Letter to Blood

Silent Cerebral Infarcts and Cerebral Aneurysms are Prevalent in Adults with Sickle Cell Anemia

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Running title: Silent Cerebral Infarcts in Adult SCA
Silent cerebral infarcts (SCI) are the most commonly recognized cause of neurological injury in patients with sickle cell anemia (SCA), identified in at least 20% of children. In children with SCA, SCI are associated with an average five full-scale IQ point decrement, poor academic performance and future overt strokes. Recently, Bernaudin et al. reported that in children with SCA, the cumulative risk for SCI was 19.2% by age 8 years, 32.4% by age 14 years, and 39.1% by age 18 years. Very little is known about the prevalence of SCI in adults with SCA. We tested the hypothesis that the prevalence of SCI was significantly greater than 39% in patients >18-years-old with SCA.

Due to the high, age-dependent prevalence of SCI in children and adolescents with SCA, associated deficits in neuropsychometric performance, the association of SCI with future overt stroke and the impact of these associated morbidities on health care outcomes in adults with SCA, including adherence to complex instructions associated with management of chronic illness, we elected to obtain, as part of routine clinical practice, magnetic resonance imaging (MRI) and magnetic resonance angiography (MRA) of the brain in adults with SCA. If SCI or cerebral vasculopathy is found via neuroimaging, we refer these adults for cognitive testing, neurology consultation or both. We completed a retrospective chart review of adults with SCA (HbSS or Sβ0 thalassemia) followed in the comprehensive sickle cell disease clinic, with surveillance MRI and MRA of the brain performed as part of standard-of-care assessment for SCI from 2011-2013. The cerebral MRIs and MRAs were re-reviewed by two board-certified neuroradiologists for the purpose of this study. Consensus findings were recorded including presence of cerebral infarcts (≥3mm on T2-weighted images in two imaging planes), intracerebral hemorrhage, aneurysms and cerebral vasculopathy according to prior established criteria for MRI and MRA. If no neurological concerns were reported in the medical record and neurological exam was normal, infarcts were judged to be silent. STATA version 13 (StataCorporation, College Station, TX) was used for all analyses. Patient characteristics were described by median and interquartile range (IQR) for continuous measures and by number and percent for categorical measures. A two-sided p-value ≤0.05 was considered statistically significant. This study was approved by the Vanderbilt University Institutional Review Board as a retrospective cohort analysis.

The study population included 121 adults with SCA (HbSS or Sβ0 thalassemia) out of approximately 200 individuals with sickle cell disease that were followed in the clinic. Of these 121 individuals, 69 unselected adults underwent neuroimaging with brain MRI. Nine adults with SCA and overt strokes were excluded. The final study population included 60 adults with SCA and neuroimaging. Of note, a total of 52 individuals were excluded because they did not have neuroimaging, primarily because of failure to keep scheduled appointments during the study time period, insurance coverage issues, and implanted devices that were contraindications for MRI. There were no significant differences between those with and without neuroimaging with regards to age, gender, genotype, median hemoglobin, reticulocyte count or number of hospitalizations. However, those without neuroimaging were more likely to be on hydroxyurea compared to the imaging group (81% vs 63% on hydroxyurea; p=0.043), but were not more likely to be receiving chronic transfusion therapy (16% vs 19%; p=0.668). Of the 60 adults with imaging, 48% were male, median age 30 years (IQR: 22-35 years), all had MRI and MRA of the brain. SCI were present in 53% (n=32) of the adults with SCA; 37% with SCI (22 of 60) had more than one lesion. When compared to the Bernaudin report of 39% with SCI by age 18, our finding of a prevalence of 53% SCI in an unselected adult cohort with SCA, at a median age of 30 years is significantly different than the younger cohort (X² = 3.75; p=0.05).

MRA of the brain was of adequate quality to assess for vascular disease or aneurysm in 55 patients. Incidental findings include microhemorrhages in five participants (9%); of these five, four also had SCI present on MRI. Unruptured saccular aneurysms were identified in 9% (five of 55 patients). The aneurysms were <5mm in size (Table). Significant cerebral vasculopathy was not identified. We note that
of the adults excluded due to the presence of overt stroke, five of nine had moyamoya-type cerebral vasculopathy.

For the first time, we have described the prevalence of SCI in an unselected group of adults with SCA, occurring in at least 50%. Based on prior work by Bernaudin et al., we had anticipated the rate of SCI to be approximately 40%, but our recent findings support the hypothesis that the incidence of new SCI in patients with SCA does not attenuate in adulthood (Figure).

The saccular aneurysm prevalence of 9% in a relatively young adult cohort (median age 30 years) confirms that adults with SCA may have a higher prevalence of cerebral aneurysms than the general population (reported between 1.8% and 3.2%). The natural history of saccular aneurysm in SCA is unknown, however, in the general population, cigarette smoking, size of the unruptured intracranial aneurysm, hypertension, aneurysm location, and age have been implicated in aneurysmal rupture. No consensus exists on the influence of these reported risk factors.

The high prevalence of SCI (53%) and saccular aneurysms (9%) in adults with SCA provide evidence of both a morbid and pre-morbid condition that may warrant medical and/or neurosurgical intervention in this high-risk population. The impact of SCI on cognitive function in children is well recognized, and the recently reported association of anemia and age with poor cognitive performance in adults with SCA may underlie some of the cognitive challenges observed in adults with SCA, such as low employment or changes in treatment patterns after transition to adult care. Vichinsky et al. evaluated cognition in 141 young adults with SCA; 13% had lacunar infarcts defined as ≥5 mm hyperintensity on the T2-weighted and proton density weighted images, with corresponding hypointensity on T1-weighted images. The Vichinsky study excluded adults with overt strokes and those with known co-morbidities associated with SCI, such as poor cognition or hypertension. However, similar to prior pediatric studies describing the prevalence of SCI, our study only excluded those with overt strokes. Perhaps the inclusion of a selected, less severely affected adult SCA population in Vichinsky et al., along with the different imaging criteria for SCI, explain the striking difference in SCI prevalence between this study and ours.

The current study is limited by the lack of cervical MRA to assess the extracranial internal carotid artery as stenoses have been reported to be a risk factor for SCI in children. Also, in this retrospective study, accurate assessment of the duration of hydroxyurea and chronic transfusion use was not possible. Therefore, we were not able to assess whether these therapies were protective against the development of SCI or aneurysm. Further study is warranted to assess optimal strategies for primary and secondary prevention of SCI in adult SCA. Also given the higher prevalence of hemorrhagic stroke, and the association of subarachnoid hemorrhage in adults with SCA and intracranial aneurysm, further investigation is also needed to determine whether monitoring for aneurysms is warranted. There appears to be an age-dependent increase in neurological and neurovascular morbidity in adults with SCA.
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Authorship

Contribution:

S.P and M.D. reviewed the neuroimaging.

M.R. analyzed results and made the figures.

M.C.G. and M.A, B. collected and entered the data and critically revised the manuscript.

A.A.K., M.R.D., and L.C.J. designed the research and wrote the paper.

All authors reviewed and critically revised the manuscript.

Conflict-of-interest disclosure:

None.

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### Table. Cerebral Aneurysms in Adults with Sickle Cell Anemia

<table>
<thead>
<tr>
<th>Hemoglobin Genotype</th>
<th>Age (years)</th>
<th>Aneurysm Size(s) (mm)</th>
<th>Aneurysm Location(s)</th>
<th>Aneurysm Treatment(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS</td>
<td>30</td>
<td>3</td>
<td>ICA (near PCOM)</td>
<td>Observation</td>
</tr>
<tr>
<td>SS</td>
<td>21</td>
<td>2</td>
<td>Basilar artery</td>
<td>Observation</td>
</tr>
<tr>
<td>SS</td>
<td>35</td>
<td>3</td>
<td>ICA (distal to ophthalmic artery)</td>
<td>Observation</td>
</tr>
<tr>
<td>Sβ0</td>
<td>42</td>
<td>2</td>
<td>ICA terminus</td>
<td>Observation</td>
</tr>
<tr>
<td>SS</td>
<td>33</td>
<td>3.5, 2</td>
<td>Right and left ophthalmic arteries</td>
<td>Observation</td>
</tr>
</tbody>
</table>

ICA=internal carotid artery; PCOM=posterior communicating artery; SS=hemoglobin SS; Sβ0=hemoglobin S beta zero thalasemia.

### Figure Legend

**Prevalence of SCI in children and young adults with SCA.** The figure displays the cumulative prevalence of SCI in children and young adults based on four cross sectional studies, the current cross sectional study and one longitudinal study. The cumulative prevalence of SCI suggests that the incidence of SCI does not plateau in young adulthood to at least 30 years of age. Figure adapted from our review of SCI in children.
References

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