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To the editor:

Increased stroke size following MCA occlusion in a mouse model of sickle cell disease

Sickle cell disease (SCD) is associated with both microvascular and macrovascular complications.¹ Stroke is considered 1 of the most common and disabling vascular complications in patients with SCD, occurring in approximately 24% of individuals by age 45.^{2,3} The etiology of stroke remains unclear, although preexisting obstructive lesions in major intracranial vessels have been reported.⁴

The microvasculature in SCD may be less reliable in maintaining viability in stroke border zones because of predisposition to microvascular occlusions by sickled red blood cells (RBCs). Patency of the microvessels may be particularly important in the setting of acute stroke in which tissues distal to the occlusion are hypoxic; this may trigger occlusive microvascular sickling. The effect of stroke size following macrovascular occlusion in SCD has not been previously reported to our knowledge. The effect of SCD on stroke size in humans is difficult to determine because there is no suitable control group for the SCD-related strokes that occur at relatively early ages.⁵

In this study, we sought to determine whether stroke size following macrovascular occlusion would be affected in mice with SCD. Male SCD and control mice were generated by bone marrow transplantation as previously described.^{6,7} SCD mice were anemic (hemoglobin: 9.7 ± 0.3 vs 12.6 ± 0.5 g/dL, $P < .001$) with splenomegaly (494.5 ± 51.5 vs 131 ± 11.5 mg, $P < .001$) compared with wild-type (WT) mice. Eight weeks after bone marrow transplantation, middle cerebral artery (MCA) occlusion was induced by photochemical injury as previously described.⁸ As early as 1 hour after occlusion, cortical discoloration representing the ischemic zone was greater in SCD mice compared with WT mice ($n = 5$ /group) (Figure 1A-C). Another group of control and SCD mice ($n = 10$ /group) were analyzed at day 3 following MCA occlusion to determine effects of SCD on completed stroke size as previously described.⁹ Although there was no mortality in the control group, mortality occurred in 4 SCD ($P < .001$) mice on days 2 ($n = 2$) and 3 ($n = 2$) following induction of stroke. Of the surviving mice, completed stroke size was greater in SCD mice compared with WT mice (Figure 1D-F). This was associated with widespread occlusion of the microvasculature by sickled RBCs in the stroke border zone (Figure 1G).

Because the microvasculature may preserve the viability of the stroke border zone, it is likely that this was the cause of the increased stroke size. The increased mortality in SCD mice was unexpected and may be due to the triggering of a sickle cell crisis following induction of stroke. However, circulating sickled RBCs constituted only $1.1 \pm 0.2\%$ of the circulating RBCs following stroke.

Overall, these findings indicate that in addition to being at high risk of stroke, SCD patients may suffer greater damage when stroke occurs. Although identification of the predisposing factors for macrovascular occlusion is the highest priority for stroke prevention in SCD, cellular events in the microvasculature could affect outcomes once macrovascular flow disturbance occurs. Therapies targeting microvascular sickling may reduce morbidity associated with stroke in SCD.

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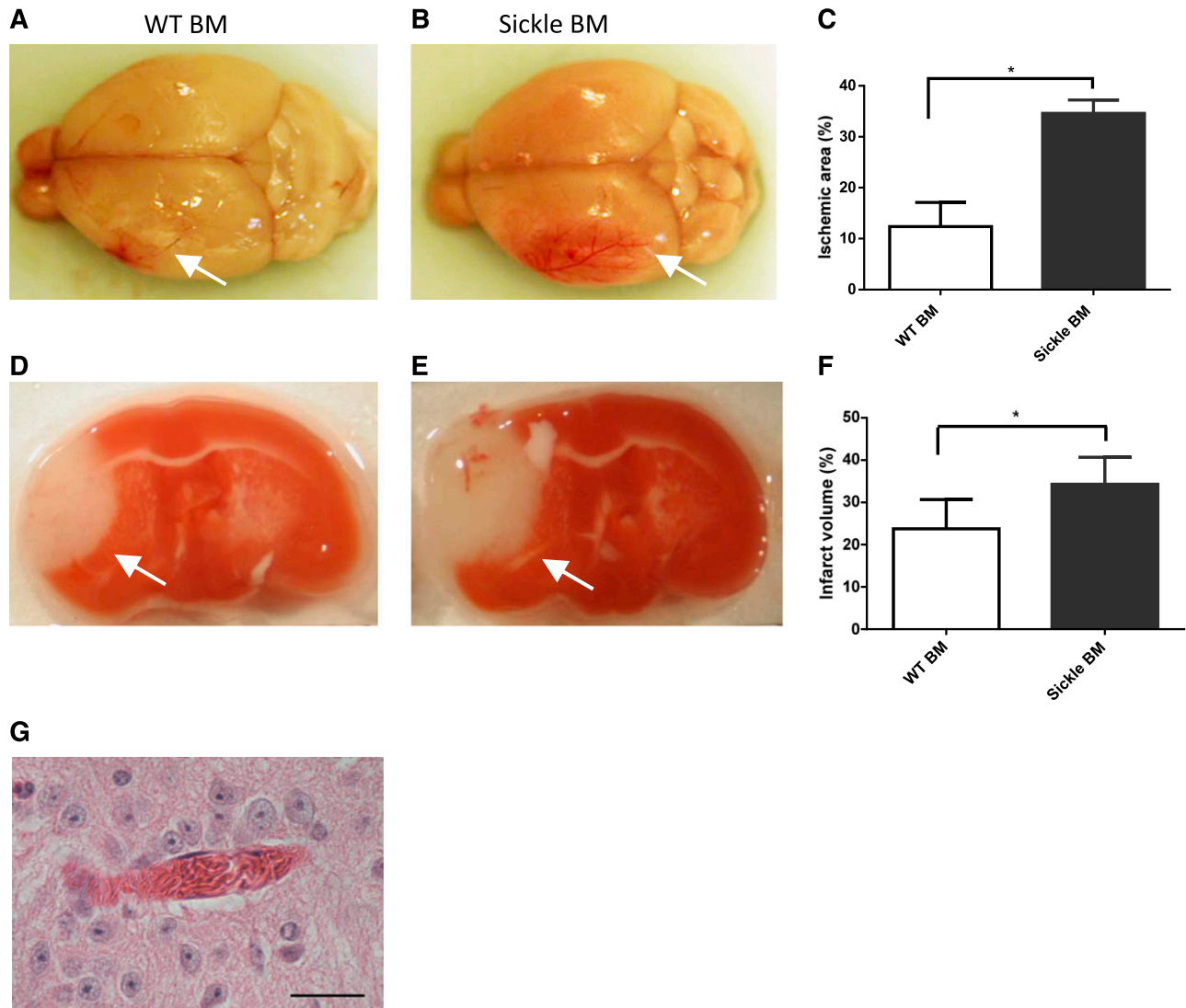


Figure 1. Effect of SCD on stroke after MCA occlusion. At 1 hour following MCA occlusion, the area of erythema representing ischemic zone was greater in SCD compared with WT mice (A-C). At 3 days following MCA occlusion, infarct size by 2,3,5-triphenyltetrazolium chloride staining was larger in SCD mice compared with WT BM mice (D-F). Microvascular occlusions by sickled RBCs were widespread in brain sections of SCD BM mice (G), but not in WT mice. Bar = 50 μ m. * P < .05. BM, bone marrow.

W.L. and E.J.S. contributed equally to this work.

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