

The BRAIN

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BY THE **QUEENSLAND
BRAIN INSTITUTE**

Issue One

CONCUSSION

A SPECIAL REPORT ON THE
LATEST SCIENCE

Does concussion lead to
brain injury?

Why top athletes
want research

Your kids and contact sport



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A MESSAGE FROM
Professor Pankaj Sah
QUEENSLAND BRAIN INSTITUTE
DIRECTOR



PHOTOGRAPHY NICK VALMAS

CONCUSSION IS EMERGING AS A MAJOR HEALTH ISSUE.

More and more professional sportspeople are speaking out about their experiences of head injury, including well-known former rugby league players such as Mario Fenech and Peter FitzSimons. Furthermore, concussions have forced a growing number of current athletes to take time out from or cut short their sporting careers, including rugby league professional James McManus, who plays with the Newcastle Knights, former Australian tennis powerhouse Casey Dellacqua, former Australian cricketer Chris Rogers and former Brisbane Lions player Justin Clarke.

Outside of sport, but also garnering significant attention is the spate of 'one-punch' attacks that has plagued young Australians since the turn of the century – responsible for almost 100 deaths since 2000. Where does concussion fit with this appalling phenomenon that has also ignited public

discussion about the wide-ranging and too-often tragic consequences of head injuries?

It's not just major head trauma that we need to worry about or the short-term consequences of head impacts. Research on the brains of former athletes is raising awareness of the long-term neurological damage that can be caused by repeated, apparently minor knocks to the head.

At the Queensland Brain Institute, we have the expertise to be able to explain some of the confusion surrounding concussion and to explore many of the unanswered questions. We have produced this booklet as the first part of a major new public awareness campaign surrounding concussion and traumatic brain injury.

Our intention is to inform and support a community response to what is emerging as a significant and confounding health condition affecting the lives of a growing number of us.

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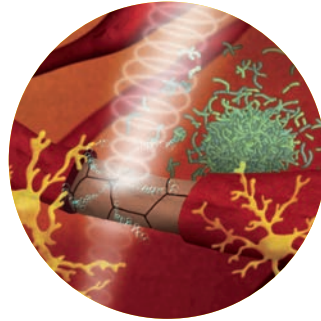
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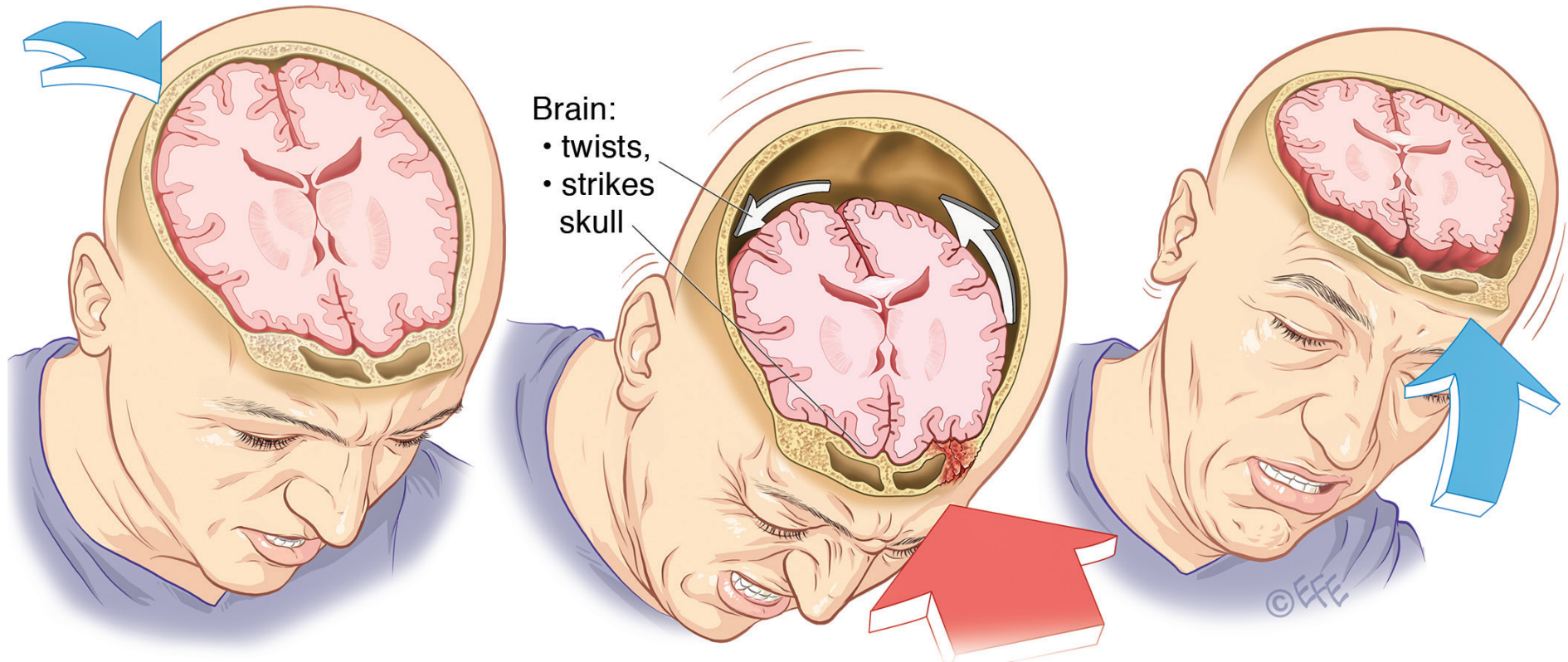
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Chapter 1. WHAT IS CONCUSSION?

MEDICAL ILLUSTRATION LEVENT EFE



WHAT CAUSES CONCUSSION?

The brain floats inside the skull, suspended within a protective cushion of cerebrospinal fluid. A direct blow to the head, face or neck, or from an impact to somewhere else on the body, can create a force that shakes the brain. When that force is strong enough, or comes from a particular direction, the

brain can move so that it strikes the skull or twists upon itself. Just as for any body part that is struck, bruising and cell damage can occur. When those cells are neurons, however, concussion is the outcome. Because the brain is so central to our lives, controlling mood, perception and movement, the effects of concussion can be far-reaching.



WHO IS MOST AT RISK FROM CONCUSSION?

The connection between contact sport and concussion has been widely publicised. In the general population, however, concussion is in fact extremely common. Typically caused by a fall or car accident, it can also be sustained by a wide variety of other activities.

The outcome of a blow to the head can be either mild or severe. While anyone who has been ‘knocked out’ has usually suffered concussion, you can be concussed without losing consciousness. When concussion occurs in sport, players in most cases remain conscious, and the condition often goes undiagnosed. And while protective headgear prevents skull damage during high-impact knocks, it doesn’t prevent the brain from moving inside the skull.

People in certain sports have a higher risk of being concussed than the general population – rugby players and boxers, for example. People in the military who are exposed to explosions and victims of domestic abuse are also at particularly high risk. These groups are also more likely to suffer repeated concussions.

HOW IS CONCUSSION MEDICALLY DEFINED?

CONCUSSION IS THE MILDEST FORM OF TRAUMATIC BRAIN INJURY (TBI).

THERE IS NO UNIVERSALLY ACCEPTED DEFINITION OF CONCUSSION, BUT IT RESULTS IN:

➔ Rapid impairment in brain function that is temporary and gets better by itself

➔ A variety of symptoms, but not necessarily loss of consciousness

➔ Disturbance to the brain’s function rather than physical structure, which means that standard neuroimaging tests such as MRIs and CT scans can’t detect any changes

➔ Symptoms that gradually improve over time, but which may be prolonged in a small percentage of people

WHAT ARE THE SIGNS OR SYMPTOMS OF CONCUSSION?

Many people who sustain a concussion have no observable signs, which can make diagnosis difficult. Recognising the condition often depends on the affected person reporting the symptoms they are experiencing. These can occur either immediately after the head injury or minutes to hours later.









DOCTORS LOOK FOR THE FOLLOWING SIGNS IN SOMEONE SUSPECTED OF SUFFERING FROM CONCUSSION:

- Confusion and inability to speak coherently**
- Disorientation** (e.g. unaware of time and place)
- Lack of co-ordination** (e.g. stumbling, inability to walk in a straight line)
- Loss of memory** (e.g. about the causative event)
- Slurred speech**
- Delayed response to questions**
- Appearing dazed or with a vacant stare**
- Inappropriate emotion** (e.g. crying for no reason)
- Any temporary loss of consciousness**

PEOPLE WHO HAVE SUSTAINED A CONCUSSION MAY ALSO REPORT THE FOLLOWING SYMPTOMS:

- Headache or a feeling of pressure in the head**
- Confusion or difficulty concentrating**
- Dizziness**
- Changes in vision** (e.g. 'seeing stars')
- ringing in the ears**
- Nausea and vomiting**
- Fatigue**
- Sensitivity to light**
- Loss of smell or taste**

SIGNS AND SYMPTOMS OF POST-CONCUSSION SYNDROME

	
PROBLEMS WITH MEMORY & LEARNING		BALANCE & STABILITY PROBLEMS
	
DIFFICULTY SLEEPING OR STAYING ASLEEP		DOUBLE OR BLURRY VISION, SENSITIVITY TO LIGHT
	
FATIGUE & WEAKNESS		DIFFICULTY CONCENTRATING
	
DIZZINESS & HEADACHES		DEPRESSION

“I WAS SO DESPERATE TO JUST FEEL MYSELF AGAIN BUT I STRUGGLED TO DO EVEN DAILY ACTIVITIES SUCH AS THE GROCERY SHOPPING.”

RECOVERING FROM CONCUSSION

In terms of short-term recovery, the brain changes that occur after a single concussion don't appear to have clear long-term cognitive effects. Return to contact sport should be gradual: the 'if in doubt, sit it out' rule-of-thumb is now adhered to by many sporting codes.

A very small percentage of people who sustain a concussion go on to develop what is known as **post-concussion syndrome**. Symptoms usually develop seven to 10 days after a concussion, and can persist for weeks, months, and sometimes years. Why the syndrome occurs remains unclear. This was the experience of Australian tennis player Casey Dellacqua.

Dellacqua, who suffered a heavy on-court fall in October 2015, wrote in a blog post that post-concussion syndrome was “honestly some of the scariest stuff” she had experienced. Her symptoms included headaches, inability to sleep, memory problems and constant drowsiness. “I was so desperate to just feel myself again but I struggled to do even daily activities such as the grocery shopping,” she wrote.



Left:
Concussion from
a freak accident
while competing in a
doubles tournament
in Beijing, in
October 2015,
forced Australian
tennis player Casey
Dellacqua out of the
game indefinitely
in 2016.

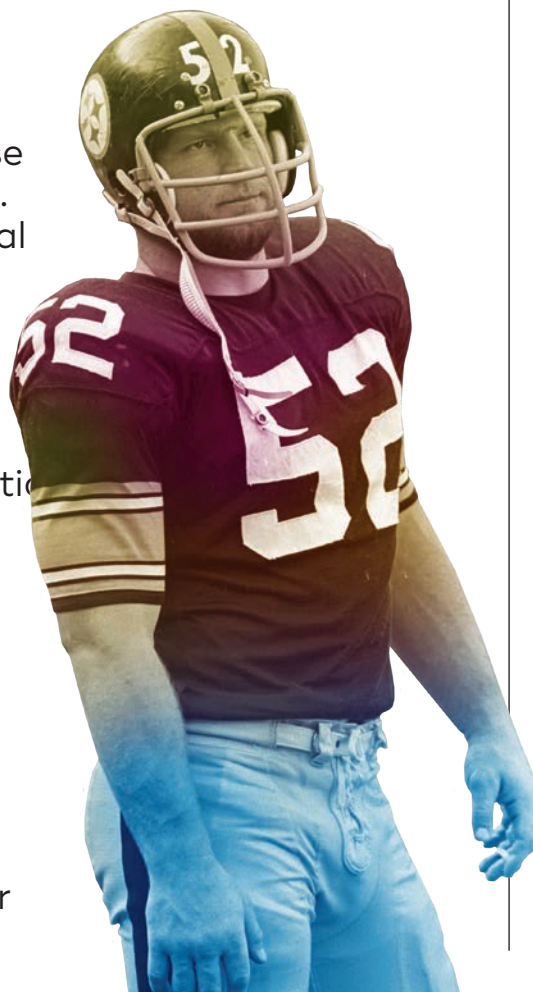
THE LONG-TERM CONSEQUENCES OF CONCUSSION

Former
NFL player
Mike Webster
(below)

While the short-term symptoms of concussion are reversible, research suggests that even a single knock to the head can have severe consequences later in life. For example, figures from one study that analysed the records of more than 160,000 trauma patients identified that, in patients aged 65 and older, just one concussion was associated with a 22-26% increase in dementia risk in the following five to seven years.

Even clearer is research showing that neurological damage accumulates with multiple knocks to the head, even when they are apparently symptomless, or 'sub-concussive'. Repeated concussion has been linked to increased risk of neurodegenerative conditions such as Alzheimer's and Parkinson's disease, as well as chronic traumatic encephalopathy (CTE) – see page below about the medical identification of this condition.

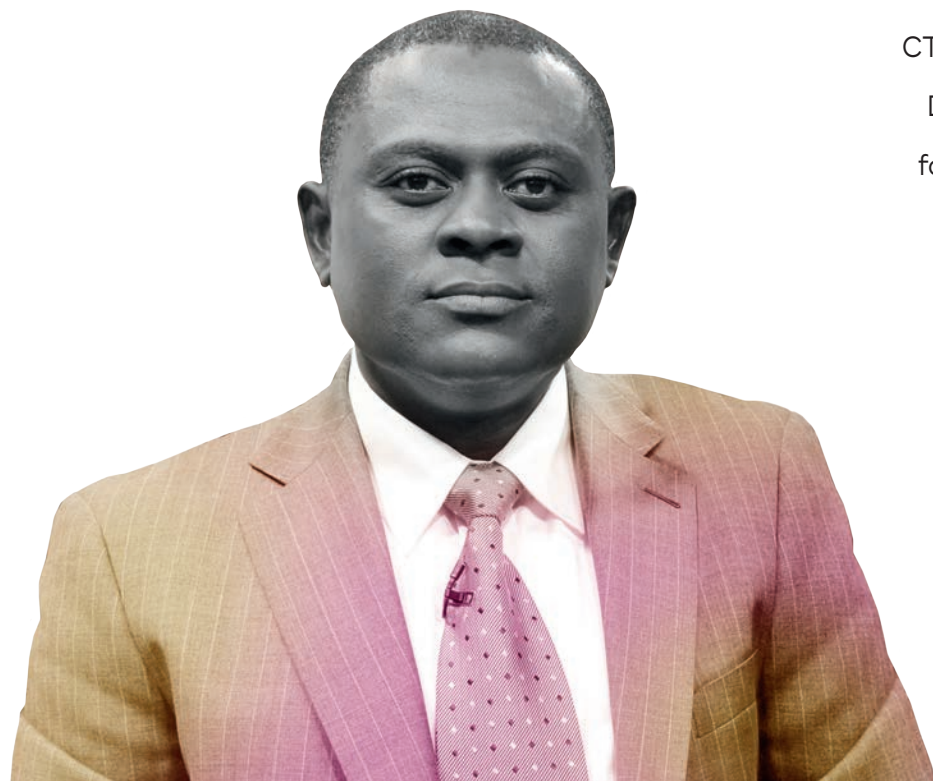
Data from studies of former American footballers is staggering. A survey of more than 2000 retired professional players found that those with a history of multiple concussions were three times more likely to have been diagnosed with clinical depression. Another study of death certificates found that the death rate from neurodegenerative diseases was three times higher for pro-footballers than the general population.



THE MESSAGE

WHEN SHOULD YOU SEEK MEDICAL ADVICE?

Because the symptoms usually resolve by themselves, a concussion is best managed with physical and cognitive rest. However, stories about the potentially tragic consequences of undetected brain injuries are difficult to ignore. Symptoms of severe TBI can develop over several hours. Therefore, after a knock to the head, it's important to be alert for the first 24 hours. Some symptoms are red flags for more severe brain injury: if a head injury results in a loss of consciousness, increasing confusion, vomiting or a worsening headache, the person should seek medical advice. It's important that a doctor makes an assessment to rule out more severe TBI.



CTE was first discovered by neuropathologist Dr Bennet Omalu (left) in the brain tissue of former NFL player Mike Webster. Their story has been depicted in the motion picture *Concussion*.

CHRONIC TRAUMATIC ENCEPHALOPATHY (CTE)

CTE is a progressive disease with Alzheimer's-like symptoms. It was first discovered by neuropathologist Dr Bennet Omalu in the early 2000s in the brain of Mike Webster, a former National Football League (NFL) player. When Omalu looked at Webster's brain tissue under the microscope he observed concentrations of a material known as tau. This is one of two proteins known to accumulate in the brain in Alzheimer's disease. Since then, CTE has been found in the brains of 76 out of 79 former NFL players who have donated their brains to research.

THE NEED FOR EARLY DIAGNOSIS

Repeated head trauma doesn't always lead to CTE and it is likely a person's genetic background also plays a role. Currently, the only way to diagnose CTE is post-mortem, which means it's impossible to determine how prevalent the condition is in the general population or catch the condition at an early stage. The next challenge for TBI researchers is to develop techniques that can identify CTE in living brains. QBI's Dr Fatima Nasrallah is using the support of a Motor Accident Insurance Commission Senior Research Fellowship to work on TBI, specifically to try and develop an early diagnostic test for concussion. She hopes to use biomarkers and imaging to develop a test that will be able to detect even subtle changes in brain function following a head injury.

Chapter 2. TRAUMATIC BRAIN INJURY (TBI)

WHAT IS TRAUMATIC BRAIN INJURY?

Traumatic brain injury (TBI) is an injury to the brain caused by an external force. Common causes (see right) include falls, car accidents, assault or being struck by objects such as might occur during sport. TBI is classified according to its severity: mild, moderate or severe. From a medical perspective this judgment is based on what's known as the Glasgow Coma Scale (GCS), which assesses motor, verbal and eye-opening responses. The scale runs from 3 to 15, where 3 is assigned to someone who is dead or comatose and 15 is normal. Someone with a mild TBI generally has a GCS of 13–15.

In the absence of clinical assessment, TBI is considered moderate-to-severe if there is a loss of consciousness that is longer than 30 minutes and amnesia – memory loss – lasts for more than 24 hours. It's mild if those conditions are *not* met. **Concussion is classified as a mild TBI.**

SYMPTOMS OF TBI

MODERATE TO SEVERE TBI

Accounts for 10% of all cases

SYMPTOMS:

- slurred speech
- profound confusion
- seizures
- persistent headaches
- coma

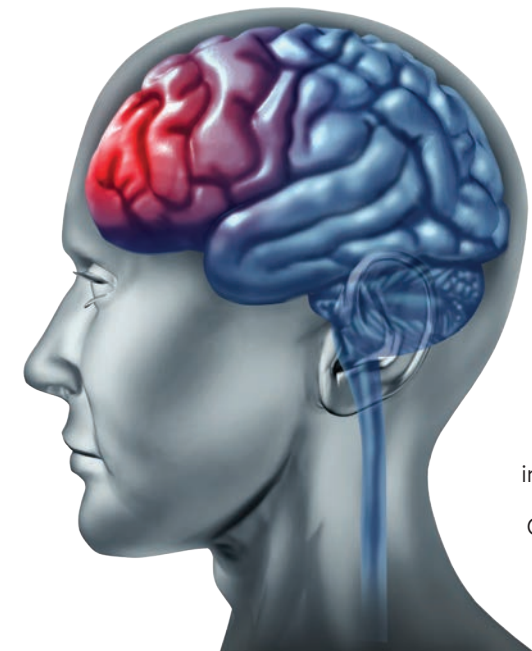
MILD TBI

Accounts for 90% of all cases (based on WHO information)

SYMPTOMS:

- headaches
- dizziness & fatigue
- sleeping difficulties
- memory & concentration problems
- blurred vision

MAJOR CAUSES OF TRAUMATIC BRAIN INJURIES*



*Based on information from the National Center for Injury Prevention and Control, CDC

1%	SUICIDE
11%	ASSAULT
19%	STRUCK BY OBJECTS (INCL. SPORTS)
20%	MOTOR VEHICLE ACCIDENTS
21%	OTHER
28%	FALLS

PROMINENT TBIs

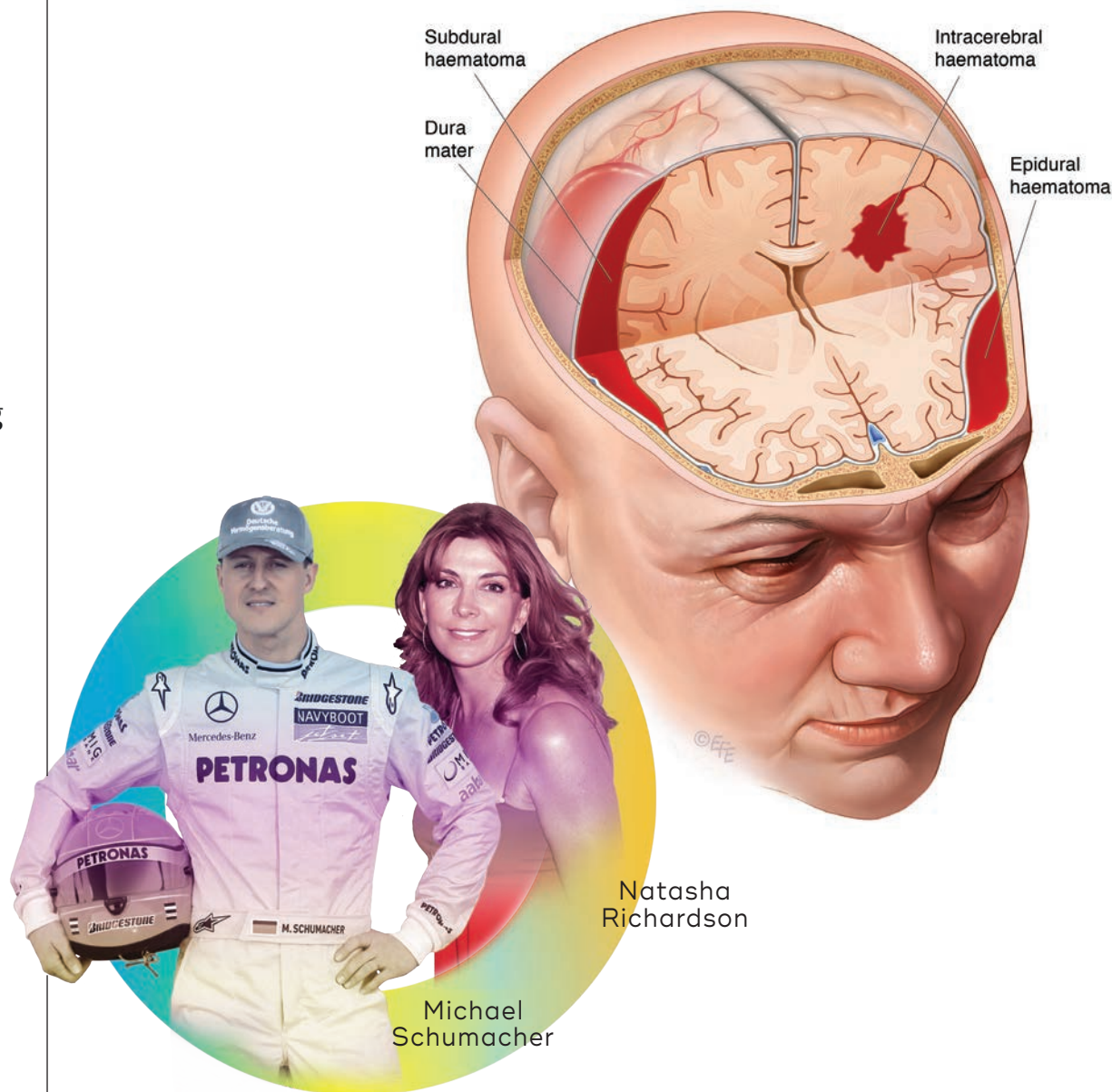
The tragic outcomes of a spate of one-punch attacks – so-called ‘coward punches’ – in recent years has drawn considerable attention and resulted in harsher sentencing laws for perpetrators. Many researchers in the TBI field argue the tough laws are justified because even when a single punch isn’t lethal, or doesn’t have any apparent immediate effects, the head trauma can lead to irreversible consequences years or decades later.

Recent highly publicised cases of severe TBI have included Formula One driver Jules Bianchi who died as the result of head injuries received when the car he was driving crashed during the 2015 Japanese Grand Prix.

Retired Formula One driver Michael Schumacher continues to receive intensive treatment for severe head injuries that he suffered during a skiing accident in France, in 2013. In both of these cases, a severe TBI resulted in an immediate and prolonged loss of consciousness.

However, a loss of consciousness isn’t always necessary for the consequences of TBI to be catastrophic. In 2009, British actress Natasha Richardson knocked her head while skiing. Thinking she was fine, she refused medical care on multiple occasions before later experiencing headaches that prompted her to go to hospital. Richardson subsequently died due to an epidural haematoma, a build-up of blood between the skull and the membrane that surrounds the brain (see illustration right). Haematomas are considered secondary injuries, meaning that the damage done to the brain doesn’t coincide directly with the blow to the head.

BRAIN HAEMATOMA



CONCUSSION BY NUMBERS (ESTIMATES ONLY)

The ratio of men to women who are likely to suffer concussion.

2:1

The proportion of injuries that are head injuries in rugby union, league and Australian rules football.

10%

6-10

Number of concussions per 1000 hours of playing rugby union, league or Australian rules football.

0.4-0.7

Number of concussions per 1000 hours of playing soccer.

70-90%

The percentage of traumatic brain injuries that are concussions.

42 MILLION

The number of annual concussions worldwide.

5%

The percentage of all sporting injuries that concussion makes up.

89%

The percentage of concussions that may go unassessed by medical professionals.



THE MESSAGE

Most blows to the head are minor and nothing to worry about, producing no symptoms other than pain and perhaps a small tender lump. However, the Natasha Richardson case highlights the fact that even seemingly innocuous head knocks can *later* produce devastating effects. Warning signs to watch for after any form of head injury, no matter how minor it might seem, include: persistent headaches, balance problems or cognitive changes. **If a head injury results in a loss of consciousness, increasing confusion, vomiting or a worsening headache, the person should see a doctor.**

HELMETS: WHAT ARE THEY GOOD FOR?



Before describing how helmets work and what they're capable of, it's important to understand how injuries can result from head impact. A blow to the head can cause the brain to move back and forth (translational movements) or rotate and twist on itself (rotational movements).

In translational – back and forth – movements, the brain crashes against the skull, potentially even rebounding in the other direction and receiving a second impact with the opposite side of the skull. The damage is done by direct impact and is much like bruising. In rotational movements, as occurs when the head is struck at an angle, the brain itself twists, causing damage as neurons rub against each other in a shearing fashion.

Hard helmets protect reasonably well against translational movements and the impact injuries they cause, significantly reducing the risk of skull fractures and bleeding inside the skull – intracranial bleeding. They are far less effective against rotational movements and it's these that researchers believe are responsible for most concussions. This means that a helmet may protect the head better against severe TBI, which is caused by translational forces, than against concussion.

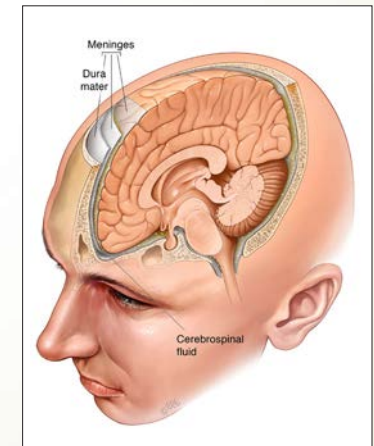
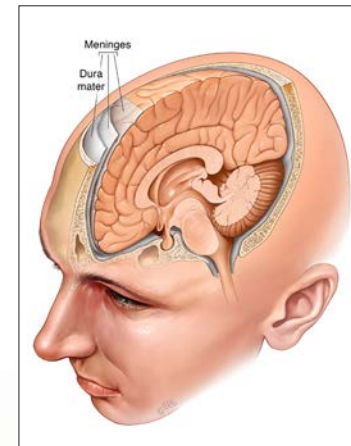
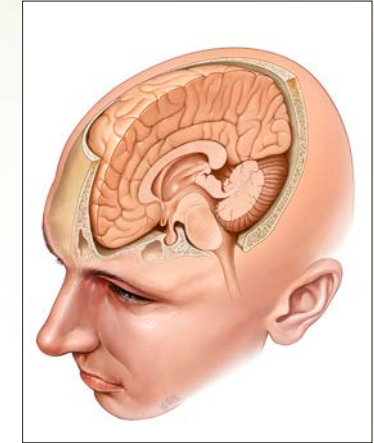
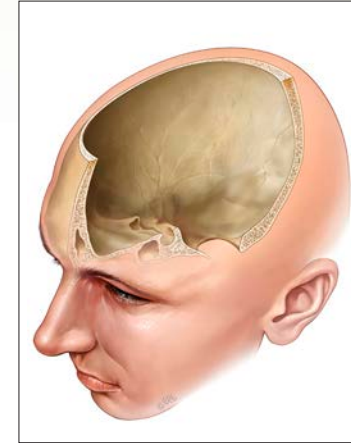
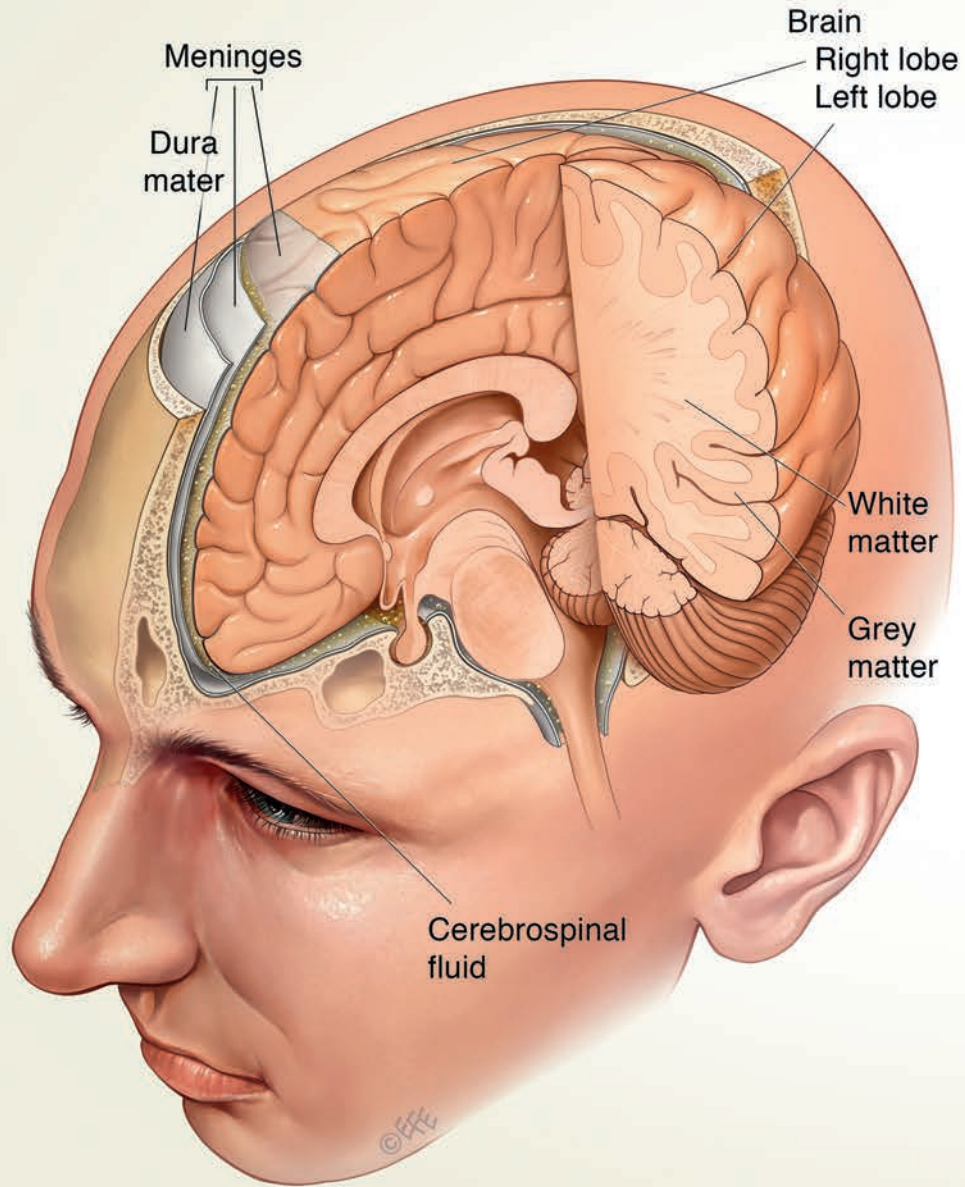
Why is this the case? Helmets are designed mainly to dissipate force. Most sports helmets consist of a hard outer shell and an inner foam layer, normally of polystyrene. The hard shell spreads or dissipates the impact force over a larger area. Meanwhile the foam inner section also reduces the peak impact by extending the distance of head deceleration – meaning that it takes longer for the head to slow down, which makes the movement less abrupt. The foam layer also crushes and deforms, which absorbs as much of the remaining energy as possible. While these factors decrease the level of the impact force, they do little to address rotational forces caused by head movement and any concussion this might cause. There is no evidence that the soft headgear players in some Australian football codes wear protects against head injury.

Many current attempts to improve helmets still focus on decreasing impact by using new materials, or on developing different foam and shell arrangements. However, the growing concussion crisis has led some researchers to try to limit rotational forces as well, with helmet manufacturers now looking to incorporate elements that slide against each other upon impact.



THE MESSAGE

Helmets, of course, are good for protecting against brain injuries. But they don't do a good job against all types of head impact. Different impacts cause different head movements, and different head movements result in different injuries.



The FRAGILE BRAIN

Several layers protect the fragile brain. The meninges are membranes that lie between the brain and the hard skull; the dura is the toughest of these layers and adheres to the skull, providing a sac that limits brain movement. Cerebrospinal fluid cushions the brain when the head moves around, limiting contact with the skull.

ILLUSTRATION BY LEVENT EFE

Perspectives

NICK RUSHWORTH

EXECUTIVE OFFICER,
BRAIN INJURY AUSTRALIA

Nick Rushworth is more familiar than most CEOs with the effects of traumatic brain injury (TBI). Twenty years ago, he was in a major bicycle accident involving a head-on collision with a car. He was hit mid-leg, breaking both his femur and the bicycle frame.

“I was catapulted over the bonnet of the car and took the full force of the impact near my right ear,” Rushworth says. “I pretty much fractured my skull right around.”

Motor vehicle accidents are the second-most common cause of TBI in Australia, after falls. Depending on its severity, TBI can cause a range of long-term disabilities and changes in feeling, thoughts and behaviour.

Rushworth has no memory of his accident – nor of the proceeding two weeks he spent in hospital. “My almost-continuous memory starts again when I was discharged from hospital into rehabilitation, but even then, it was very fragmented,” he recalls now.

He also suffered short-term memory impairment. “I used to tell anyone who



“THE LACK OF PUBLIC AWARENESS ABOUT BRAIN INJURY MEANS THAT, IN A RETURN-TO-WORK CONTEXT, THEIR INABILITY TO CONCENTRATE, TO PAY ATTENTION, AND THEIR FATIGUE IS OFTEN MISTAKEN FOR LAZINESS.”

cared to listen about the story of my accident, and tell them repeatedly,” he says.

A neuropsychological assessment brought sombre news: it found “that my intellectual capacity, my ability to concentrate, to plan, to organise, was going to be ‘radically impaired’.”

Despite this, Rushworth began a graded return to work as a journalist at the ABC in Sydney, and was back working full-time six months following the accident. Initially, he found the noise of the busy newsroom environment challenging, but feels fortunate that his working life was able to continue more or less unaffected.

“I had a really easeful return to work, given the severity of my injury,” he says, adding however that this isn’t the case for the vast majority of people who suffer a brain injury. “For a lot of people, the lack of public awareness about brain injury means that, in a return-to-work context, their inability to concentrate, to pay attention, and their fatigue – which is a huge issue post-brain injury – is often mistaken for laziness.”

Behavioural problems, Rushworth adds, are sometimes perceived as simply being “who’ve they’ve always been as a person”, a misconception that he says is “re-disabling” for the injured individual.

Rushworth is now the Executive Officer of Brain Injury Australia, the peak body for more than 700,000 Australians living with acquired brain injury. In this role, he raises awareness about the causes, types, and effects of brain injury, ranging from concussion in sport to more severe brain injury resulting from assault or accidents.

“The aim,” he says, “is to make someone’s return to work or return to community life as easeful as it was for me.”

Chapter 3. CONCUSSION & SPORT

It's not often a major Hollywood movie is devoted to a single medical condition. But in late 2015, the film *Concussion* was released, telling the story of a forensic pathologist's attempts to shine light on the American National Football League's hidden secret of chronic traumatic encephalopathy (CTE) – a long-term complication of repeat concussions.

The film's release represented a peak in public attention on a condition that had previously not been discussed much outside medical circles but suddenly seemed to be worryingly common. The film is set in 2009. In the years since then, attitudes towards concussion in professional sport have come a long way. Concussion is now widely recognised as a medical issue for many sports. In many codes it's team doctors who are being given final say about if and when a player can return to play after a head injury. Most importantly, they're being given the authority to apply medical reasoning to override the wishes of coaches and even the players themselves.



'IF IN DOUBT, SIT IT OUT'

Melbourne-based neurosurgeon and concussion expert Professor Gavin Davis says the general attitude to the condition just 10 years ago was that players should 'get over it and get on with it'. Today it is no longer seen as a sign of weakness to be ruled out of play because of concussion. In the Australian Football League (AFL), there are specific rules around head knocks, such as a mandated 20-minute period off the ground to complete a concussion medical assessment, and no return-to-play

if a concussion diagnosis is made.

Professor Davis says the AFL has been ahead of the game on concussion, working with concussion experts for many years and convening a concussion working group in 2010, long before head knocks began grabbing headlines. That working group has developed guidelines to help doctors, coaches and players diagnose and manage the estimated 6–7 cases of concussion that occur per team per season across all levels of AFL competition. The key principles of these guidelines are that concussion is a complex and still poorly understood

condition that needs to be managed using an individual-based approach with a number of steps, including:

- A period of rest
 - Monitoring for ongoing or changing signs and symptoms
 - Neuropsychological tests to monitor recovery
 - A graduated return to activity in conjunction with monitoring
 - A doctor's OK before returning to play
- These recommendations are now found in a similar form in many other sport

concussion guidelines around the world. The overarching mantra, however, is ‘if in doubt, sit them out’.

FROM NATIONAL LEAGUES TO SCHOOL COMPS

The heightened awareness of concussion at the professional level has also filtered down to community sport, says Professor Caroline Finch, director of the Australian Centre for Research into Injury in Sport and its Prevention – a unit based at Victoria’s Federation University Australia. Unfortunately, the messages about concussion are often mixed or misinterpreted. Some parents are so concerned about the risks and consequences that they keep their child off the sports field altogether.

Others see professional players return to the field after a head knock during a game, and assume therefore that concussion isn’t *that* serious. Professor Finch says concussion guidelines also apply to community sport. But without the same level of medical support that’s available to professionals, those guidelines aren’t always implemented with as much rigour. However, it’s an issue taken seriously by many codes, some of which issue guidelines specifically targeted at the community level.

“Whatever sport you play it’s a short stand career. You want to make the most of it but there’s life to live afterwards,” says Tatafu Polota-Nau, (pictured below).



TATAFU POLOTA-NAU

As a player with the NSW Waratahs and Australian Wallabies, Tatafu Polota-Nau has had his fair share of concussions and knows how tough it can be to accept the doctor’s advice to take a break from play, even for a short time. “Straight away, your basic instinct as a rugby player tells you that you need to get back on the field straight away,” he says. “But in hindsight, you look at the [television] footage and you see clearly you were in a dazed state.

“That tension is felt by player, coach and doctor because they’re looking after the game and the health of the player too. It’s a hard one to judge, and especially in a final game – there is no bigger stage.”

The changing attitudes to concussion have had a big impact on players, and ultimately on the teams and game. “It has been a big eye-opener, particularly for professional players because although you think you’re doing the right thing by your team mates by playing on, you’re not because you’re not 100% in focus,” Polota-Nau says. “At the end of the day, becoming more mature with it but also having a bit of experience means you can definitely tell what’s better for the team initially and also for your health as well.”

There’s also the awareness now that repeat concussions could have longer term implications for players; something that Polota-Nau says made him more aware of proper tackle technique, so as to reduce the chance of him suffering a concussion from, for example, a ‘flying superman’ tackle.

“Whatever sport you play it’s a short stand career,” he says. “You want to make the most of it but there’s life to live afterwards.”

Players' Perspectives

IAN PRENDERGAST

CEO, RUGBY LEAGUE
PLAYERS ASSOCIATION

Former Australian Rules footballer Ian Prendergast has seen a big change in attitude to head injuries since he was playing professionally for the Carlton Football Club in the early 2000s. “Back in my day, there wasn’t as much awareness around concussion,” he says. “It was almost a badge of honour for players to continue playing after a serious knock.”

Now, educating coaches and players about concussion is an integral part of his working life. After finishing his career as a player, Prendergast went on to represent the interests of elite footballers at state, national and international levels, first as a general manager for player relations at the AFL Players’ Association (AFLPA) and now as Chief Executive Officer of the Rugby League Players Association (RLPA).

During his time at the AFLPA, the association worked closely with the sporting code to push for a conservative approach to concussion management and Prendergast is taking a similar



“BACK IN MY DAY, THERE WASN’T AS MUCH AWARENESS AROUND CONCUSSION. IT WAS ALMOST A BADGE OF HONOUR FOR PLAYERS TO CONTINUE PLAYING AFTER A SERIOUS KNOCK.”

approach at the helm of the RLPA. “It’s really our job to continue educating people about the respect they need to have for the measures that are being put in place,” he says.

Another priority is limiting the number of incidents that go unnoticed or aren’t properly assessed. “From a health and safety point of view, there’s a huge amount of money generated from the performance of players, so equally there needs to be a huge amount of investment in protecting their safety on the field,” Prendergast says.

These days, players are being forced to take concussion much more seriously than they once did. “Now, I think there’s a greater acceptance of the need to report any symptoms that may be linked to concussion so that you can be properly assessed and removed from the game if necessary,” Prendergast says, adding that there is more work to be done. “We still need to be able to assess in a more objective way the impact that concussion is having, both immediately after the incident, but also with respect to the recovery and treatment required to rehabilitate a player.”

Prendergast believes that finding answers to the unknowns about concussion is crucial. “Research is key because knowledge is power,” he says, “and the more information we discover, the better informed our approach can be.”

Players' Perspectives

JUDE BOLTON

RETIRED AFL PLAYER,
SYDNEY SWANS

During more than a decade playing first grade with the Sydney Swans, retired Australian Football League (AFL) star Jude Bolton experienced several major head collisions.

He concedes that throughout his career he prided himself on resilience at the expense of his brain and once wore concussion as a badge of honour. “That meant taking any hits and just getting up and getting on with it,” Bolton recalls. “I remember my grandfather always saying, ‘It’s better to wake up in an ambulance than to duck out of a contest.’”

But concern about the long-term consequences has since made him an advocate for player welfare. “It was actually my same grandfather who then said to me after I sustained two concussions in one game – and played the following week – ‘You don’t want to be a dribbling mess when you’re an old man,’” Bolton explains. “A brain injury is not like any other injury. Each head knock is different and sometimes the



“A BRAIN INJURY IS NOT LIKE ANY OTHER INJURY. EACH HEAD KNOCK IS DIFFERENT AND SOMETIMES THE INNOCUOUS ONES CAN BE THE WORST.”

innocuous ones can be the worst.

“I know that having sustained multiple concussions puts me in a high-risk category. I would hate to think that the way I played may contribute towards potentially having something like dementia, CTE or depression later in my life.”

Bolton emphasises, however, that he doesn’t want the sport to change. “AFL is a tough and sometimes brutal sport that I love,” he says. “I never want to see the physicality taken from the game, nor do I ever want families to not allow their kids to play sport. There are so many health issues that kids and adults have just through not being as active as they should.”

Bolton says better protocols and increased awareness are important steps forward and senior players sitting out of the game for a week, or not returning to the game after a concussion, are wonderful examples for young players to look up to.

He believes science is the key to improving player safety: “I would love to see the research be to a point where we have absolute certainty on the protocols and that kids, families and all sporting clubs know what to do if a concussion is sustained, and have an ability to limit any long-term effects.

“In the end it is just a game. You only get one brain.”

Players' Perspectives

JUSTIN CLARKE

RETIRED AFL PLAYER,
BRISBANE LIONS

Justin Clarke has no memory of the head knock that ended his promising Australian Football League (AFL) career at the age of just 22. Nor can the former Brisbane Lions defender recall the three weeks following that concussion.

“That period was a tough time because I wasn’t able to do much,” Clarke says, explaining that he had a severe headache, and spent most of that time in the dark, because his symptoms became worse in light. “Every little thing sort of set me off, and I struggled to get outside much.”

Clarke sustained the concussion during a routine training session, and footage of the collision appears innocuous. “I just got a little shove in the back and that propelled me into a bloke who was running in the opposite direction, into his knee,” he says. The impact knocked Clarke unconscious. He had sustained head knocks in the past, but soon realised this concussion was different. One month later, his symptoms still hadn’t improved. His brother had gone through a similar experience and Clarke “had an inkling that things might not turn out for the best.”



He was assessed separately by three doctors and each urged that he avoid future contact sport – a heavy recommendation for a young athlete with his entire football career ahead. Although his decision to retire, in March 2016 after four years playing with the Lions, has been heartbreaking, it wasn’t difficult. “When you have three specialists all tell you that you’d be pretty silly to play footy again, then you’d be a stupid man to go against

that advice,” Clarke says.

But calmly taking medical advice can be a different story when a player sustains a head knock during a game. Clarke agrees that concussions are common in sport, particularly football, and believes that managing how they are diagnosed and treated is crucial. An objective field-side test would be ideal, he says, as it would override a player’s often-skewed self-assessment. “A player in that moment—whether it’s for the best or not—they’ll want to be back out there. I wanted to be back out there,” Clarke explains. “It’s about being able to control how much say that player has in that moment, and being able to ensure their safety first and foremost.”

Clarke says increased awareness of the symptoms of concussion is also important. “Amateurs experience concussions just as much as professionals do,” he says, adding that his message to young players is, “there’s no need to be a hero and go back out into the field if they’ve been concussed or have concussion symptoms.”

But Clarke doesn’t hesitate in his praise of AFL. “I would be really encouraging of my kids to play contact sports because it’s such a wonderful environment to grow up around,” he says. “It’s such an important thing that we can increase concussion awareness, and increase research into it, so that people can keep on playing the sports that they love.”

Players' Perspectives

JOCELYN BARTRAM

HOCKEY PLAYER,
HOCKEYROOS

Jocelyn Bartram was destined for a career in sport. She was an active, outgoing child who always wanted to be involved in any sporting activity that was going and eventually followed in the footsteps of her mum and brother who played hockey.

“Despite playing soccer, water polo, basketball and tennis during my childhood and adolescence,” Bartram recalls, “hockey has always been my most loved sport and passion.”

Through years of perseverance and hard work, she finally caught the attention of national selectors and has been part of the development squad for the Australia women’s national field hockey team – the Hockeyroos – for the past 18 months. Now she’s set her sights

firmly on this year’s Olympics in Rio.

Despite its sticks, hard balls and the furious pace at which it’s played, hockey is not a contact sport and so it’s not normally an activity that springs to mind when concussion is mentioned. And yet Bartram has experienced concussion regularly on the hockey field.

“My first experiences with concussion and hockey came at an U21 Nationals when a teammate missed six consecutive games due to a concussion and at an international level when I witnessed a Great Britain team member escorted away in an ambulance after she fell and her head collided with an opponent’s knee resulting in a major concussion,” Bartram says. “Personally, just a few months ago I missed a training session after I collided with a teammate in a contest for the ball, where my helmet was knocked off, and I suffered a reasonable headache. I was monitored for the remainder of the day and concussion-tested to make sure I hadn’t suffered any further damage.”

Bartram was attracted to QBI’s concussion campaign because growing up as a hockey goalkeeper, with a parent in the medical profession, she was always very aware of both the short- and long-term potential effects of concussion.

“As I’ve grown older and started studying exercise and sport science, the importance of concussion awareness and treatment has only become more

prevalent,” she says. “I would love the opportunity to educate a wider audience about the importance of looking after your brain whilst playing contact and non-contact sport at all levels.”

In hockey, players are at risk of colliding during play when they go in to contest the ball, during a low defensive tackling situation. Goalkeepers are at even higher risk due to the nature of the position.

“Although, I feel I have a good understanding of the range of effects that concussion can result in, I think some sportspeople are not aware but also feel ‘that it won’t happen to me’, especially in non-contact sports, where concussions aren’t as regular as other more visible injuries,” Bartram says. She believes that just because concussion isn’t a visible injury, it shouldn’t be taken lightly.

“It’s important to have a strict concussion protocol in place and, although it may feel like a bit of overkill at the time of your concussion, it will make all the difference in the future when you have moved on from elite sport and are living the next chapter of your life.”



Players' Perspectives

GABI SIMPSON

NETBALLER,
QUEENSLAND FIREBIRDS



For netballer Gabi Simpson, who plays mid-court with the Queensland Firebirds, the most eye-opening aspect of sustaining a concussion was that it initially went unrecognised. Netball at the elite level is intensely physical but is not classified as a contact sport. Although concussions do occur, they are rare.

During a game, 23-year-old Simpson was accidentally hit by a teammate. “She was running backwards and I got an elbow to the jaw,” Simpson recalls, explaining that the impact threw her head backwards, resulting in whiplash. “I felt my eyes go a bit blurry, but I didn’t think anything of it. I did get some migraine symptoms pretty soon after, but we thought that was because of the whiplash effect on my neck.”

Unaware that she had just sustained a concussion, Simpson continued to play. It wasn’t until three days later, on her way to a university class, that her symptoms worsened and she sought medical attention. Simpson experienced a severe headache, sensitivity to light, and vomiting. “It was pretty horrific,” she says. “I ended up having to be in a dark room for three days – no screens, no light

“I ENDED UP HAVING TO BE IN A DARKROOM FOR THREE DAYS – NO SCREENS, NO LIGHT AT ALL. IT PROBABLY TOOK A WEEK-AND-A-HALF FOR ME TO BE FULLY SYMPTOM FREE.”

at all. It probably took a week-and-a-half for me to be fully symptom free.”

Since the incident, Simpson has gained a greater awareness about head injury and its lasting impacts. “The thing that scares me the most is that we didn’t know I had concussion,” she says.

Simpson agrees that loyalty to a team often factors into a sportsperson’s

decision to play on after sustaining an injury. “As an athlete, you’re there for your team. Your culture is that you’d do anything for the team, anything for the win,” she says. “So if you do get a knock, you think, no, I’m going to stay on for my team.”

Now her own concussion experience has shown Simpson the importance of recognising, and not ignoring, the symptoms.

Athletes put their minds and bodies on the line, but it’s about “knowing when it’s time to stop,” she says.

Simpson believes that research is the key to more accurate concussion diagnosis. “The more information we know, the stricter we can be on our reaction to concussion,” she says. “I think that’s extremely important.

“I value my brain, and I study, and I need to think about the long term.”

Chapter 4. KIDS & CONCUSSION

Most parents would say childhood is a concussion waiting to happen. Whether it's toddlers with a fascination for staircases, children who love riding bikes, or adolescents playing sports with reckless enthusiasm, at some point many young people will thump their head hard enough to make a parent's heart stop.

Just as with concussion in adults, there is growing awareness of the potential long-term consequences of the injury in young people. Where once a child or adolescent might have been sent back to the playground or back to school after a head impact, now parents, teachers and doctors are taking a much more conservative approach to managing concussion.



THE DEVELOPING BRAIN

Because children have weaker necks and torsos than adults, less force is needed to cause a brain injury. Most concussion cases occur in young people aged 5 to 14. In children and adolescents, the two most common causes are sporting and cycling accidents.

There is still only a limited understanding of the effects of concussion on the developing brain, partly because studying these is difficult. The developing brain responds to trauma differently to the adult brain, and is in some respects more vulnerable to damage.

The frontal and temporal

lobes of the brain – regions responsible for executive functions and processing sensory input – continue maturing into the early 20s. Damage to still-developing areas has the potential to result in detrimental long-term effects.

However, most children recover fully from concussion. For children who have suffered a concussion – or other mild traumatic brain injury – studies have found no significant differences in learning performance in school-aged students compared to their peers. However, in another study of students aged five to 18, the presence of more severe post-concussion syndrome symptoms was associated with more school-related problems and poorer academic performance.

In 2016, the Australian Medical Association (AMA) and Australian Institute of Sport (AIS) released a joint position statement on concussion. They recommended that parents, coaches and sports administrators should “err on the side of caution” and not allow any child or teenager with a potential concussion to return to the sporting field until at least two weeks after being cleared of symptoms.

See ama.com.au/position-statement/concussion-sport-2016

CLEAR COMMUNICATION IS KEY

Children often play sport in an informal setting with little supervision. As a result, many concussions in children and adolescents go undiagnosed and unmanaged, which can lead to repeat concussion and is best avoided. No child with a suspected concussion should be allowed to return to play until medically cleared, as the risk for subsequent concussion is increased.

Diagnosis in children is also complicated by difficulties with communication. While adults may be able to recognise and articulate their symptoms, younger children can struggle, which means parents and doctors have to be a little more direct in their questioning.

Professor Andrew Kaye, a neurosurgeon at the Royal Melbourne Hospital, says the best approach is to ask simple questions, like asking the child if they have a headache, feel dizzy, nauseated or unwell,

or whether they are having trouble concentrating.

One challenge with diagnosis, particularly in adolescents, is that many of the typical symptoms of concussion are also the typical 'symptoms' of being a normal teenager. One US study found a remarkably high prevalence of concussion-like symptoms, such as fatigue, headaches, sadness, difficulty concentrating and trouble sleeping, in a group of high-school athletes who had not actually experienced a concussion.

The authors of Canadian guidelines on concussion in children and adolescents, released in 2014, recommended that one way to address this could be to conduct baseline neurocognitive testing in children and adolescents who play sports with a significant risk of concussion, such as football, soccer, basketball and hockey.

GRADUAL RECOVERY

Another recommendation made by the guidelines was a gradual return to activity, with both physical and cognitive rest. For example, an adolescent who has experienced a concussion might be prescribed a period of



24 to 48 hours of complete rest, followed by a guided return to school but not physical activity, and finally, when the concussion is judged by a doctor to have resolved, a full return to activity. Throughout this process, their symptoms should be monitored, and their

plan tailored to their recovery.

This recovery can take a long time. A recent US study found that while the more well-known and immediate symptoms of concussion, such as headache and dizziness, can ease, emotional disturbances can linger. The study of

more than 200 young people presenting with concussion showed that irritability and sleep disturbances lasted 16 days on average, while frustration and poor concentration lasted an average of 14 days. Young people who have sustained multiple concussions are more likely to experience prolonged symptoms.

Professor Kaye stresses that while it's important to be aware of the risk of concussion, and to manage it appropriately when it does happen, the low risk of a concussion in children's sport is far outweighed by the benefits of physical activity that come with playing sport.

Chapter 5. DIAGNOSING CONCUSSION

Visualising concussion-related changes in the brain is particularly challenging. Unlike the bleeding inside the brain that might occur with a severe head impact, no obvious structural changes accompany concussion. This lack of obvious damage means that much of the imaging research in concussion focuses on changes in brain *function* rather than brain *structure*.

LOOKING FOR PATTERNS IN THE BRAIN

MRI

Although techniques such as magnetic resonance imaging (MRI) are usually unable to detect structural changes in the brain following a concussion, specific specialised MRI scans can. MRI uses a strong magnetic field and radio waves to build up a picture of the



brain. One imaging technique that can currently detect structural changes in the concussed brain is diffusion imaging, which looks at patterns of water movement through brain tissues.

Professor David Reutens,

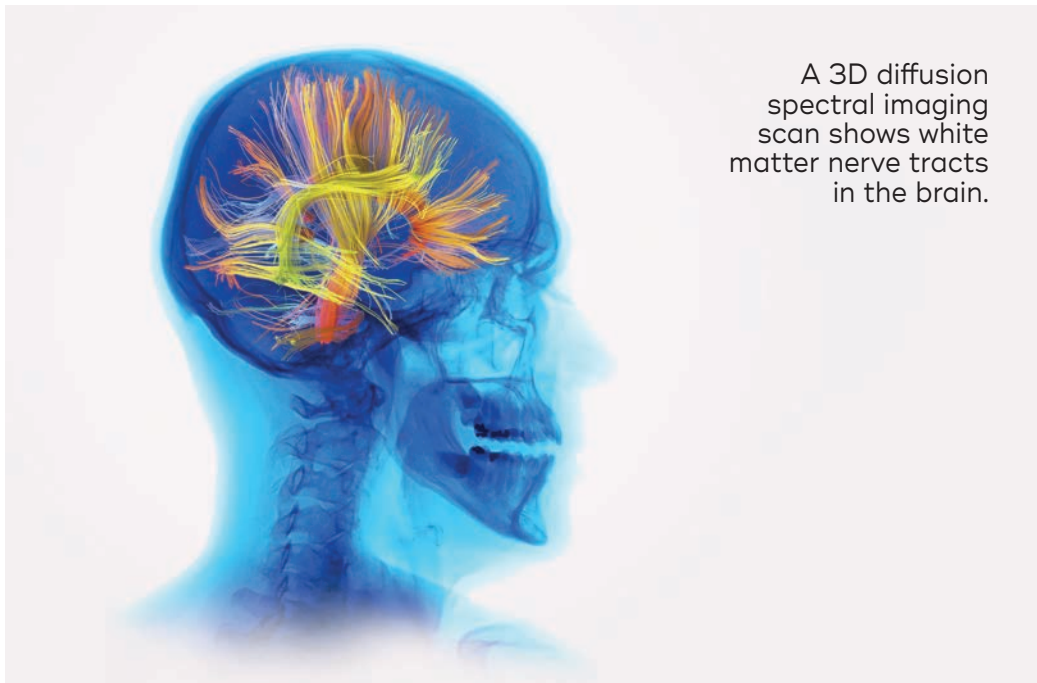
Director of the Centre for Advanced Imaging at The University of Queensland, says that diffusion imaging is revealing some of the subtle damage of concussion. This includes, for example, evidence of disruptions in

the white matter. White matter is like the ‘skeleton’ of the brain; it’s a framework made up of the main parts of nerve cells – the long sections known as axons – and glial cells, which are the most common type of cells throughout the central nervous system.

These disruptions to the white matter are microscopic breaks that, Professor Reutens explains, may affect connectivity and impair brain function. Instead of neurons firing together in coordinated networks, they are out of sync. It’s like, he says, a bunch of loudspeakers playing the same thing but slightly out of time with each other, giving the sound a fuzzy quality.

MR SPECTROSCOPY

A second approach to studying concussion using imaging technology involves a technique called magnetic



A 3D diffusion spectral imaging scan shows white matter nerve tracts in the brain.

resonance (MR) spectroscopy, which looks at changes in brain chemistry. MR spectroscopy is revealing that certain substances produced by brain cells as part of their usual activity are altered by concussion. This is the case even in people who don't show outward signs of concussion. This suggests that in even the mildest concussion, the energy processes going on in brain cells are altered by the impact.

fMRI

Researchers can look at changes in brain function by using another type of MRI known as a functional MRI (fMRI). This imaging allows us to see regions in the brain that are active. Dr Fatima Nasrallah from the Queensland Brain Institute has been using fMRI and other imaging techniques to study what happens to the brain in the immediate aftermath of a

In Profile

DR FATIMA NASRALLAH



Dr Fatima Nasrallah has a very personal reason for dedicating her professional life to the study of brain trauma. Her grandmother had dementia and Parkinson's disease, which worsened dramatically after a fall. Since then, Dr Nasrallah has applied the full spectrum of imaging technologies to advance our understanding of what is going on inside the brain during and after a traumatic brain injury. She began her research career studying biochemical brain changes using imaging, then shifted her focus to use MRI to study physical brain changes in animals.

A move to a clinical research facility in Singapore brought Dr Nasrallah into contact with military personnel who had been exposed to blast injuries. It allowed her to begin exploring how these injuries could be visualised using imaging technologies. Dr Nasrallah is now leading a large QBI study that will follow people with concussion over a long period of time. She's using imaging technologies to study brain changes and the effects of different treatments and interventions to reduce long-term damage from concussion.

PHOTOGRAPHY NICK VALMAS

concussion, as well as in the following weeks and months.

Specifically, she has been examining brain networks, which are the different patterns of activity associated with different brain functions. There are networks in the brain that are engaged during different activities, for example, during movement or emotional responses. The symptoms in diseases such as Alzheimer's and schizophrenia result from disruption to these networks.

For concussion, research is showing a similar brain network disruption, but one network in particular is affected. It's known as the 'default mode' network and it's the one that's most active when our brain is in what could be called 'idling mode'. We don't yet understand why this network is so important, or why it is particularly badly affected by concussion. But, says Dr Nasrallah, changes to this network are apparent soon after concussion.

For her work on brain networks she's been using laboratory mice, which provide good clues to what's going on in our brains because like us they're mammals. Dr Nasrallah has also been gathering information about what happens inside the heads of military personnel exposed to blast injuries, when they're not close enough to be knocked over but close enough to feel shock waves, which may shake the brain about inside the skull.

PET

Positron emission tomography (PET) is a form of imaging that uses a radioactive tracer to highlight certain types of material in the brain. For concussion, it's being used to study the development of abnormal tau tangles. These are known to be a feature of chronic traumatic encephalopathy (CTE), which is a form of dementia associated with repeated concussions.

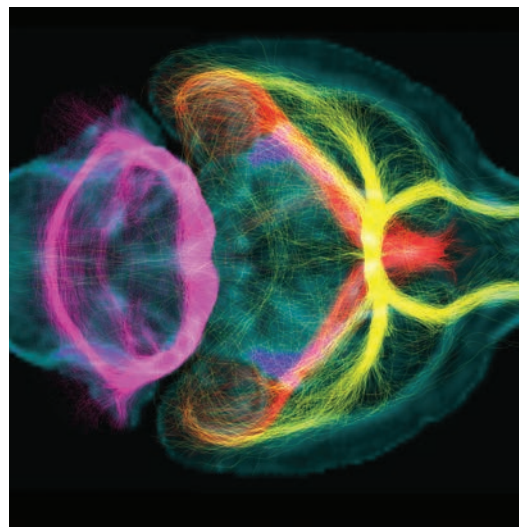
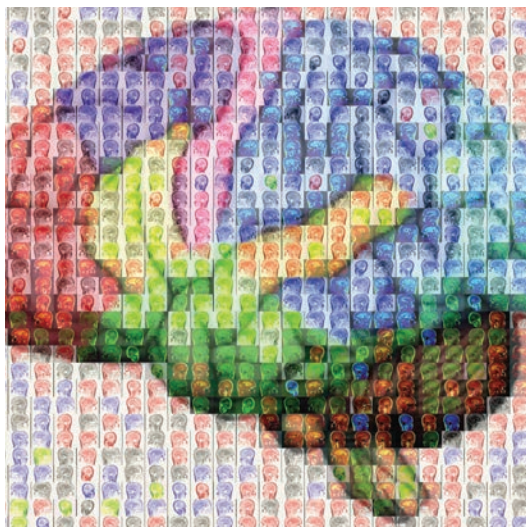
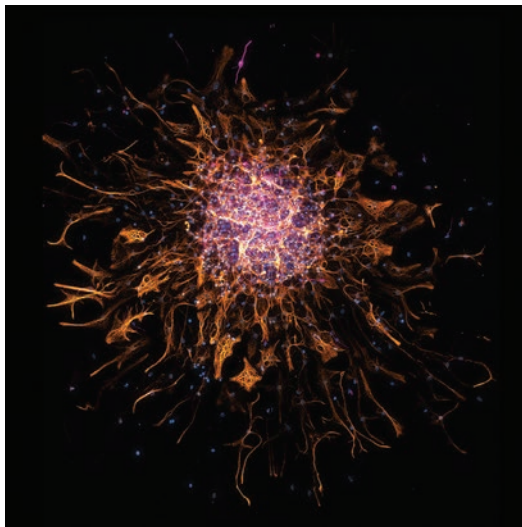
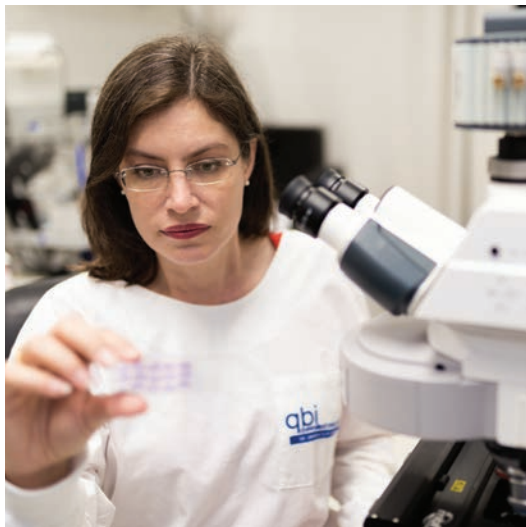
A US study of former NFL players suspected of having CTE used PET to generate maps of how tau tangles were distributed through the brain. Firstly, these tangles were confirmed to be absent from the brains of people who hadn't played football. In the ex-footballers the tangles were present and appeared to follow a particular pattern of formation. They appeared

first in the midbrain region, then moved to subcortical areas and the part of the brain that controls anxiety and stress, and finally showed up in the cortex. This was in contrast to what is seen in Alzheimer's patients, where tau tangles appear first in two areas: the hippocampus and the entorhinal cortex, which are both important in memory and navigation.



THE MESSAGE

Brain imaging studies are helping us understand what is going on in the brain during concussion. It's also hoped they might show characteristic changes with concussion or CTE that can be used to diagnose these conditions and monitor recovery. The reality is that what researchers are likely to find are a series of indicators that can be used by doctors in combination with clinical assessments to make a diagnosis of concussion and assess the recovery time required. That will enable doctors to predict who is more likely to suffer long-term consequences from concussion and allow them to intervene early to prevent or limit the damage.



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Email: Mikaeli.Costello@uq.edu.au
SMS 'BRAIN' to 0437 371 371 to donate



Queensland Brain Institute

Chapter 6. LONG-TERM CONSEQUENCES

Back in 1928 Dr Harrison Martland, a medical examiner in the US state of New Jersey, published observations in the *Journal of the American Medical Association* about a condition affecting boxers – notably “fighters of the slugging type”. His article was entitled *Punch Drunk* – a term used around boxing



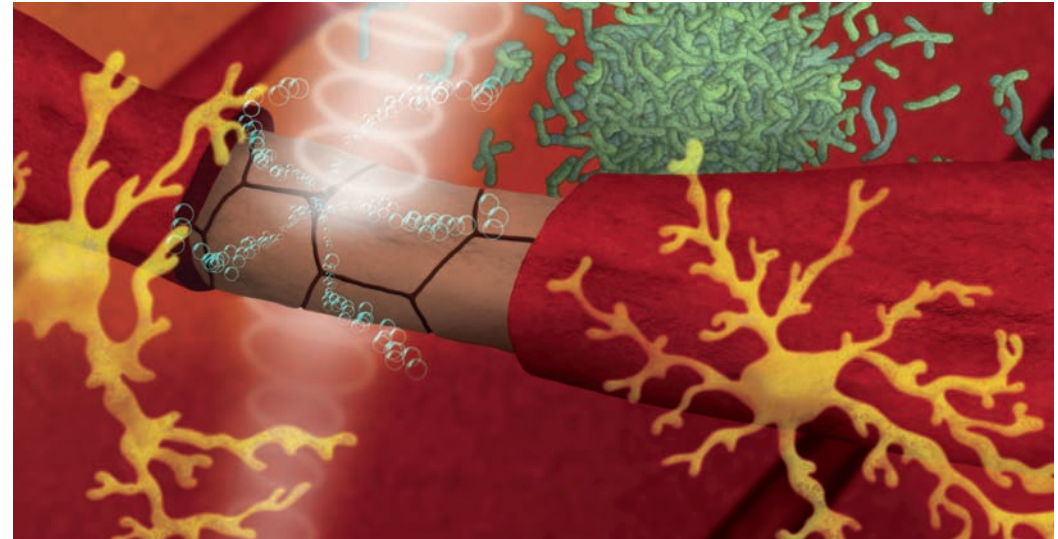
rings to describe men who’d taken “considerable head punishment”. They had tremors, a dragging foot or drooping hand, hesitant speech and walked with an unsteady gait.

It was the earliest published record of what we now call dementia pugilistica, a disorder found in people who have suffered repeated concussions. Martland saw it in boxers. But it has since been observed in a range of people who suffer head injuries, such as professional athletes in other sports and military personnel exposed to combat.

A PROTEIN CALLED TAU

There is now evidence that repeated concussions could be associated with the development in later life of a particular kind of degenerative disease called chronic traumatic encephalopathy (CTE).

ILLUSTRATION NICK VALMAS



Ultrasound can be used to transiently open the blood-brain barrier in models of Alzheimer’s disease, activating the brain’s waste disposal system and decreasing the build-up of amyloid protein. Another protein that builds up in Alzheimer’s is tau, which is also associated with chronic traumatic encephalopathy (CTE). Evidence suggests that the risk of developing CTE may be increased with repeated concussion.

This disorder has many of the same physiological hallmarks of forms of dementia, including Alzheimer’s disease, particularly the abnormal accumulation in the brain

of a protein called tau.

In a healthy brain, tau is found in the axons – the transmission lines – of neurons, where it plays an important role in maintaining the structure of the internal

transport system of these nerve cells. In conditions such as Alzheimer's and CTE, tau instead forms tangles that clump together to disrupt the cells' transport system. These are known as neurofibrillary tangles and sometimes simply tau tangles. They're a cellular signpost of what are known as tauopathies: the group of degenerative diseases associated with aggregations of tau protein in the brain. These tangles are thought to eventually lead to the death of neurons.

As more and more neurons die and large areas of brain tissue become affected, symptoms such as those described by Martland appear: memory loss, confusion, Parkinson's-like tremors, walking problems, impaired judgement, depression and personality changes.

CONCUSSION AND OTHER DISORDERS

Evidence also suggests that repeated concussion may

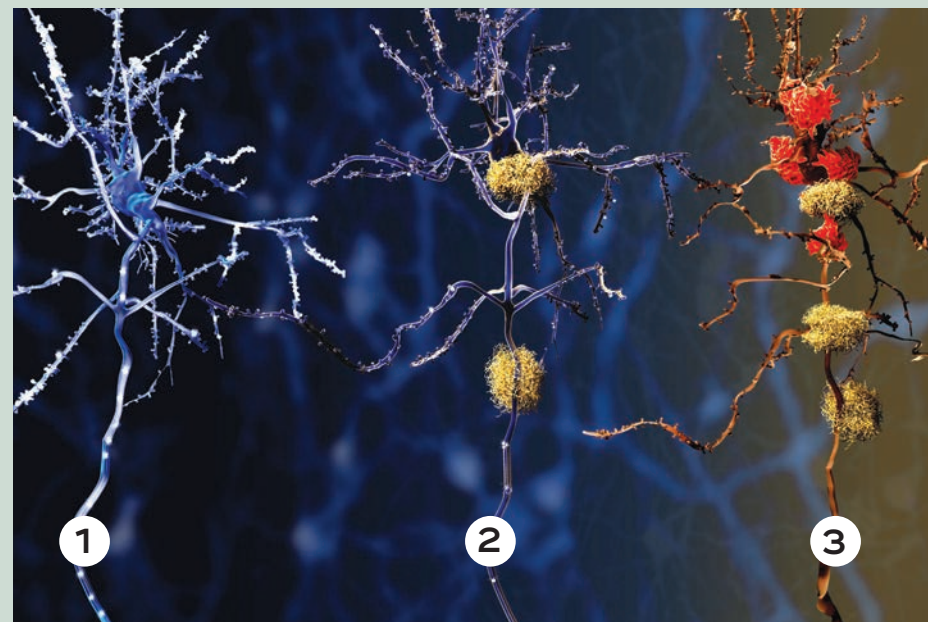
increase the risk of developing other neurodegenerative conditions such as Alzheimer's and Parkinson's disease, as well as conditions such as depression. A study of more than 2000 former American footballers, for example, found that players with a history of multiple concussions were three times more likely to have been diagnosed with clinical depression than the general population. A 2014 report from the American National Football Association predicted that nearly 30 per cent of former players may go on to develop chronic brain conditions as a result of trauma.

CTE RESEARCH BRINGS MORE QUESTIONS

It's only since the early 2000s that CTE has been linked to concussion and, not surprisingly, there is still much work to be done in understanding the relationship between the two. We are, however, only

THE SOURCE OF TANGLED TAU

We now have a reasonable understanding of how the accumulation of tau that can form tangles damages neurons and causes the symptoms of dementia. However, explains QBI's Professor Jürgen Götz, we have less of an understanding about what causes tau to accumulate in the first place. One theory, he says, is that tau is physically dislodged from its orderly structure inside axons by the impact of a concussive head injury, altering its conformation and localisation in a nerve cell.



3 PHASES OF ALZHEIMER'S DISEASE.

1. Healthy neuron.
2. Neuron with amyloid plaques (yellow).
3. Dead neuron being digested by microglia cells (red).

just developing ways to see tau using imaging techniques such as positron emission tomography or PET. One major difficulty with studying CTE is that the only definitive way to make a diagnosis is by autopsy – looking at people’s brains after they’ve died.

We also don’t know how many or what type of concussions it takes for someone to develop CTE or how long it takes for the disorder to appear. Most importantly, we don’t know what can be done to prevent or reverse the damage.

The presence of abnormal tau tangles does offer a diagnostic and therapeutic target, just as it does in other tauopathies such as dementia and Alzheimer’s. Researchers like Professor Götz are exploring ways to remove the tau tangles, while others are focusing on imaging techniques that can reveal tau when CTE is still in its early stages, offering a greater chance of treatment.



In 2015, the QBI team led by Professor Götz (pictured above) announced one of the most exciting recent breakthroughs in Alzheimer’s disease research, one that is likely to also have consequences for concussion.

They discovered that ultrasound – as used to view babies in the womb – can also trigger the brain’s own waste disposal system to clean up deposits of a protein known as beta-amyloid in the brains of mice with Alzheimer’s disease (AD). These protein deposits are called amyloid plaques, and along with tau tangles, are a key feature of AD.

The team found that injecting safe microbubbles into the bloodstream and then pulsing the brain with ultrasound caused the impermeable blood-brain barrier to open temporarily. This opening is thought to activate microglia, resident garbage collector cells, which clean up waste products in the brain.

Professor Götz’s team found that the ultrasound method reduced the amount of abnormal protein and was also linked with improvements in the memory of mice with AD. The challenge now is to translate such a method to the human brain, but Professor Götz and colleagues in this field around the world are excited about the potential.

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Chapter 7. TESTING FOR CONCUSSION

If in doubt, sit it out. That's currently the best way to ensure that a concussion isn't made worse by a second head impact. But it can be a tough call to make, particularly for a professional sportsman whose career could hang on how quickly they get back on the field.

What if there was a simple test using blood or saliva that could be given within a few minutes of a suspected concussion to provide a definitive, reliable answer as to whether a player was concussed or safe to rejoin a match? It could also be used regularly in the days and weeks after a concussion to determine exactly when the player had recovered enough to return to the sport.

A bedside – or in this case, field-side – test is a key area of concussion research. It has become particularly important in recent years with the growing understanding of

the more serious long-term consequences of repeated concussions.

Developing such a test involves finding a suitable biomarker – something released into our body fluids in response to a head impact. The challenge is determining which specific biomarkers and their 'amounts' are unique to concussion.

It's still early days, but there are already some promising candidate biomarkers that could form the basis of such a test. For example, there are already blood tests in use for TBI, such as the S-100B test. However, this looks for a marker of more serious brain injury, the kind that would need neurosurgery. On a sporting field, that sort of injury would be obvious enough that a blood test wouldn't be needed.

A distinctive physiological feature of concussion is



Damage to the brain as a result of a head injury. A severed axon (above), shown in the centre of the illustration, prevents impulses travelling from one neuron to another. Blood vessels can also be torn during head injuries, and the resulting bleeding causes a compression of the axons with the risk of a coma.

damage to axons – the main shafts of neurons – caused by the shear forces associated with a knock to the head or whiplash movement.

Professor Henrik Zetterberg, a neurochemist from the University of Gothenburg in Sweden, has been looking at indicators of axon damage that might meet the criteria of a marker for more subtle brain damage. He says that, so far, research has singled out two key candidates. The first, the protein tau, is already making a name for itself as a biological villain of other conditions such as Alzheimer’s disease.

Research has shown that amateur boxers have higher levels of tau in the blood stream the week or so after a bout, even if they’re not knocked out. These levels then slowly return to normal around eight to 10 weeks after the impact, as long as the boxer doesn’t have any more head impacts during that time.

Similarly, a study by Zetterberg and his colleagues,

conducted among Swedish ice-hockey players, showed that tau levels were elevated in the blood after a concussion when compared to measurements taken at the start of the hockey season. They also found the levels of the protein S-100B increased following a concussion, although not nearly as much as tau increased.

Research has also found a correlation between blood

tau levels and the severity of a TBI, where levels were higher in patients with a poorer outcome following injury. These studies suggest the potential for tau to be used as a diagnostic indicator for concussion.

Another promising biomarker candidate for concussion is neurofilament light protein. Like tau, this is also a marker of damage to axons. Levels seem to peak four to 10 days after

the injury, but unlike tau, neurofilament light protein levels are raised in the cerebrospinal fluid. This liquid cushions the brain and spine, and samples can only be taken in a sterile hospital setting. The challenge now for researchers is to refine the tests for these biomarkers and use them in combination with imaging techniques in order to better diagnose concussion and assess when it is safe to return to play.

HELP QBI MAKE A DIFFERENCE.

Australia has a strong sporting culture. We love our sport: we watch our kids grow up playing it on the weekends, and our professional athletes are household names. The nature of contact sports means that head knocks are sometimes unavoidable. But changing the fundamental rules of these sports isn’t the only way to make them safer. Through research, we can improve the diagnosis and management of concussive episodes. Finding a suitable biomarker to test for concussion will enable rapid diagnosis and reduce the risk of repeated head injury. And imaging technology is helping us understand how concussion affects the brain. Longitudinal studies to track brain changes have never been undertaken before, and are the missing piece of the concussion puzzle. In the long-term, they are critical to understanding the lasting consequences of head injury, and will enable us to intervene early and prevent or reduce lasting damage. Through research, we can begin to tackle some of concussion’s unanswered questions.



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