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Should sports consider neuroimaging in the assessment of concussion?

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Title: Should “high impact” contact sports consider neuroimaging in the assessment of the short and long term consequences of concussion?

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What are the new findings:

There is heightened awareness of concussion in sports that have previously not thought to be at risk of long term consequences.

Appropriate care is needed in sports participants who demonstrate clinical symptoms of concussion, these include rule changes and training of those in a supervisory role.

There is no evidence regular neuroimaging would be beneficial without clinical evidence of intracranial lesion.

Use of functional imaging techniques have potential in identifying those at risk of long term consequences although more research will be needed.

Monitoring participants of contact sport over prolonged periods of time would be beneficial in establishing patterns in relation to chronic developments later in life.

MCQs

According to Baird (2010), how many deaths were recorded within United States Boxing over a 57 year period?

- a) 246
- b) 301
- c) 417
- d) 339

According to Jordan (2009), what is the most commonly identified head injury in boxing?

- a) Cerebral contusion
- b) Tripod fracture
- c) Sub-arachnoid haemorrhage
- d) Plaque formation

In 2013 which sport's regulatory body, settled a class action in relation to players suffering repeated concussions?

- a) Ice Hokey
- b) American Football
- c) Rugby Union
- d) Australian Rules Football

With reference to the Zurich Consensus, how long should a player demonstrating signs of concussion wait before returning to the game?

- a) 10 minutes
- b) 20 minutes
- c) 30 minutes
- d) They should not return

Which of the listed imaging techniques have potential in evaluating intracranial trauma?

- a) Computed Tomography
- b) Magnetic Resonance Imaging
- c) Single-Photon Emission Computed Tomography
- d) All of the above

Introduction

Sport and recreational activities are undertaken by many participants across the globe. The overwhelming majority of those participants will do so without injury and will return to play again on future occasions. The types of sports and recreational activities undertaken vary dramatically with some giving a greater risk of serious injury than others. Sporting injuries vary in nature from the minor to those with potentially life threatening or life altering consequences. Those sports that include repeated high impact collisions or involve deliberate attempts to strike the head give greater potential for intra-cranial injury which can have both short and long term consequences.

A newspaper headline of August 2013 referred to “rugby’s ticking time bomb”. The paper discussed the potential consequences of head injuries within this particular sport, describing the link between repeated concussion and early onset dementia, depression and other neurological conditions¹. Anecdotal evidence in rugby union, rugby league, Gaelic football and hurling suggests that the players are getting fitter, stronger and heavier. The rules of these games in some cases have been altered to make play more open and creating greater space between attack and defence, making the game more open and attractive to spectators. One result of this is to create bigger collisions between players at higher speed. Concussion is not a new phenomenon in sport but the former International Rugby Board Chief Medical Officer Dr Barry O’Driscoll warned of a tragedy waiting to happen within rugby union¹. Routine neuroimaging is used in professional boxing to, in the first instance; ensure that fighters who enter the ring are not at increased risk of intra-cranial trauma. The question posed is that could these images taken with short term monitoring in mind show the potential of a fighter to develop longer term neurological conditions. Routine neuroimaging of participants of other sports is not undertaken but given the popularity of rugby union, rugby league, Gaelic football and, more recently Mixed Martial Arts, cranial imaging could potentially help identify those players at increased risk of both short and long term neurological symptoms.

Acute pathology

Intra-cranial head injury as a direct result of sport is a rare occurrence but can be particularly tragic when they occur. Baird et al’s (2010) study gave the statistic of 339 deaths in 57 years in boxing in the United States with a mean age of 24². Given the raison d’etre of boxing is to render an opponent unable to defend themselves as opposed to scoring goals or making yardage, the potential for serious intra-cranial head trauma could be assumed to be greater.

A recent case of a 14 year old schoolboy dying as a result of “second impact syndrome” following a game of rugby union also highlighted that many of those who die from a sporting injury are young³. Cantu’s 1998 study on second impact syndrome described the condition as occurring when an athlete who sustains a head injury sustains a second injury before the symptoms of the first have cleared⁴. The pathophysiology is described as a loss of auto regulation of blood supply leading to vascular engorgement resulting in increased intracranial pressure and herniation of the temporal lobe or lobes below the tentorium of the cerebellar tonsils through the foramen magnum⁴. MRI

imaging is seen as the more sensitive to intra-cranial trauma with CT scanning being regarded as adequate in this 1998 study⁴.

Weinstein et al's 2013 case report of a 17 year old American Football player who suffered a head injury, complained of persistent headache and fatigue for three days. The CT scan on the fourth day post injury was interpreted as normal although the player was requested to not engage in practice until symptoms had resolved, a request that was ignored. The patient subsequently became unresponsive with generalised seizure activity at a practice session. Follow up CT scans reported thin bilateral subdural haematomas before MRI scans at the specialist centre revealed mild downward transtentorial herniation, bilateral subdural haematomas with abnormal T2 signal and restricted diffusion in the medial left thalamus. Midline structures were displaced caudally. Three years post injury, the player has regained some verbal, motor and cognitive skills. Significantly for imaging, the authors identify that both CT and MRI scanning are not guaranteed to identify the first impact pathology and should not be relied upon to do so. Clinical assessment is regarded as the most important step in identifying those who are at risk of second impact syndrome⁵.

Culturally, the commonly participated sporting past times of the United States and the UK differ but, it is important that research related to sports such as American Football and Ice hockey can be related to similar sports practiced in other countries.

Neuroimaging in Boxing

Boxing has existed in various forms for centuries with greater regulation coming in the last 150 years. Unlike most other sports, the purpose of boxing is to inflict punches on an opponent. Many of those punches are inflicted to the head area. Baird et al identified a reduction in mortality from head injuries since 1983, citing reasons for this as being shorter professional careers, fewer fights and better overall medical supervision. Such changes do not eliminate the risk of intra-cranial trauma and the first boxer since 1995 to die in the UK passed away in 2013, despite a normal pre-bout MRI scan².

Jordan (2009) identified cerebral contusion as the most commonly encountered injury in boxing with the more significant subdural haematoma, intra-cerebral haemorrhage, epidural haematomas and diffuse axonal injury being much less common⁷. The incidence of intracranial head trauma is believed to be higher in professional boxing than in the amateur game. The author identifies pre-bout neuroimaging as invaluable in the detection of pre-existing brain lesions alongside neuropsychological testing. Qualified medical personnel including an ambulance should be immediately available and that referees should be able to identify the early stages of concussion⁶.

Professional rugby matches will also have medical personnel and an ambulance immediately available although not purely for the purpose of evaluating potential head trauma. This will not be the case at matches played at a lower level, nor would resources permit this given the high number of games played. Training of players, match officials and club staff in a similar way to boxing referees in recognising the symptoms of concussion could be a potential way of reducing the risk to players. What is also of paramount importance is that the health of player must come before the result of the game.

Chronic Traumatic Brain Injury (CTBI) and Chronic Traumatic Encephalopathy (CTE)

Jordan (2000) associated CTBI with 20% of professional boxers with particular risk factors including length of career and number of bouts. Pathologically, there are considerable similarities with Alzheimer's disease including the presence of amyloid plaques⁷. Categorical diagnosis of CTBI can only be undertaken after death but clinical and radiological signs can demonstrate the presence of signs of degeneration⁷. McKee et al (2009) noted a similarity between CTE and Alzheimer's disease. Using the evidence available, they concluded that there is overwhelming evidence that CTE to repeated brain trauma well before the start of clinical symptoms. The examples they cite are predominantly American football players and boxers but the potential significance for other contact sports is present⁸.

In addition to CT and MRI scanning, there is evidence that single-photon emission computed tomography (SPECT) may demonstrate hypometabolism and signs similar to Alzheimer's disease in younger boxers⁸. More evidence will be needed as to the potential of functional scanning in identifying those at higher risk of developing CTE.

In 2013, the National Football League in America reached a settlement with over 4,500 former players in a class action, alleging that the NFL hid research that showed the harmful effects of concussion. The NFL did not accept liability or that the injuries were the result of playing the game. What is significant is the establishment of a duty of care that the regulator may have to those who participate in that particular sport⁹. Regardless of the liability issue, this should raise awareness for other regulatory bodies.

The role of regulatory bodies

The rules of boxing have had to change over the years to protect those participants from serious intra-cranial injury. In the professional game, the number of rounds was reduced from 15 to 12, a mandatory count of eight seconds was introduced to allow referees to make judgements on the fighter's ability to continue and doctors will routinely assess fighters at the end of each round. Amateur fighters will routinely wear a head guard for each bout¹⁰.

Both codes of rugby have brought in changes to make the games safer but the motivation for these has predominantly been the prevention of cervical spine injury rather than head injury. The engagement of scrums has been changed and tackles such as the "spear tackle" or "tip tackle" are outlawed, as is tackling players whilst in the air. Rugby Union also ensures that any player who is off their feet must be brought back to the ground safely. Rugby players have traditionally shunned the use of head protection and Daneshvar et al (2011) is sceptical as to the effectiveness of such head guards in both codes of rugby in preventing concussion¹¹. Mandatory wearing of head protection is not seen in the professional games but some hurling players can be seen wearing head protection, possibly more to do with the ball travelling at speed than direct collisions. More research will be needed before all participants will be seen with head protection.

Specific rule changes to reduce the chances of head injuries occurring in rugby, Gaelic Games or similar sports would be extremely difficult without reducing the intensity of the matches and potentially, lose spectators and revenue. Safety has improved dramatically over recent decades and pitch side medical crews are now common place at professional matches. There is increased awareness of concussion and how players demonstrating concussion are handled although there is some conjecture as to whether cases are handled appropriately. What the regulatory bodies and

clubs may need to consider is the amount of matches played over a season (and therefore over a player's career) considering the long term potential for CTE and how players who suffer concussion, and particularly those players who suffer repeat concussions are handled, particularly at amateur level.

Routine pre-match or pre-season neuroimaging for all participants as occurs pre-boxing would be simply undeliverable and more evidence as to whether the imaging would contribute to a diagnosis of either short term or long term complications is needed although, as in boxing, an MRI scan may identify those players at particular risk of intra-cranial injury. These players will be the rare exceptions and it remains unrealistic and clinically unjustified for mass screening of players.

Clinical Indications of acute head injury

Players who are suspected of suffering concussion will normally be assessed by the pitchside medical team. Who that will be depends on the standard of sport being played. The Zurich Consensus on Concussion in Sport represents the most recent version of international guidance on how concussion is handled. The guidance for on-field or sideline evaluation of acute concussion is listed in table one¹¹:

Table One: On-field or sideline evaluation of acute concussion¹²

A The Player should be evaluated by a physician or other licensed healthcare provide onsite using standard emergency management principles and particular attention should be given to excluding a cervical spine injury.
B The appropriate disposition of the player must be determined by the treating healthcare provider in a timely manner. If no healthcare provider is available, the player should be safely removed from practice or play and urgent referral to a physician arranged.
C Once the first aid issues are addressed, an assessment of the concussive injury should be made using the SCAT3 or other sideline assessment tools.
D The player should not be left alone following the injury and serial monitoring for deterioration is essential over the initial few hours following injury.
E A player with diagnosed concussion should not be allowed to return to play on the day of injury.

The consensus states that neuroimaging contributes little to the evaluation of acute concussion but should be used when intra-cerebral or structural lesions are suspected. It is therefore clinical assessment that is of particular importance when examining patients with suspected concussion and how they are subsequently handled following diagnosis. Players are notoriously reluctant to leave the field and coaches can be reluctant to lose their better players in match situations. However, the protection of the player has to be paramount. Referees in both codes of rugby have the authority to order players from the field who are bleeding; it could be argued that a similar rule for those who have suspected concussion could be introduced following better training for match officials.

Clinical Indications of chronic head injury and chronic traumatic encephalopathy

Gavett et al (2011) link CTE with some sporting activities and military personnel who have been subjected to blast injury. They describe a usual onset in mid-life, earlier than that of Alzheimer's disease, frontotemporal lobar degeneration or frontotemporal dementia. Progression of the disease is slow. The earliest symptoms include impairments in cognition, mood and behaviour. Although

many of the symptoms are similar to that of other degenerative diseases, the presence of depressive moods, emotional instability, suicidal ideation and behaviour, and anger management issues which have been associated with CTE have particular impact on a patient's socio-economic and family situation¹³.

Conclusion

There are two issues that confront contact sports. Firstly, managing the short term potential consequences of concussion and secondly, managing the long term potential consequences of repeated head trauma. Greater awareness of concussion in contact sport is becoming apparent. The GAA in Ireland produce a GAA player welfare booklet which details to participants how to recognise the signs of concussion¹⁴ which represents a sensible policy of advising those who have limited medical knowledge on awareness of clinical symptoms and seeking appropriate professional guidance. The International Rugby Board has also created concussion management interactive learning modules which are available online¹⁵. The National Rugby League in Australia also provides guidance via its website on the management of concussion¹⁶. There has been some debate in the written media as to whether clubs have been abiding by the guidance in place and indeed in some cases, whether the guidance itself is appropriate^{1,17}. What is clear is that sporting regulatory bodies and medical professional need to work closely together to ensure the safety of the players and that regulatory bodies are responsive to any change in the evidence base as to the management of concussion. Second impact syndrome is extremely rare but awareness of it is important, particularly at games where medical supervision is less than would be seen at a professional game.

The short term appreciation of concussion is better appreciated than the long term appreciation of developing CTE. It is important that regulatory bodies take on board the growing evidence base that has come from American Football and boxing in particular regarding the impact of repetitive head trauma. Given the changes to the rules to speed up the codes of rugby in particular, the incidences of concussion are likely to have increased which raises the possibility that players of today may be more susceptible to developing CTE.

The role of neuroimaging in the evaluation of concussion is very limited and should only be considered when there is suspicion of intra-cranial lesion or skull fracture. The management of concussion should be a more clinical decision where the welfare of the player is the only concern. Even in cases of second impact syndrome, the evidence is that imaging would contribute little to the overall management although would inevitably be performed. The role of imaging in assessing long term development is also limited although both CT and MRI scans may identify some significant signs and rule out other causes of symptoms. The role of functional MRI and SPECT in the assessment of the early signs of CTE has significant potential and further research will be needed in this area, particularly in players who may be at higher risk of developing CTE due to multiple concussions over a long career.

Recommendations

Increased awareness of concussion in contact sports is necessary both from a long term and short term management perspective. This would include greater awareness of second impact syndrome in players, coaches and match officials.

The law makers of contact sports need to consider how the incidence of head injuries can be reduced without affecting the popularity of the sport. This includes consideration as to whether players suffering concussion should be permanently removed from a match situation and whether the amount of games played per season is appropriate.

Neuroimaging is only necessary when intra-cranial lesions are suspected and clinical decision making is key in the management of patients with concussion. More research is needed to support the use of functional MRI and SPECT in the assessment of CTE.

Regulatory bodies should take interest in the long term situation of those who have played their sport. Collaboration between such bodies in researching the long term effects on their participants should be encouraged.

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