

FEATURE

CONCUSSION

Grappling with concussion: discovery, policy, and practice

Bob Roehr looks at the latest evidence, policy, and developments around concussion

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Injury to the brain from concussion and other lesser trauma might result at least in part from damage to the blood-brain barrier and a complex immune feedback loop that mimics autoimmune disease. Evidence supporting the theory was gathered through collaboration between researchers at the University of Rochester Medical Center and the Cleveland Clinic and published this month in *PLoS ONE*.¹

The blood-brain barrier is best known for preventing some molecules in the blood, most notably some drugs, from entering into the brain compartment. But it also works the other way, keeping some proteins unique to the brain from entering into the rest of the body. One of these is S100B, a protein associated with traumatic brain injury.

The study looked at blood samples from 67 college football players before and after a game; none had experienced a concussion. In the samples taken after the game small amounts of S100B and other brain proteins that are not supposed to be in the rest of the body were found. Looking back at video footage of the game, higher levels of S100B correlated with exposure to rougher contact during the event.

"The blood-brain barrier opens up, after every game, every practice, every scrum. Small amounts of protein, in particular S100B leak into peripheral circulation," explains Jeffrey J Bazarian, associate professor at the University of Rochester Medical Center and coauthor of the paper. The immune system treats them like invaders; "It looks like the body forms antibodies to that protein because it is not used to seeing that protein in the peripheral circulation."

"We speculate that when the blood-brain barrier opens up again, those antibodies enter the brain and potentially do damage." He says this new way of thinking "opens up a whole array of different therapeutic options for interfering with this process" of trauma induced harm to the brain.

Another piece of research on concussion is a study of high school girls in Houston who played soccer and regularly headed the ball as part of practice.² It used an iPad app to measure brain

voluntary reaction time at the end of practice and found that players had slower reaction times than girls who did not play soccer.

That decline in function showed a correlation with the number of hours a week and number of years that a girl had played the game. However, the authors left open the possibility that functional loss is transitory and not permanent.

The National Football League instituted mandatory post concussion sideline assessment last season and is moving to an iPad based version of the assessment next season. They demonstrated the new protocol and tool at a news conference (<http://www.nfl.com/videos/nfl-videos/0ap2000000144247/Sideline-concussion-protocol>). The app will make it easier to compare earlier baseline results of the test. The players' association believes it will be more objective than simply relying on the team physician, who is paid by the owner.

Some of the most reliable numbers on concussion come from the Pentagon through its care of soldiers and their dependants. Surprisingly, just 16% of concussions are associated with the battlefield; most occur playing sports, in incidents involving motor vehicles, and other everyday activities.

Sarah Goldman, traumatic brain injury program manager in the army office of the surgeon general, said 75% of concussions were mild, and 92% resolve in 5 to 10 days. A policy change in 2010 "mandates a medical evaluation and a minimum of 24 hours downtime following any potentially concussive event in Afghanistan." She said it takes the burden off the soldier to say they are having problems, "it helps reduce the stigma."

The Pentagon has invested more than \$700m (£469m; €541m) in traumatic brain injury research since 2007. It will publish updated guidelines on managing concussion later this year.

Policy

Last week an Institute of Medicine committee began looking at sports related concussion in young people. Public school systems are inconsistent in their awareness and management of

concussion. "State laws have made this an issue for high schools, but it is slow in its translation down to that third grader," said Gerard Gioia, "But it is a lot better than five years ago." He is director of the Safe Concussion Outcome, Recovery and Education (SCORE) Program (www.childrensnational.org/score/) at the Children's National Medical Center in Washington, DC. "Concussions affect school learning and performance, but school learning and performance can also affect concussion recovery, it's a circular thing," he explains.

More than 60% of children who have experienced a concussion report that headaches are interfering with their learning, according to Gioia's research. They are not able to pay attention adequately, homework takes much longer, and they feel tired. High school students on average report more than three of these symptoms, and are more likely to notice them than are their parents.

"The four things that we monitor closely are headache exacerbation, fatigue, difficulty concentrating, and irritability. We actually teach kids to do that monitoring. It is not unlike what you do with diabetes, asthma, or other illnesses where you try to help kids self manage, as well as the parents and teachers, so that you can introduce the activity of school in a measured way."

"Different classes put different demands on kids' brains; number one is math" in terms of functional demand on the brain, he says. "Cognitive activities and demands clearly affected the symptoms" of 62.5% of high school children. "Interestingly, physical demands did not" affect symptoms. Gioia believes the explanation is that "We are managing physical activity at a better rate than cognitive activity."

"When people really understand concussion they tend to be more sympathetic and will make accommodations," says Brenda Eagan Brown. She coordinates BrainSTEPS (Strategies Teaching Educators, Parents and Students, (www.brainsteps.net), an initiative on concussion funded by the Pennsylvania Departments of Health and Education, in conjunction with the Brain Injury Association of Pennsylvania.

BrainSTEPS has created educational materials on concussion, including a six page guide for teachers and return to school and return to play protocols that are available online. Under the program an academic monitor and a symptoms monitor evaluate weekly reports on each student who has had a concussion. Students who do not improve in one to four weeks are referred to medical consulting teams.

The biggest struggle for students who have symptoms that linger after concussion is "striking that balance between the need for rest and keeping up with academic content in school," says Brown.

School plans should "front load accommodations" for students, often beginning with no school for a few days, then part days with rest periods built into the day. The individual plan should outline what academic materials need to be covered during the recovery period, and what portions will and will not be graded. She says, "This alleviates stress on the parents, teachers, and the students."

One Pittsburgh area school system will not let concussed students drive to school. Brown says, "They don't want any accidents to occur on school property and two, their hope is that it curbs students from faking concussion symptoms" to avoid tests or other responsibilities.

"Even with my most committed athletes, when we clear them to go back to sports they are very happy," says Gioia. "When we clear them to go back to driving they are elated. It is one of

the signature moments for adolescents in their return, it is their independence being given back to them."

Schools have become much better at managing concussion incurred while at school, but they cannot make accommodations for concussion incurred elsewhere unless they are informed of it.

Physician practice

Pediatricians have limited understanding and training in how to deal with concussion and are largely referring patients with concussion to neurologists, says Paul Graham Fisher, a pediatric neurologist at Stanford University. "The problem is, there is a bottleneck; just 1200 child neurologists in the country and wait times of 2-3 months" for existing neurological issues. Adding potential concussion to the workload will stretch them even thinner.

It also is common for a blow to the head to exacerbate or bring to light conditions that had not been identified earlier. Fisher referred to a recent patient who "probably had longstanding learning disabilities that came to light after being hit in the head. It had nothing to do with a concussion."

Evaluation is complicated by limited data from concussion in young people, says Stanley Herring. During those years of rapid growth, a young person's physical, mental, and social development often does not exactly fit with their chronologic age. Herring is a University of Washington physician, co-director of the Seattle Sports Concussion Program, team physician for two of the city's pro sports franchises, and he works closely with the National Football League.

He cautions against over-medicalizing concussion. There is a risk of either overlooking or misinterpreting persisting symptoms and being overly protective of young people. He says we might be assigning too much blame to concussion instead of other underlying conditions, and in doing so, prevent students from participating in sports, classroom, and social activities at an important time in their lives.

Yvette Rooks brings to the table her experience as team physician for many of the squads at the University of Maryland College Park. She says an established and ongoing doctor-patient relationship is critical to evaluating concussion. But physicians for primary education sports teams seldom have that same close relationship with their players.

Change from baseline often is the crucial factor and knowing something as simple as whether a student reported having headaches at the start of season physical examination could change the way post concussive symptoms are evaluated. She says, "I know these kids very well, I know their personalities before something happens."

Standardized neurocognitive testing can be tricky, Rooks told the *BMJ*. Maryland athletes take a baseline ImPACT test (www.impacttest.com/). "They know what is it for. Some of them don't want to take it, and so their concussed ImPACT score is higher than their baseline, and it shouldn't be that way." So she cautions that all tests need to be used carefully.

Rooks calls the balance fitness test "the best test because you can't cheat on that. It is testing your body's cognitive and physical response."

When a head or neck injury occurs during a game, Rooks takes the player into the locker room for an evaluation. "The emotional stability of that young person is most apparent when they are by themselves with the physician or trainer. You are not going

to see that right there on the field." In the locker room there isn't the same pressure from peers, coaches, and the fans. Post concussive syndrome is a complication that lasts beyond three months, such as the onset of headaches doing exercises. "There is no current suggestion that young people with ADHD are more prone to concussion," but it can complicate evaluation for return to play, according to Rooks. "Repeated head injuries may worsen depression. We also know that depression, if it is preexisting and not treated, can make the concussion symptoms worse.

"Cognitive rest is extremely important," says Rooks. "If the brain isn't functioning properly, how can they go back to the classroom and be expected to be competitive in the classroom with their colleagues?

"There should be no rigid return to play guidelines, each should be individualized" to the student and the sport. And it should be a progressive process not an all or nothing option.

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- 1 Marchi N, Bazarian JJ, Puvenna V, Janigro M, Ghosh C, Zhong J, et al. Consequences of repeated blood-brain barrier disruption in football players. *PLoS ONE* 2013;8:e56805, doi:10.1371/journal.pone.0056805.
- 2 Zhang MR, Red SD, Lin AH, Patel SS, Sereno AB. Evidence of cognitive dysfunction after soccer playing with ball heading using a novel tablet-based approach. *PLoS ONE* 2013;8:e57364, doi:10.1371/journal.pone.0057364.

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