Cognitive Impairment Before Intracerebral Hemorrhage Is Associated With Cerebral Amyloid Angiopathy

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Background and Purpose—Although the association between cerebral amyloid angiopathy (CAA) and cognitive impairment is increasingly recognized, it is not clear whether this is because of the impact of recurrent intracerebral hemorrhage (ICH) events, disruptions caused by cerebral small vessel damage, or both. We investigated this by considering whether cognitive impairment before ICH was associated with neuroimaging features of CAA on magnetic resonance imaging.

Methods—We studied 166 patients with neuroimaging-confirmed ICH recruited to a prospective multicentre observational study. Preexisting cognitive impairment was determined using the Informant Questionnaire on Cognitive Decline in the Elderly (IQQCODE). Magnetic resonance imaging markers of cerebral small vessel disease, including CAA, were rated by trained observers according to consensus guidelines.

Results—The prevalence of cognitive impairment before ICH was 24.7% (n=41) and, in adjusted analyses, was associated with fulfilling the modified Boston criteria for probable CAA at presentation (odds ratio, 4.01; 95% confidence interval, 1.53–10.51; P=0.005) and a higher composite CAA score (for each point increase, odds ratio, 1.42; 95% confidence interval, 1.03–1.97; P=0.033). We also found independent associations between pre-ICH cognitive decline and the presence of cortical superficial siderosis, strictly lobar microbleeds, and lobar ICH location, but not with other neuroimaging markers, or a composite small vessel disease score.

Conclusions—CAA (defined using magnetic resonance imaging markers) is associated with cognitive decline before symptomatic ICH. This provides evidence that small vessel disruption in CAA makes an independent contribution to cognitive impairment, in addition to effects due to brain injury caused directly by ICH.

Clinical Trial Registration—URL: https://www.clinicaltrials.gov. Unique identifier: NCT02513316.

Key Words: cerebral amyloid angiopathy ■ cerebral hemorrhage ■ cerebral small vessel diseases ■ cognitive dysfunction ■ prevalence ■ siderosis

Although the associations between dementia and ischemic stroke have been comprehensively described,1 fewer data are available for spontaneous intracerebral hemorrhage (ICH), in part because of its high case fatality.2,3 Cognitive impairment often develops in survivors of ICH who were previously dementia free, particularly if the ICH is lobar, and has been associated with baseline neuroimaging markers of cerebral amyloid angiopathy (CAA).2 In those presenting with ICH, cognitive impairment before the event is common, with an estimated pooled incidence of 16.7%,4 suggesting that the underlying neurovascular and neuropathological processes that result in cognitive impairment after ICH might already be present at the time of initial presentation with ICH.4,5 However, it is not clear to what extent subsequent cognitive impairment after ICH is mediated by direct damage...
from the index ICH, the effects of recurrent ICH, or the impact of the underlying small vessel disease (SVD)\(^2\); understanding the contribution of these mechanisms is potentially important in developing rational dementia prevention strategies.

We therefore investigated whether neuroimaging evidence of CAA (specifically, meeting the modified Boston criteria for probable CAA\(^2\) at presentation, and increases in a composite CAA score\(^3\)) was associated with the presence of cognitive impairment before ICH. We then performed further analyses investigating the associations between individual magnetic resonance imaging (MRI) neuroimaging markers of SVD and cognitive impairment before ICH.

### Materials and Methods

#### Patient Selection

We included patients recruited to a prospective multicentre observational cohort study of symptomatic patients with confirmed ICH (The Clinical Relevance of Microbleeds In Stroke Study; CROMIS-2). Those aged ≥18 years with an ICH confirmed on brain imaging (either computed tomography or MRI) were eligible, providing that there was no evidence that the ICH was because of an underlying structural cause or secondary to head trauma. This study has been preregistered, and the full details of the study protocol have been published previously.\(^4\) The study was approved by the National Research Ethics Service (IRAS reference 10/H0716/61). Written informed consent was obtained from each patient. The primary and substudy analyses for the CROMIS-2 study are ongoing; once all of these analyses are completed, the CROMIS-2 Steering Committee will consider applications from other researchers for access to anonymized source data.

The Informant Questionnaire for Cognitive Decline in the Elderly (IQCODE) is a validated questionnaire given to a patient’s family member or caregiver which aims to establish whether there have been specific changes in cognitive and functional performance over the preceding 10-year time period.\(^5\) \(^11\) Specifically, the informant was asked to compare the patient’s performance from 10 years ago with their performance just before their stroke. The 16-item IQCODE was requested for all participants (score range, 1.0–5.0); this version of the IQCODE has been reported to have similar accuracy to the original 26-item version.\(^6\) \(^11\) We defined pre-ICH cognitive impairment as an IQCODE score of ≥3.3, based on previously reported pooled specificity and sensitivity values for detecting cognitive impairment from a meta-analysis investigating IQCODE accuracy in a general hospital setting.\(^10\)

For inclusion in the final analysis, it was necessary for patients to have an IQCODE from the time of their admission, together with the MRI sequences needed for imaging analysis (described below).

#### Imaging Acquisition and Analysis

Imaging was undertaken at each study center according to local protocols, and all brain imaging performed as part of the participant’s standard clinical care was sent to the study’s coordinating center in anonymized DICOM format.

Imaging analysis was performed by 2 clinical research associates (D.W., G.B.) and 2 MSc students (K.O.-B.A, S.L.), all of whom were trained in neuroimaging rating and blinded to the participant clinical details. All structural imaging markers of cerebral SVD were rated in accordance with the Standards for Reporting Vascular Changes on Neuroimaging consensus criteria.\(^12\) Only those with an available MRI and all of the necessary sequences for cerebral SVD rating (ie, axial T2, axial, and coronal fluid-attenuated inversion recovery (FLAIR), and a blood-sensitive sequence) were included in the neuroimaging marker analysis.

Lacunes were identified and counted (D.W.) on T2 and FLAIR sequences.\(^13\) Cerebral microbleeds were rated (D.W.) using blood-sensitive (T2\(^*\) weighted or susceptibility-weighted images) sequences and the validated Microbleed Anatomical Rating Scale.\(^14\) MRI-visible perivascular spaces (PVS) in the centrum semiovale (CSO-PVS) and basal ganglia (BG-PVS) were defined and rated (G.B.) on T2 and FLAIR sequences using a validated 4-point visual rating scale\(^14,15\) on a single predefined slice (first slice above the anterior commissure for the basal ganglia, and the first slice above the level of the lateral ventricles for the centrum semiovale). The hemisphere contralateral to the ICH was preferentially rated. White matter hyperintensities (WMH; also termed leukoaraiosis) were rated (K.O.-B.A.) on T2 and FLAIR sequences using the Fazekas scale.\(^16,17\) Cortical superficial siderosis (cSS) was identified on blood-sensitive sequences and classified (D.W.) as either focal (involving ≤3 sulci) or disseminated (involving ≥4 sulci), in keeping with previously described terminology.\(^18\) Medial temporal atrophy (MTA) was rated (G.B.) on T1 or FLAIR coronal images using the Scheltens visual scale.\(^19,20\) Global cortical atrophy (GCA) was rated (G.B.) using the Pasquier scale on axial T1 or FLAIR images. In cases where these sequences were not available, T2 images were used. For both MTA and GCA, there was good agreement between all sequences used (MTA k=0.77; GCA k=1.00). For both MTA and GCA, the hemisphere contralateral to the ICH was preferentially rated.

ICH location was defined as infratentorial, deep, or lobar, with the latter in cortical or cortical–subcortical regions and not involving any of the deep grey matter structures. Hematoma volume was calculated (S.L.) using a previously described validated semiautomated planimetric method.\(^21\)

A clinico-radiological diagnosis of probable CAA was based on meeting the modified Boston criteria.\(^2\)

The CAA score was calculated from a previously described 6-point scale.\(^2\) This scale awards 1 point for CSO-PVS rating of

### Table 1. Baseline Demographic and Clinical Characteristics

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>IQCODE ≤3.3</th>
<th>IQCODE &gt;3.3</th>
<th>Mean or Proportion Difference (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (%)</td>
<td>166</td>
<td>125 (75.3)</td>
<td>41 (24.7)</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Age, y, mean (SD)</td>
<td>68.9 (12.9)</td>
<td>67.0 (13.1)</td>
<td>74.5 (10.9)</td>
<td>−7.5 (−11.9 to −3.0)</td>
<td>0.0012</td>
</tr>
<tr>
<td>Sex, male, n (%)</td>
<td>104 (62.7)</td>
<td>76 (60.8)</td>
<td>28 (68.3)</td>
<td>−7.5 (−24.1 to 9.1)</td>
<td>0.389</td>
</tr>
<tr>
<td>Hypertension, presence, n (%)</td>
<td>96 (58.1)</td>
<td>75 (60.5)</td>
<td>21 (51.2)</td>
<td>9.3 (−8.3 to 26.8)</td>
<td>0.297</td>
</tr>
<tr>
<td>Hypercholesterolemia, presence, n (%)</td>
<td>58 (35.8)</td>
<td>37 (30.6)</td>
<td>21 (51.2)</td>
<td>−20.6 (−38.0 to −3.0)</td>
<td>0.017</td>
</tr>
<tr>
<td>Diabetes mellitus, presence, n (%)</td>
<td>20 (12.1)</td>
<td>11 (8.9)</td>
<td>9 (22.0)</td>
<td>−13.1 (−26.7 to 0.5)</td>
<td>0.026</td>
</tr>
<tr>
<td>Atrial fibrillation, presence, n (%)</td>
<td>33 (21.3)</td>
<td>22 (19.0)</td>
<td>11 (28.2)</td>
<td>−9.2 (−25.1 to 6.6)</td>
<td>0.223</td>
</tr>
<tr>
<td>Previous ischemic stroke or TIA, presence, n (%)</td>
<td>29 (18.1)</td>
<td>18 (14.8)</td>
<td>11 (29.0)</td>
<td>−14.2 (−29.9 to 1.5)</td>
<td>0.047</td>
</tr>
<tr>
<td>Previous ICH, presence, n (%)</td>
<td>9 (5.5)</td>
<td>4 (3.2)</td>
<td>5 (12.5)</td>
<td>−9.3 (−20.0 to 1.4)</td>
<td>0.025</td>
</tr>
</tbody>
</table>

Percentage values were calculated using the total number of patients for whom data was available as the denominator. P values are from χ\(^2\) and independent t tests. Proportion differences and their confidence intervals are given as percentages. CI indicates confidence intervals; ICH, intracerebral hemorrhage; IQCODE, Informant Questionnaire on Cognitive Decline in the Elderly; and TIA, transient ischemic attack.
frequent-to-severe grades (ie, presence of >20 CSO-PVS) and WMH that is either Fazekas grade 3 if periventricular, or Fazekas grade ≥2 if deep.22 Additional points are awarded for the presence of lobar microbleeds (1 point if 2–4 are present; 2 points if there are ≥5) and cSS (1 point if focal; 2 points if disseminated).7

The SVD score was determined using a previously described 4-point scale.22,23 This scale awards 1 point for the presence of lacunes, microbleeds, BG-PVS rating of moderate-to-severe grades (ie, presence of >10 BG-PVS), and WMH that is either Fazekas grade 3 if periventricular or Fazekas grade ≥2 if deep.22

Statistics
We investigated for selection bias within our final cohort by comparing the characteristics of people with appropriate MRI and those without. IQCODE was dichotomized using a cutoff of 3.3, and base-line characteristics were compared (Table 1) for those with scores >3.3 (ie, with cognitive impairment) and those with scores ≤3.3. Continuous data were reviewed for normality, and if normally distributed we used the independent t test. Where continuous variables were not normally distributed, we used the (nonparametric) Mann-Whitney U test. We used the χ² tests for categorical variables. The independent t test (normally distributed continuous data) and the 2-sample test of proportion (categorical data) were used to compare means and proportions, respectively.

Univariate comparisons were used to identify potential confounders for inclusion in the multivariable models; all variables with P<0.05 were included. We then performed adjusted logistic regression analyses, adjusting for significant associations identified in univariate analyses (Table 2). In further analyses (Table 3), we investigated associations with other neuroimaging markers suggestive of CAA (the presence of strictly lobar microbleeds, and presentation with lobar ICH), as well as a composite SVD score and its component elements. In these analyses, each neuroimaging marker was considered individually (ie, each adjusted model included only 1 neuroimaging marker at a time). Given that these analyses were exploratory, we did not make an adjustment for multiple testing.

Statistical analysis was performed (G.B.) using Stata (Version 11.2).

Results

Cohort Characteristics

The demographic and imaging characteristics of those included (n=166) are shown in Table 1. Patients without MRI (n=588) and those with MRI but with missing or uninterpretable sequences (n=43) were excluded (online-only Data Supplement). When compared with the excluded patients (online-only Data Supplement), those included were younger (mean, 68.9 versus 75.0 years; P<0.0001), less likely to have hypertension (58.2% versus 70.9%; P=0.002), hypercholesterolemia (35.8% versus 47.9%; P=0.006), diabetes mellitus (12.1% versus 19.8%; P=0.024), and atrial fibrillation (12.3% versus 43.5%; P<0.0001), and more likely to have previously had an ischemic stroke or transient ischemic attack (24.7% versus 18.1%; P=0.081), lower Glasgow Coma Scale at presentation (interquartile range, 13–15 versus 14–15; P=0.003) and pre-ICH cognitive decline (38.2% versus 24.7%; P=0.001).

When comparing those with and without pre-ICH cognitive decline, those with (n=41) were older (mean difference, 18.1%; P=0.006), diabetes mellitus (35.8% versus 47.9%; P=0.024), and atrial fibrillation (12.3% versus 43.5%; P<0.0001), and more likely to have previously had an ischemic stroke or transient ischemic attack (24.7% versus 18.1%; P=0.081), lower Glasgow Coma Scale at presentation (interquartile range, 13–15 versus 14–15; P=0.003) and pre-ICH cognitive decline (38.2% versus 24.7%; P=0.001).

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Our results show that a composite CAA score has a per-
time of ICH are associated with later progression to demen-
or without macrohemorrhage). We found a strong association
with milder CAA (including those not fulfilling Boston criteria,
helpon whether such a score might be useful in patients
between cSS and pre-ICH cognitive impairment, suggest-
ging that leptomeningeal hemorrhage, rather than parenchymal
microbleeds, might be an especially important pathological
process impairing cognition in CAA. Our findings also con-
tribute to our understanding of the mechanisms by which CAA
disrupts cognition, which include hematomata damage (via direct
effects on cortical integrity and function3) and small vessel
mechanisms. The latter may include effects on brain network
efficiency,25 which correlates with cognitive performance and
shows disturbances in the non-ICH hemisphere.26 Our finding
that CAA is associated with cognitive impairment before ICH
shows that hematomata damage cannot be the only mechanism
contributing to cognitive disruption and supports the hypothesis
that small vessel mechanisms are important.

A further possibility is that cognitive impairment before
ICH is because of coincident Alzheimer’s disease.4 Although
the co-occurrence of CAA and Alzheimer’s disease pathology
is well recognized,27 CAA seems to have a cognitive profile
distinct from that seen in Alzheimer’s disease, characterized
primarily by deficits in processing speed and executive func-
tion.28,29 Recent neuropathological work30 found that CAA
makes an independent contribution to cognitive performance in
Alzheimer’s disease. Together, this evidence suggests that CAA
has a specific neurovascular impact on cognitive performance,
independent of coexistent Alzheimer’s pathology. Although
we did not find an association between MTA or GCA (as puta-
tive imaging markers of Alzheimer’s pathology31) and pre-ICH
cognitive impairment, we acknowledge that our sample size is
small and so we cannot rule out missing subtle effects.

The main strength of this study is our detailed neuroimaging
description of the structural markers of cerebral SVD in the con-
text of pre-ICH cognitive decline, in a richly phenotyped pro-
spective nationwide cohort of patients. However, our work also
has limitations. Those included in our study were younger, with
fewer comorbidities and a lower IQCODE than those who did
not have an interpretable MRI; additionally, we acknowledge
that a suspicion of CAA could increase the likelihood of an MRI
being performed (50% of our included patients presented with
lobar ICH), and so our final cohort might not be representative
of those presenting with a spontaneous ICH to an acute stroke
service. Brain imaging at each study center was completed
according to local protocols, and so there are unavoidable varia-
tions in the nature and manner of the sequences obtained, which
could influence our results. In particular, the use of suscepti-
bility-weighted versus T2*-weighted gradient echo sequences
may result different microbleed counts, as the former is more
sensitive to this; we did not adjust for this in our analyses. There
are inherent limitations of using the IQCODE, including varia-
tions in the threshold used to define cognitive impairment and
the lack of validation against a reference standard for prestroke
cognitive impairment. Finally, we acknowledge that our study
size is small, and so our results should be interpreted cautiously,
particularly the adjusted analyses. As detailed, we chose not to
apply an adjustment for multiple testing in order not to miss
potential associations of interest. In addition, although our
study is powered to detect moderate effect sizes, it may have
missed smaller effects.

Cognitive impairment before ICH is common and is asso-
ciated with imaging findings consistent with an important
contribution from CAA. This suggests that any future strategy
aiming to reduce the impact of poststroke dementia in ICH will

**Associations With Pre-ICH Cognitive Decline: Univariate and Multivariate Analyses**

Univariate logistic regression analyses showed that pre-ICH
cognitive decline was associated with meeting the modified
Boston criteria for probable CAA at presentation and increas-
ing CAA score (Table 2). In our multivariable analysis, we
adjusted for age at event, hypercholesterolemia, presence
of diabetes mellitus, previous ischemic stroke or transient
ischemic attack, and previous ICH, which were statistically
significant in univariate analyses (Table 1). Meeting the modi-
fied Boston criteria for probable CAA at presentation (odds
ratio [OR], 4.01; 95% confidence interval [CI], 1.53–10.51; P
=0.005) and increasing CAA score (for each point increase,
OR, 1.42; 95% CI, 1.03–1.97; P=0.033) remained associated
with pre-ICH cognitive decline (Table 2).

We then performed further analyses investigating the asso-
ciations between individual neuroimaging markers of SVD
and cognitive impairment before ICH. In univariable analyses
(Table 3), we identified associations between pre-ICH cogni-
tive decline and increasing SVD score, WMH, the presence
of cSS, presence of strictly lobar microbleeds, and lobar ICH
at presentation. In analyses adjusted for clinical and demo-
ographic variables identified in the univariate analysis (as above),
the presence of cSS (OR, 4.08; 95% CI, 1.28–13.05; P=0.018),
strictly lobar microbleeds (OR, 2.47; 95% CI, 0.95–6.37;
P=0.062), and lobar ICH at presentation (OR, 2.29; 95% CI,
0.99–5.31; P=0.053) showed associations with pre-ICH cog-
nitive impairment. The previous associations with increasing
SVD score and WMH were no longer statistically significant,
although for WMH a large effect size remained (OR, 2.03).

**Discussion**

Our main finding is that MRI neuroimaging markers
of CAA are associated with pre-ICH cognitive impairment.
This suggests that cognitive impairment in CAA is not only
because of brain injury caused directly by ICH but also inde-
pendently related to the underlying small vessel disruption
associated with CAA.

Our findings add to growing evidence that CAA plays an
important role in the development of cognitive impairment and
dementia in those with ICH. The prevalence of pre-ICH demen-
tia in lobar ICH is near double that in deep ICH,24 and structural
imaging markers of CAA (cSS, cerebral microbleeds) present
at the time of ICH are associated with later progression to demen-
tia.2 Our results show that a composite CAA score has a per
point association with cognitive decline; further studies could
help establish whether such a score might be useful in patients
with milder CAA (including those not fulfilling Boston criteria,
or without macrohemorrhage). We found a strong association
between cSS and pre-ICH cognitive impairment, suggest-
ing that leptomeningeal hemorrhage, rather than parenchymal
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7.5 years; P<0.0012) and more likely to have hypercholes-
terolemia (51.2% versus 30.6%; P=0.017), diabetes mellitus
(22.0% versus 8.9%; P=0.026), previous ischemic stroke or
transient ischemic attack (29.0% versus 14.8%; P=0.047), and
previous ICH (12.5% versus 3.2%; P=0.025).
need to extend beyond stroke prevention and include strategies that address the small vessel impact of CAA. Further work on the natural history of when and how CAA may influence an individual’s cognitive profile is a priority for future research.

Appendix

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Sources of Funding

The CROMIS-2 study is funded by the Stroke Association and British Heart Foundation. G. Banerjee receives funding from the Rosetrees Trust. Dr Ambler receives funding from the National Institute for Health Research University College London Hospitals Biomedical Research Centre. Dr Al-Shahi Salman is funded by an Medical Research Council senior clinical fellowship. M.M., Brown’s Chair in Stroke Medicine is supported by the Reta Lila Weston Trust for Stroke Medicine is supported by the Reta Lila Weston Trust. Dr Ambler receives funding from the Stroke Association, the British Heart Foundation, and the Rosetrees Trust. This work was undertaken at University College London Hospitals and University College London which receive a proportion of funding from the Department of Health National Institute for Health Research (NIHR) Biomedical Research Centres funding scheme.

Disclosures

Dr Cohen has received institutional research support from Bayer; honoraria for lectures and an Advisory Board from Bayer, diverted to a local charity; and travel/accommodation expenses for participation in scientific meetings covered by Bayer and Boehringer Ingelheim. G.H.Y. Lip has served as a consultant for Bayer, Astellas, Merck, AstraZeneca, Sanofi, BMS/Pfizer, Biotronik, Portola, and Boehringer Ingelheim and has been on the speakers’ bureau for Bayer, BMS/Pfizer, Boehringer Ingelheim, and Sanofi-Aventis. The other authors report no conflicts.

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*Stroke*. 2018;49:40-45; originally published online December 15, 2017;
doi: 10.1161/STROKEAHA.117.019409

*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0039-2499. Online ISSN: 1524-4628

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### Supplementary Table

Baseline characteristics of those included and excluded subjects. P values are from chi-squared and independent t-tests, except where indicated († for Mann-Whitney U test).

<table>
<thead>
<tr>
<th></th>
<th>All with IQCODE</th>
<th>Included in final analysis</th>
<th>Excluded</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>797</td>
<td>166</td>
<td>631</td>
<td>-</td>
</tr>
<tr>
<td>Age, years, mean (SD)</td>
<td>73.7 (12.1)</td>
<td>68.9 (12.9)</td>
<td>75.0 (11.6)</td>
<td>&lt;0.00001</td>
</tr>
<tr>
<td>Sex, female, n (%)</td>
<td>328 (41.2)</td>
<td>62 (37.4)</td>
<td>266 (42.2)</td>
<td>0.263</td>
</tr>
<tr>
<td>Hypertension, presence, n (%)</td>
<td>539 (68.2)</td>
<td>96 (58.2)</td>
<td>443 (70.9)</td>
<td>0.002</td>
</tr>
<tr>
<td>Hypercholesterolaemia, presence, n (%)</td>
<td>351 (45.4)</td>
<td>58 (35.8)</td>
<td>293 (47.9)</td>
<td>0.006</td>
</tr>
<tr>
<td>Diabetes mellitus, presence, n (%)</td>
<td>144 (18.2)</td>
<td>20 (12.1)</td>
<td>124 (19.8)</td>
<td>0.024</td>
</tr>
<tr>
<td>Atrial fibrillation, presence, n (%)</td>
<td>285 (38.8)</td>
<td>33 (21.3)</td>
<td>252 (43.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Previous ischaemic stroke or TIA, presence, n (%)</td>
<td>176 (23.3)</td>
<td>29 (18.1)</td>
<td>147 (24.7)</td>
<td>0.081</td>
</tr>
<tr>
<td>Previous intracerebral haemorrhage, presence, n (%)</td>
<td>38 (4.9)</td>
<td>9 (5.5)</td>
<td>29 (4.7)</td>
<td>0.683</td>
</tr>
<tr>
<td>GCS, median (IQR)</td>
<td>15 (14 – 15)</td>
<td>15 (14 – 15)</td>
<td>15 (13 – 15)</td>
<td>0.003†</td>
</tr>
<tr>
<td>IQCODE, median (IQR)</td>
<td>3.12 (3.0 – 3.5)</td>
<td>3.0 (3.0 – 3.3)</td>
<td>3.13 (3.0 – 3.5)</td>
<td>&lt;0.00001†</td>
</tr>
<tr>
<td>IQCODE &gt; 3.3</td>
<td>282 (35.4)</td>
<td>41 (24.7)</td>
<td>241 (38.2)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Abbreviations: GCS, Glasgow Coma Scale; IQCODE, Informant Questionnaire on Cognitive Decline in the Elderly; IQR, interquartile range; SD, standard deviation; TIA, transient ischaemic attack.
Supplementary Figure
Description of the study population.
Only those with an available MRI and the necessary sequences for cerebral small vessel disease rating (i.e. axial T2, axial and/or coronal FLAIR, and a blood sensitive sequence) were included in the neuroimaging marker analysis.

Abbreviations: CROMIS-2, Clinical Relevance of Microbleeds in Stroke Study; ICH, intracerebral haemorrhage; IQCODE, Informant Questionnaire on Cognitive Decline in the Elderly.
STROBE Statement—checklist of items that should be included in reports of observational studies

<table>
<thead>
<tr>
<th>Item No</th>
<th>Recommendation</th>
</tr>
</thead>
</table>
| **Title and abstract** | 1 | ☒ (a) Indicate the study’s design with a commonly used term in the title or the abstract  
( ) (b) Provide in the abstract an informative and balanced summary of what was done and what was found |
| **Introduction** | | |
| **Background/rationale** | 2 | ☒ Explain the scientific background and rationale for the investigation being reported |
| **Objectives** | 3 | ☒ State specific objectives, including any prespecified hypotheses |
| **Methods** | | |
| **Study design** | 4 | ☒ Present key elements of study design early in the paper |
| **Setting** | 5 | ☒ Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection |
| **Participants** | 6 | (a) **Cohort study**—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up  
( ) **Case-control study**—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls  
**Cross-sectional study**—Give the eligibility criteria, and the sources and methods of selection of participants  
(b) **Cohort study**—For matched studies, give matching criteria and number of exposed and unexposed  
( ) **Case-control study**—For matched studies, give matching criteria and the number of controls per case |
| **Variables** | 7 | ☒ Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable |
| **Data sources/measurement** | 8* | ☒ For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group |
| **Bias** | 9 | ☒ Describe any efforts to address potential sources of bias |
| **Study size** | 10 | ☒ Explain how the study size was arrived at |
| **Quantitative variables** | 11 | ☒ Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why |
| **Statistical methods** | 12 | (a) ☒ Describe all statistical methods, including those used to control for confounding  
( ) (b) Describe any methods used to examine subgroups and interactions  
( ) (c) Explain how missing data were addressed  
(d) **Cohort study**—If applicable, explain how loss to follow-up was addressed  
( ) **Case-control study**—If applicable, explain how matching of cases and controls was addressed  
**Cross-sectional study**—If applicable, describe analytical methods taking account of sampling strategy  
( ) (e) Describe any sensitivity analyses |

Continued on next page
## Results

<table>
<thead>
<tr>
<th>Participants</th>
<th>13*</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed</td>
<td></td>
</tr>
<tr>
<td>(b) Give reasons for non-participation at each stage</td>
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<tr>
<td>(c) Consider use of a flow diagram</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Descriptive data</th>
<th>14*</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders</td>
<td></td>
</tr>
<tr>
<td>(b) Indicate number of participants with missing data for each variable of interest</td>
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<tr>
<td>(c) Cohort study—Summarise follow-up time (eg, average and total amount)</td>
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</table>

<table>
<thead>
<tr>
<th>Outcome data</th>
<th>15*</th>
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</thead>
<tbody>
<tr>
<td>Cohort study—Report numbers of outcome events or summary measures over time</td>
<td></td>
</tr>
<tr>
<td>Case-control study—Report numbers in each exposure category, or summary measures of exposure</td>
<td></td>
</tr>
<tr>
<td>Cross-sectional study—Report numbers of outcome events or summary measures</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Main results</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included</td>
<td></td>
</tr>
<tr>
<td>(b) Report category boundaries when continuous variables were categorized</td>
<td></td>
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<tr>
<td>(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Other analyses</th>
<th>17</th>
</tr>
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<tbody>
<tr>
<td>Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses</td>
<td></td>
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</tbody>
</table>

## Discussion

<table>
<thead>
<tr>
<th>Key results</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summarise key results with reference to study objectives</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Limitations</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias</td>
<td></td>
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</tbody>
</table>

<table>
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<tr>
<th>Interpretation</th>
<th>20</th>
</tr>
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<tbody>
<tr>
<td>Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence</td>
<td></td>
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</tbody>
</table>

<table>
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<tr>
<th>Generalisability</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discuss the generalisability (external validity) of the study results</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Other information</th>
<th>22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based</td>
<td></td>
</tr>
</tbody>
</table>

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.