[Primary Care]

Cerebral Microhemorrhages in a Collegiate Football Player: Clinical Implications in the Management of Sports Concussion

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Most concussions in sports medicine are managed without advanced neurological imaging. However, computed tomography and magnetic resonance imaging are sometimes used in the management of complex sports concussions to identify acute/delayed intracranial bleeding or other associated pathology. Advances in imaging techniques have led to greater resolution and the identification of pathology of uncertain clinical significance. This report describes the presence of persistent cerebral microhemorrhages identified on magnetic resonance imaging in a collegiate football player who suffered a concussion. The associated risks and clinical significance of cerebral microhemorrhages have not been determined in the young athletic population. This case highlights provocative issues in the management of sports concussions as related to findings on modern neurological imaging and their potential implication on to return-to-play considerations.

Keywords: microhemorrhages; microbleeds; concussion

Concussion is a common injury in athletes, and most concussions are managed without advanced imaging. When indicated in the acute setting, computed tomography (CT) scans have been the modality of choice in the evaluation of complex sports concussions because of their relative accessibility and ability to identify intracranial bleeds. By definition, both CT and conventional magnetic resonance imaging (MRI) show negative results for concussion. There are documented changes on functional MRI and PET (positron-emission tomography) scans after concussion; however, these are not frequently utilized outside research protocols, and their significance and clinical utility remain unknown. Advances in "routine" MRI have also led to the identification of pathology of unclear clinical significance, posing diagnostic dilemmas for the clinician.

Gradient echo T2*-weighted MRI sequences are now routinely included in many brain-imaging protocols. These sequences are highly sensitive in detecting breakdown products of blood (eg, hemosiderin) that are millimeters in size, termed microhemorrhages.[2,7,22,27] The associated risks and clinical significance of these microhemorrhages have not been determined, especially in the young athletic population. Most research has focused on their implications in the elderly.[5,6,16-18,25,31] This case highlights the complexities of interpreting modern MRI findings in the management of the sport concussion and raises questions regarding the type and indication for advanced imaging.

CASE HISTORY

A 22-year-old senior college football player (free safety) suffered a head injury while making a tackle. He drove his head into the opposing player; his helmet flew off; and a player landed on top of him. Medical staff responded immediately and found the player unconscious, with shallow respirations and a heart rate in the 120s. He was spine boarded and transported to an ambulance on the sideline. His loss of consciousness lasted approximately 4 minutes. When he regained consciousness, he was combative and agitated. Because of this, he was sedated and intubated with succinylcholine, diazepam, and pancuronium and transported to a level 1 trauma center.

On arrival, he was afebrile, slightly tachycardic and hypertensive, intubated but arousable. His cardiovascular, pulmonary, and abdominal exams were normal. His pupils

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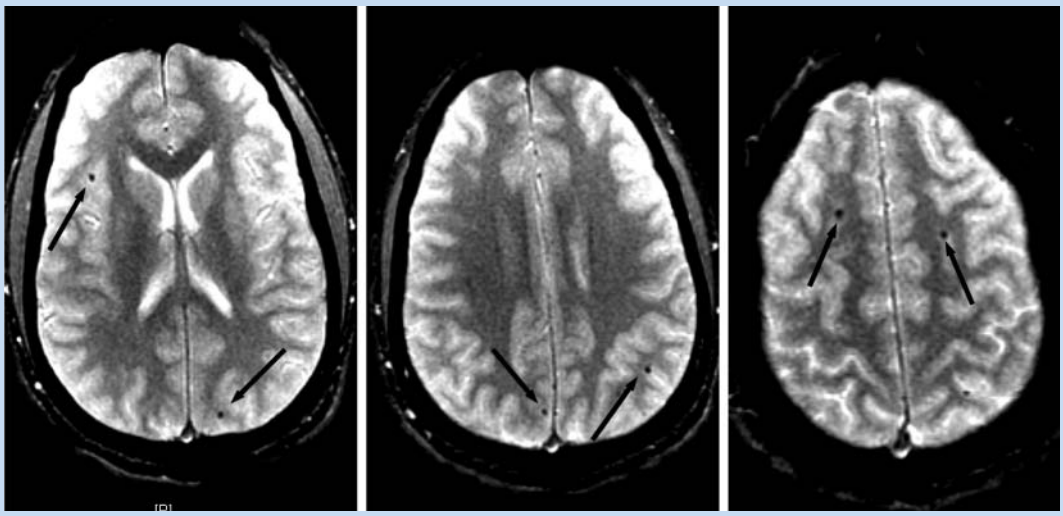

Figure 1. Multiple microhemorrhages (arrows) throughout the cerebral hemispheres, pituitary, and parietal lobes, consistent with shear injury.

were 4 mm and reactive. He also had normal corneal, deep tendon, and Babinski reflexes. Results of studies—including blood counts, basic metabolic panels, electrocardiogram, cervical spine, chest radiographs, and head CT—were all normal. He was diagnosed with a concussion, extubated in the emergency room, and admitted to the neurology service for overnight observation.

During a routine evening neurologic examination, he was noted to have disconjugate gaze, and an MRI was ordered to rule out delayed bleeding. A 3-T MRI showed multiple microhemorrhages in the cerebral hemispheres, pituitary, and parietal lobes on the gradient echo sequences (Figure 1). Despite these findings, the patient progressed clinically with improved mental status testing. His symptoms of headache and a subjective feeling of "fogginess" diminished. His balance and cerebellar tests also slowly improved.

His medical history was remarkable for prolonged symptoms of nausea, vomiting, fatigue, and difficulty concentrating after rapidly drinking 3 quarters of a fifth of rum 3 years before his injury. At that time, he presented to the emergency room 8 days after the binge-drinking incident. Laboratory results were normal, and a CT of his head yielded negative findings. His symptoms took approximately 4 weeks to fully resolve and were attributed to his excessive alcohol intake. He had a history of 2 prior concussions, in 2005 and 2007. Each resolved without complications and took approximately 1 week for return to football. He was diagnosed with primary hypertension in 2006, with blood pressures that ranged from 120 to 160 (systolic) and 80 to 90 (diastolic). He was initially treated with antihypertensive medications but discontinued them on his own.

Consultations were obtained from neurosurgery and a sports neurologist. The clinical significance of the MRI pathology was uncertain. It was possible that the microhemorrhages were from the acute injury, found incidentally, or represented findings from previous head injuries. After discussing the case with the consulting physicians, the team physicians decided to obtain a repeat MRI at 6 weeks postinjury. If the microhemorrhages resolved, he was clinically asymptomatic, and had returned to his baseline on neuropsychological testing, a return to football could be considered.

Seven weeks later, a repeat 3-T MRI showed no change, with persistent microhemorrhages throughout the brain parenchyma on the gradient echo sequences (Figure 2). Results of a transthoracic echocardiogram were normal (obtained to rule out a patent foramen ovale as a possible cause of embolic phenomena). ImPACT testing at this time was at his baseline; however, the patient continued to have difficulty with concentration, depression, and memory. A formal neuropsychological evaluation showed mild to moderate impairments in several areas, including left-hand fine motor speed, complex attention, executive function, and delayed memory recall of complex verbal information. Some of the affected domains correlated with the areas of microhemorrhage on MRI.

The final diagnosis was concussion with postconcussion syndrome and microhemorrhages evident on MRI. The patient continued to have symptoms long after his injury. He reported headaches and developed depression, for which he was started on bupropion but discontinued on his own. Given his continued symptoms and persistent microhemorrhages, he was medically disqualified from football.

DISCUSSION

Recent estimates suggest that 1.6 to 3.8 million concussions occur in sporting events across the United States, with American football recording the highest rates.[19] Given the number of concussions encountered, there is limited imaging

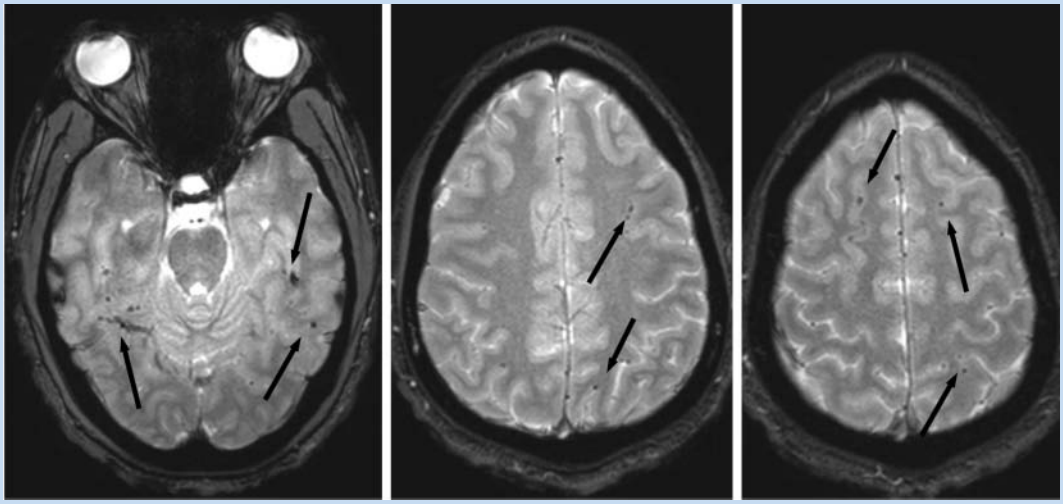

Figure 2. Persistent microhemorrhages throughout brain parenchyma (arrows).

in concussion management. This case highlights the detection of cerebral microhemorrhages using modern MRI techniques after a negative CT scan result, and it raises the question, what is the clinical significance of microhemorrhages after acute sports-related concussion? Is this an incidental finding? What is the prevalence of microhemorrhages in athletes with a history of concussion? Do the findings represent acute pathology, or are they related to previous head injuries?

Gradient echo imaging has the sensitivity to detect the rupture of blood vessels that are < 200 µm in diameter and result in hemosiderin deposition.[29] Cerebral microhemorrhage, or microbleed, has been defined as rounded hypointense foci that are < 5 mm in size and distinct from vascular flow voids, often seen on the gradient echo sequence.[2,7,22] Because hemosiderin remains in macrophages for years after hemorrhage,[10,23,24] the age of the lesions identified on MRI cannot be determined, thus complicating their interpretation in the acute setting.

It is unclear whether the microhemorrhages identified in this patient represent pathology from his acute injury, the effect of multiple prior head injuries, or another unknown cause. Microhemorrhages have not been well characterized in a young athletic population. The study of cerebral microhemorrhages has primarily been focused on the elderly, for whom they have been described in individuals with intracerebral hemorrhage,[16,17,24,31] ischemic cerebrovascular disease,[5,6,16-18,31,32] cerebral amyloid angiopathy,[10-12,26] and cerebral autosomal dominant arteriopathy with subcortical infarcts and leukoencephalopathy.[4,21] Microhemorrhages have been associated with increasing age, hypertension, and smoking.[15,20,25,31] In the elderly, mild hypertension for an average duration of 8 years was found to be a risk factor for microhemorrhage.[20] It seems unlikely that this patient's hypertension for short duration was related to his cerebral microhemorrhages.

The prevalence of microhemorrhages in traumatic head injury is 7% to 30%.[9,13,28,30] The populations studied have included amateur boxers and persons with mild traumatic head injuries identified in the emergency room. The lesions are thought to be due to the combination of rotational and acceleration/deceleration forces during impact, leading to shear injury.[1,3,8,14] To our knowledge, microhemorrhages in football players have not been reported, and no study has characterized microhemorrhages in the setting of sports-related concussions.

With the patient's persistent symptoms, the team physicians decided to medically disqualify this player from returning to football. The significance of the microhemorrhages is unknown, and the decision would have been more difficult if his symptoms had completely resolved despite the lingering MRI findings. Newer sequencing techniques and increasing field strengths will continue to lead to the identification of new pathology on MRI and other imaging modalities. Several questions remain regarding the timing and type of advanced imaging and how microhemorrhages relate to prognosis and decisions for return to play. Future studies are needed to characterize the risk factors, prevalence, and clinical implications of these lesions in contact sports and the management of sports concussions.

REFERENCES

1. Arfanakis K, Haughton VM, Carew JD, Rogers BP, Dempsey RJ, Meyerand ME. Diffusion tensor MR imaging in diffuse axonal injury. *AJNR Am J Neuroradiol.* 2002;23(5):794-802.
2. Atlas SW, Mark AS, Grossman RI, Gomori JM. Intracranial hemorrhage: gradient-echo MR imaging at 1.5 T comparison with spin-echo imaging and clinical applications. *Radiology.* 1988;168(3):803-807.
3. Besenski N. Traumatic injuries: Imaging of head injuries. *Eur Radiol.* 2002;12(6):1237-1252.
4. Dichgans M, Holtmannspotter M, Herzog J, Peters N, Bergmann M, Yousry TA. Cerebral microbleeds in CADASIL: a gradient-echo magnetic resonance imaging and autopsy study. *Stroke.* 2002;33(1):67-71.

5. Fan YH, Mok VC, Lam WW, Hui AC, Wong KS. Cerebral microbleeds and white matter changes in patients hospitalized with lacunar infarcts. *J Neurol.* 2004;251(5):537-541.
6. Fan YH, Zhang L, Lam WW, Mok VC, Wong KS. Cerebral microbleeds as a risk factor for subsequent intracerebral hemorrhages among patients with acute ischemic stroke. *Stroke.* 2003;34(10):2459-2462.
7. Fazekas F, Kleinert R, Roob G, et al. Histopathologic analysis of foci of signal loss on gradient-echo T2*-weighted MR images in patients with spontaneous intracerebral hemorrhage: evidence of microangiopathy-related microbleeds. *AJNR Am J Neuroradiol.* 1999;20(4):637-642.
8. Friedman SD, Brooks WM, Jung RE, Hart BL, Yeo RA. Proton MR spectroscopic findings correspond to neuropsychological function in traumatic brain injury. *AJNR Am J Neuroradiol.* 1998;19(10):1879-1885.
9. Giugni E, Sabatini U, Hagberg GE, Formisano R, Castriota-Scanderbeg A. Fast detection of diffuse axonal damage in severe traumatic brain injury: comparison of gradient-recalled echo and turbo proton echo-planar spectroscopic imaging MRI sequences. *AJNR Am J Neuroradiol.* 2005;26(5):1140-1148.
10. Greenberg SM, Eng JA, Ning M, Smith EE, Rosand J. Hemorrhage burden predicts recurrent intracerebral hemorrhage after lobar hemorrhage. *Stroke.* 2004;35(6):1415-1420.
11. Greenberg SM, Finklestein SP, Schaefer PW. Petechial hemorrhages accompanying lobar hemorrhage: detection by gradient-echo MRI. *Neurology.* 1996;46(6):1751-1754.
12. Greenberg SM, O'Donnell HC, Schaefer PW, Kraft E. MRI detection of new hemorrhages: potential marker of progression in cerebral amyloid angiopathy. *Neurology.* 1999;53(5):1135-1138.
13. Hahnel S, Stippich C, Weber I, et al. Prevalence of cerebral microhemorrhages in amateur boxers as detected by 3T MR imaging. *AJNR Am J Neuroradiol.* 2008;29(2):388-391.
14. Holshouser BA, Tong KA, Ashwal S. Proton MR spectroscopic imaging depicts diffuse axonal injury in children with traumatic brain injury. *AJNR Am J Neuroradiol.* 2005;26(5):1276-1285.
15. Jeerakathil T, Wolf PA, Beiser A, et al. Cerebral microbleeds: prevalence and associations with cardiovascular risk factors in the framingham study. *Stroke.* 2004;35(8):1831-1835.
16. Kato H, Izumiyama M, Izumiyama K, Takahashi A, Itoyama Y. Silent cerebral microbleeds on T2*-weighted MRI: correlation with stroke subtype, stroke recurrence, and leukoaraiosis. *Stroke.* 2002;33(6):1536-1540.
17. Kinoshita T, Okudera T, Tamura H, Ogawa T, Hatazawa J. Assessment of lacunar hemorrhage associated with hypertensive stroke by echo-planar gradient-echo T2*-weighted MRI. *Stroke.* 2000;31(7):1646-1650.
18. Kwa VI, Franke CL, Verbeeten B Jr, Stam J. Silent intracerebral microhemorrhages in patients with ischemic stroke: Amsterdam Vascular Medicine Group. *Ann Neurol.* 1998;44(3):372-377.
19. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. *J Head Trauma Rehabil.* 2006;21(5):375-378.
20. Lee SH, Bae HJ, Ko SB, Kim H, Yoon BW, Roh JK. Comparative analysis of the spatial distribution and severity of cerebral microbleeds and old lacunes. *J Neurol Neurosurg Psychiatry.* 2004;75(3):423-427.
21. Lesnik Oberstein SA, van den Boom R, et al. Cerebral microbleeds in CADASIL. *Neurology.* 2001;57(6):1066-1070.
22. Offenbacher H, Fazekas F, Schmidt R, Koch M, Fazekas G, Kapeller P. MR of cerebral abnormalities concomitant with primary intracerebral hematomas. *AJNR Am J Neuroradiol.* 1996;17(3):573-578.
23. Roob G, Fazekas F. Magnetic resonance imaging of cerebral microbleeds. *Curr Opin Neurol.* 2000;13(1):69-73.
24. Roob G, Lechner A, Schmidt R, Flooh E, Hartung HP, Fazekas F. Frequency and location of microbleeds in patients with primary intracerebral hemorrhage. *Stroke.* 2000;31(11):2665-2669.
25. Roob G, Schmidt R, Kapeller P, Lechner A, Hartung HP, Fazekas F. MRI evidence of past cerebral microbleeds in a healthy elderly population. *Neurology.* 1999;52(5):991-994.
26. Rosand J, Muzikansky A, Kumar A, et al. Spatial clustering of hemorrhages in probable cerebral amyloid angiopathy. *Ann Neurol.* 2005;58(3):459-462.
27. Scharf J, Brauherr E, Forsting M, Sartor K. Significance of haemorrhagic lacunes on MRI in patients with hypertensive cerebrovascular disease and intracerebral haemorrhage. *Neuroradiology.* 1994;36(7):504-508.
28. Scheid R, Preul C, Gruber O, Wiggins C, von Cramon DY. Diffuse axonal injury associated with chronic traumatic brain injury: evidence from T2*-weighted gradient-echo imaging at 3 T. *AJNR Am J Neuroradiol.* 2003;24(6):1049-1056.
29. Tanaka A, Ueno Y, Nakayama Y, Takano K, Takebayashi S. Small chronic hemorrhages and ischemic lesions in association with spontaneous intracerebral hematomas. *Stroke.* 1999;30(8):1637-1642.
30. Topal NB, Hakyemez B, Erdogan C, et al. MR imaging in the detection of diffuse axonal injury with mild traumatic brain injury. *Neurol Res.* 2008;30(9):974-978.
31. Tsushima Y, Aoki J, Endo K. Brain microhemorrhages detected on T2*-weighted gradient-echo MR images. *AJNR Am J Neuroradiol.* 2003;24(1):88-96.
32. Werring DJ, Frazer DW, Coward LJ, et al. Cognitive dysfunction in patients with cerebral microbleeds on T2*-weighted gradient-echo MRI. *Brain.* 2004;127(10):2265-2275.