across the different ACE genotypes in the population based), which have looked into the impact of ACE on dementia in the general population. This is in contrast with most published studies (both clinic/necropsy based and population based), which may not reflect the population in which dementia occurs most frequently.

The MRC CFAS study uses AGECAT to diagnose dementia. It is a robust algorithm, with a high overall index of agreement \(\kappa = 0.82\). It is possible that the impact of ACE is greatest for AD pathology and may have less importance for the other processes that contribute to dementia in the general population. While we failed to find a significant effect of the ACE I allele on dementia risk, the point estimates suggest a dose dependent increase in risk (data not shown).

**RESULTS**

Table 1 shows the distribution of ACE genotype and allele frequencies for cases and controls, as well as crude and adjusted (for age, sex, years in full time education, and APOE4 carrier status) odds ratios. The distribution of ACE genotypes and alleles tended towards an over-representation of the I allele among cases versus the controls and risk appeared to be higher in II than DI subjects. However, all the confidence intervals included 1.0. Sex specific data did not show differences in ACE genotype and allele effects on dementia risk (data not shown).

The back transformed mean MMSE scores (see Methods) at wave 3 by ACE genotypes are: DD=25.5, DI=25.6, II=25.6. MMSE scores at the third wave were not significantly different between ACE genotypes \(F(2, df) = 0.1, p=0.9)\). We were interested in the effects of ACE genotypes on the rate of cognitive decline, as measured by the difference in MMSE scores between the initial and third assessment waves, in our entire sample. In one set of analyses, we compared the distribution of MMSE differences across ACE genotypes in the sample separated into four subgroups based on people’s MMSE scores at the prevalence wave (namely, 0 to 17, 18 to 21, 22 to 25, and 26 to 30). We adopted this strategy, since a given difference in MMSE scores over time would have a different meaning depending on the starting MMSE score. In another analysis, we looked at the distribution of MMSE difference across the different ACE genotypes among subjects scoring between 22 and 25 and between 26 and 30 on the MMSE at wave 3. This strategy was used to see whether ACE genotypes affected the rate of decline in people who were ostensibly non-demented throughout the study. In other words, we wanted to test if ACE affected the rate of cognitive decline before the onset of dementia.

**DISCUSSION**

The aim of this study was to investigate the impact of ACE on dementia in the general population. This is in contrast with most published studies (both clinic/necropsy based and population based), which have looked into the impact of ACE on AD risk specifically, and have tended to use younger samples which may not reflect the population in which dementia occurs most frequently.

The MRC CFAS study uses AGECAT to diagnose dementia. It is a robust algorithm, with a high overall index of agreement \(\kappa = 0.82\) with psychiatrists’ diagnoses in both the community and geriatric hospital settings (and excellent agreement \(\kappa = 0.82\)). It is possible that the impact of ACE is greatest for AD pathology and may have less importance for the other processes that contribute to dementia in the general population. While we failed to find a significant effect of the ACE I allele on dementia risk, the point estimates suggest a dose dependent increase in dementia risk consistent with results published in our meta-analysis.

While ACE does not appear to have a major effect on dementia/AD risk in the general population, it warrants further investigation. Larger samples are required before one can exclude small effects that may be operating at this locus for dementia/AD; in order to achieve 80% power to detect an odds ratio of 1.2, given 50% prevalence of the risk allele among

**Key points**

- The D/I polymorphism of the angiotensin-I converting enzyme (ACE) gene has been postulated to be associated with Alzheimer’s disease risk. It is crucial to understand how this genetic factor impacts on dementia in the general population, as well as among narrowly diagnosed, selected, patient groups.
- The ACE D/I polymorphism may have only very modest effects on dementia risk in the general population and appears not to affect cognitive decline in the elderly population.
- A study with larger sample sizes is needed to enable exclusion of any small effects at this locus on dementia in the general population.

**Figure 2**

Distribution of MMSE difference by ACE genotype, stratified by wave 3 MMSE score. (A) MMSE wave 3 score 26-30. DD=111, DI=189, II=119 \(\chi^2(2, df) = 0.513, p=0.8\). (B) MMSE wave 3 score 22-25. DD=65, DI=118, II=68 \(\chi^2(2, df) = 0.6, p=0.7\).
non-cases, we would need just under 400 cases and controls. Robust confirmation of an AD risk gene is valuable, even if the effect is small, as it would contribute to our understanding of AD pathology and furthermore may suggest potential therapeutic strategies.

ACKNOWLEDGEMENTS
This work was supported by the Medical Research Council. The authors thank the MRC CFAS respondents and their relatives for their participation in this long running project, and the MRC CFAS Internal Cambridge Advisory Group and Dr David Clayton for comments. AY is grateful to the Cambridge Overseas Trust and the European Dana for the Brain for funding. DCR is a Glaxo Wellcome Research Fellow.

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