Primary familial brain calcifications (PFBC) are a heterogeneous group of rare autosomal dominant disorders. Mutations in the PDGFB gene are the second most common cause of PFBC. A model for PDGFB-associated PFBC, hypomorphic PDGFB<sup>ret/ret</sup> mouse, displays impaired blood-brain barrier (BBB), progressive brain calcifications and increased flux of the oxysterol 24S-hydroxycholesterol from the brain into the circulation. Only 8 families and 2 sporadic cases with PDGFB mutations have been identified so far, one of them a Swedish-Finnish family previously described as F13. Very little is known about the natural history of PDGFB-associated PFBC. Here, we provide a comprehensive long-term follow-up of the F13 family.

**Methods.** The study was approved by the local ethics committee. The F13 family harbors the c.26T>G (L9R) mutation in the PDGFB gene (pedigree in figure e-1 at Neurology.org/ng). Participants consented to physical examination, cognitive assessment, radiologic studies, and biochemical analyses. Biomarkers for neuronal and BBB damage in plasma and CSF, physical examination, cognitive assessment, radiologic studies, and biochemical analyses. Biomarkers for neuronal and BBB damage in plasma and CSF, including oxysterols, were analyzed at a single point.

**Imaging.** Dual-energy computed scans and brain MRIs were performed according to details provided in appendix e-1. The degree of calcification was measured with the Total Calcification Score (TCS). We also used software for image coregistration (Integrated Registration, GE AW server). In brief, the region of interest placed on the baseline CT is propagated in a semiautomated fashion to the follow-up examinations. Changes in Hounsfield units are measured as relative and absolute values.

**Results.** The progression of clinical and radiologic features is summarized in appendix e-1. Mean time of clinical follow-up was 5.5 years, and the time between 2 successive brain CT scans was 4.8 years.

**Clinical features.** In brief, all the affected had a diagnosis of migraine with aura and displayed subtle movement disorders and mild eye movement abnormalities. Patient III:1, the proband, was diagnosed with mild language impairment (anomia, paraphasias, and impaired repetition ability) and cognitive deficits (reduced working memory) and has developed chorea and posturing. Her father, II:3, has developed mild motor features and impaired tandem gait. Patient III:2 has a history of mixed substance abuse; he did not progress radiologically but has progressive chorea. Patient III:3 has mild postural tremor, chorea, and significant cognitive impairment (anomia, visuospatial deficits, reduced working memory and information processing speed). The main phenotype features are displayed in videos 1–4 and summarized in tables e-1 to e-4.

**Discussion.** Brain calcifications are progressive in 3 individuals from the L9R family. All the 4 participants display some degree of subtle but progressive motor features and mild eye movement abnormalities. Chorea emerged in 2 patients of generation III (III:1 and III:3) and was progressive in another (III:2). Besides chorea, patient III:1 had a mild language impairment and reduced working memory. Patient III:3 has greater cognitive deficits than the index case (III:1).

Progressive calcifications are mentioned in only one previous PDGFB mutation; however, TCS was not provided. The progressive features and elevated CSF-NfL level in one of the cases support the notion.
that PDGFB-associated PFBC is a neurodegenerative disease. Unexpectedly, only 1 of the 3 patients had signs of an affected BBB. Likewise, the CSF level of the steroid acid 7α-hydroxyl-3-oxo-4-cholestenoic acid, a putative marker of increased BBB permeability, was normal in all the 3 patients. This is in contrast with the results in the hypomorphic PDGFB^{ret/ret} mouse. Recent work in this model has demonstrated a more intact BBB in areas prone to calcifications.

The coregistration method we tested here found evidence of progression in 3 patients and the TCS method in 2. Overcoming the ceiling effect of TCS is the main advantage of coregistration. Small sample size is the main limitation of our longitudinal follow-up.

Two levels of penetrance exist in PFBC: one radiologic and one clinical. The radiologic penetrance in PDGFB mutations is high, but, despite calcifications, some individuals are asymptomatic. Reduced clinical
penetrance has been reported in 3 other PDGFB mutations despite the presence of brain calcifications (table e-11).

When brain calcifications will appear and whether their progression will plateau is unknown. Future work has to determine whether our findings can be generalized to other cases of PDGFB-associated PFBC or other forms of PFBC.

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