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Case Reports,

Concussion in Sports (Brain concussion in Tohoku Free Blades and another Concucssion in Sports)

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Abstract:

In this paper, we discuss the 3 types of concussion that occur in sports; brain concussion, spinal concussion (spinal cord neurapraxia), and labyrinthine (inner ear) concussion.
Brain concussion data was collected from professional ice hockey players (Tohoku Free Blades, Japan) during 9 consecutive seasons. Spinal cord concussion and Labyrinthine concussion data was collected from athletes who sustained the injury in various sports including ice hockey.

Material and methods

The average incidence of brain concussion in professional ice hockey players was 2.0 per season. All 13 cases of spinal cord concussion were cervical cord concussion. Seven cases showed evidence of spinal cord compression; six cases had no radiological abnormality observed. All cases of labyrinthine concussion were sustained through a traumatic blow to the lateral aspect of the head.

Results

In any sports injury, all three of these concussions can co-exist and requires the team doctor to be at the site in order to fully assess the injury.

Key Words: brain concussion, spinal cord concussion, labyrinthine concussion, sports

Introduction:

Three separate types of concussion can co-exist in sports related head injuries: Brain concussion, spinal cord concussion (spinal cord neurapraxia) and labyrinthine concussion (inner ear concussion)[3,10]. Of these, spinal cord concussion and labyrinthine concussion are often diagnosed as brain concussion. In this paper, I would like to share my experience as a team doctor for a professional ice hockey team to assist young physicians understand the different types of concussion.

Material and Methods:

Eighteen cases of brain concussion (15 players) that occurred over nine seasons are described. All patients were professional ice hockey players who belong to the "Tohoku Free Blades, Japan". As for spinal cord concussion and labyrinthine concussion, patients engaging in different sports are described. Thirteen cases of spinal cord concussion, all of which are cervical cord concussions, occurring in professional ice hockey, professional wrestling, professional fighting, university rugby, university American football, high school wrestling and amateur boxing are described. Labyrinthine concussion in 4 cases; professional ice hockey, professional baseball and high school baseball are described. All cases are male athletes and all cases had been recorded on camera allowing detailed analysis.

Results:

Brain concussion in Ice Hockey (Tohoku Free

Blades)

In 9 consecutive seasons of professional ice hockey, Japan, the incidence of brain concussion is described in Table.1. The age of the players at the time of injury was between 22 to 37 (mean 28.9). Their professional experience ranged from 1year to 15years (mean 7.3). The position and the rate of incidence of brain concussion for Forward players, Defense players and Goal keeper were: 8 cases (7 players), 9 cases (7 players) and 1case (1 player) respectively. The period until the players returned to playing professionally ranged from 3 days to 28 days (average 6.61). Brain concussion was diagnosed using ImPACT (Immediate post-concussion Assessment and Cognitive Testing) in the first 6 seasons, and King-Devick Test was used for the remaining 3 seasons[15]. SCAT (Sports Concussion Assessment Tool) 2and SCAT 3 were used throughout the entire period. There were, on average, 2.0 cases of brain concussion per season. There were 380 matches played during those 9 seasons, meaning the rate of brain concussion in professional ice hockey is 0.05. For the rehabilitation, the performance of the player was graded from 1 to 6 with 6 being the maximum performance. None of the patients are suffering from long term adverse effects following the concussion.

Table 1: The summary of cases of brain concussion in Tohoku Free Blades ice hockey players. Position: forward (FW), defense (DF), goal keeper (GK),

Year	Age	Career (Year)	Position	Return to Play (Day)
2010	26	4	FW	3
2010	22	1	FW	4
2010	29	8	DF	5
2011	27	5	FW	28
2011	27	5	FW	7
2011	26	4	DF	4
2012	30	9	FW	8
2012	26	4	FW	6
2012	25	3	DF	4
2013	27	5	FW	5
2014	37	15	FW	10
2014	33	12	DF	8
2014	28	6	DF	4
2015	30	8	DF	7
2017	27	5	GK	5
2017	33	12	DF	3
2017	33	12	DF	5
2018	33	13	DF	3

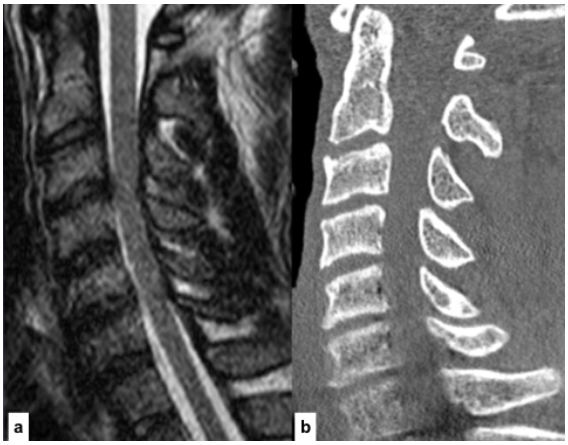


Fig. 1 the cases of spinal cord concussion occurring in professional wrestling matches. (Table 2; Case 4) MRI results showing canal stenosis especially in C3-4, intraaxial signal change and developmental spinal stenosis.

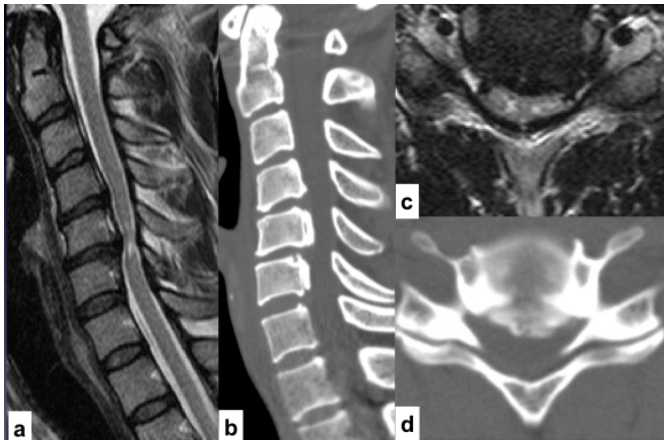


Fig.2 MRI showing severe stenosis especially in C5-C6 and intraaxial signal change (A and C) CT demonstrating ossification of longitudinal ligament in C5-C6 level.

Table 2: The summary of cases of spinal cord concussion. BC: Brain concussion, Duration: duration of neurological deficits, Laminoplasty : laminoplasty of cervical spine, R/A : Radiographical abnormality, RTP : days to return to play,

Case	Sports	Age	Duration	Type of paresis	Trauma origin	R/A	BC	Operation	RTP (Day)
1	Ice Hockey player	36	5 min	Monoparesis	Hit to Lower Body	+			
2	Ice Hockey player	24	5 min	Tetraparesis	Hit to Upper Body	-			21
3	Professional wrestler	33	15 min	Tetraparesis	Extension	+		Laminoplasty	547
4	Professional wrestler	25	24 hours	Tetraplesia	Lateral Bending	+		Laminoplasty	511
5	Professional wrestler	38	12 hours	Tetraparesis	Flexion	+			91
6	Professional wrestler	36	24 hours	Tetraparesis	Flexion	+			84
7	Rugby footballer	33	1 hours	Paraparesis	Tackle to Lower Body	+			85
8	Professional fighter	34	1 min	Paraparesis	Extension (lower jaw)	+			
9	Collage American foot baller	22	12 hours	Tetraparesis	Flexion	-			92
10	Collage American foot baller	21	30 min	Tetraparesis	Flexion	-			82
11	Collage American foot baller	21	48 hours	Central cord	Lateral Bending	-			121
12	Amateur wrestler (High school)	16	15 min	Tetraparesis	Extension (forehead)	-	+		82
13	Amateur boxer	42	5 min	Paraparesis	Extension (lower jaw)	-			

Table 3: The summary of 6 cases of spinal cord concussion without radiographical abnormality and the ratios of spinal canal/vertebral body (SC/VB) in C3-C7

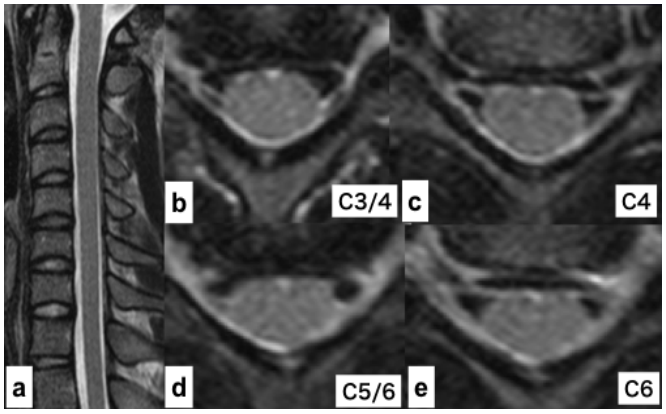
Case	Sports	Age	C3	C4	C5	C6	C7
2	Ice Hockey player	24	0.76	0.68	0.75	0.83	0.79
9	Collage American foot baller	22	0.76	0.72	0.70	0.73	0.72
10	Collage American foot baller	21	0.81	0.75	0.74	0.76	0.72
11	Collage American foot baller	21	0.75	0.77	0.82	0.77	0.74
12	Amateur wrestler (High school)	16	0.80	0.82	0.83	0.80	0.84
13	Amateur boxer	42	0.86	0.86	0.72	0.74	0.74

Table 4: The summary of 6 cases of spinal cord concussion without radiographical abnormality and MRI results showing the space available for the cord (SAC) in C3-C7.

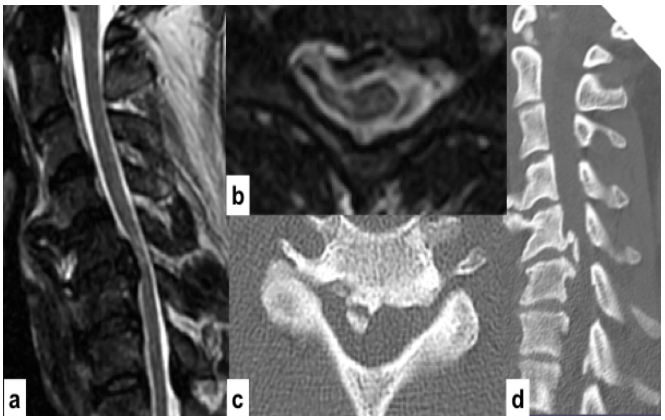
Case	Sports	Age	C3	C4	C5	C6	C7
2	Ice Hockey player	24	4.1	3.7	3.7	3.6	4.4
9	Collage American foot baller	22	3.6	2.7	3.0	2.9	2.9
10	Collage American foot baller	21	3.1	2.4	3.2	2.6	2.7
11	Collage American foot baller	21	4.6	4.9	5.2	5.4	5.9
12	Amateur wrestler (High school)	16	6.2	4.4	3.0	3.1	4.0
13	Amateur boxer	42	6.9	5.5	5.6	3.3	3.4

Table 5 the summary of cases of labyrinthine concussion. BC: brain concussion, Duration: duration to disappearance of symptoms, RTP : return to play, Trauma site : trauma site in the head

	Sports	Age	Duration	Trauma site	BC	RTP
1	Baseball player	36	7 days	Rt. temporal	unknown	+
2	Baseball player	17	5 days	Lt. temporal	unknown	+
3	Ice Hockey player	25	4 days	Rt. temporal	-	+
4	Ice Hockey player	32	7 days	Rt. temporal	-	+



MRI showing extensive narrow canal (A) and poor subarachnoid cap in C3- C6 levels.



Spine MRI of a 44-year-old male professional wrestler who has competed for more than 20 years showing compression especially in C5-6 level and abnormal intraaxial signal changes （A and B）. CT scan demonstrating hard bony spur in C5-6 (C and D). The patient has no history or symptoms of spinal cord concussion or injury.

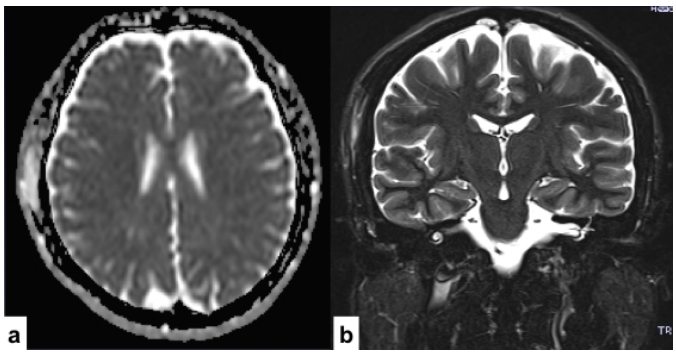


Fig.5 Brain MRI of a high school baseball player who was hit by a pitched ball showing subcutaneous hematoma in the right temporal region.

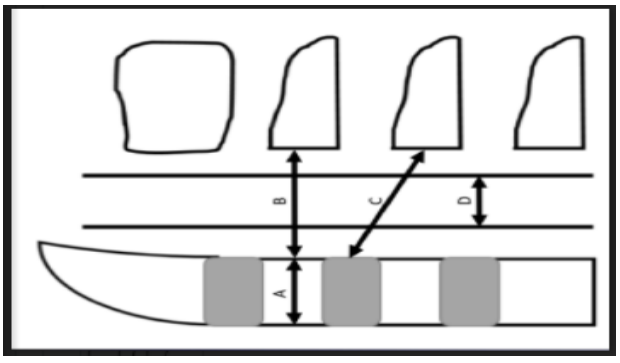


Fig.6 Schematic image showing a midsagittal section of the cervical spinal canal.

Fig6:
A: vertebral body width (VB)
B: the spinal canal diameter at the midvertebral body (SC)
C: disc level canal diameter as measured on MR imaging
D: spinal cord diameter
The SC/VB ratio is obtained by dividing B by A (B/A).
The SAC (space available for the cord) is calculated by subtracting D from C (C minus D).

【*Spinal cord concussion in sports*】

13 cases of spinal cord concussion (SCC) have been described in Table 2. The age ranged from 16 to 42 (mean 29.3). Radiological changes were observed in 7 of the 13 cases on magnetic resonance imaging (MRI)[1,16] . There were no radiological abnormality observed in the remaining 6 cases (3 cases in university level American football[18] , 1 case in professional ice hockey[19], 1 case in high-school wresting[2,13,14] and 1 case in amateur boxing (Table 3 and Table 4). Eleven of the 13 cases were as a result of a direct blow to the head[16]. These eleven patients all had strain on their neck that caused the SCC. Two cases resulted from lateral bending injury, 2 from flexion injury and 7 from extension injury. In one case, the patient received a body attack to the left upper body curing a hockey match that resulted in temporary paralysis of the left upper limb in case1 in Table 2. In another case a patient received a tackle during a game of rugby that resulted in paraplegia [17]. Neurological deficit type includes: 1 case of left upper limb monoparesis, 3 cases of paraparesis, 7 cases of tetraparesis, 1 case of tetraplegia and 1 case of central cord injury type. The time from injury to full recovery was between 1minute and 48 hours (mean 564minutes). Two of the 13 incidence resulted in the patient retiring from the sport (Table 2 ; Case 1,8). Two of the remaining eleven patients underwent surgical treatment (Fig.1)[5,9] both of whom required 1.5 years until returning to playing professionally again. Three of the thirteen cases were their second episode of SCC. One case was an ice hockey player (Table 2 ; Case 1)(Fig.2) who did not realize he had suffered from an SCC as he recovered in 5 minutes and played the following day where he suffered a second episode of SCC. This player retired after the second incident that resulted in a left upper arm monoparesis following a blow to the left upper body. The second case was a professional wrestler who suffered 2 episodes of SCC in 5 months. Both episodes were extension injuries to the neck and in both occasions, the symptoms subsided within 15minutes (Table 2; Case 3). The last case is a university level American football player who suffered 2 episodes of lateral bending injury within 1 year. Both episodes resulted in central cord type injury and the symptoms subsided within 48 hours (Table 2; Case 11). In the remaining 8 of the 13 cases of SCC, excluding an amateur boxer who has not fought since the injury, the players returned to playing between 21 to 121 days (average 72.3). The professional fighter (Table 2; Case 8) suffered a punch to the lower jaw that caused an initial paralysis of the lower limbs that recovered within 1minute that was then followed by severe pain in both upper limbs that resulted in him retiring from the sport (Table 2; Case 8).

【*Labyrinthine concussion in Sports*】

4 cases of labyrinthine concussion (LC) are described in Table 5. The age ranged from 17 to 36 (mean27.5). All cases resulted from a ball/puck directly hitting the lateral aspect of the head. In the 2 cases that occurred during an ice hockey match, nystagmus was noted in both patients that aided in the diagnosis. In the 2 cases that occurred in baseball, the symptoms described by the players were not in keeping with those in brain concussion which lead me to think it was an LC (fig.5). The period from the time of injury to returning ranged from 4 to 7 days (mean 5.75)

Discussion:

Sport injury related brain concussion, is treated with a great deal of care following the Federal NFL concussion litigation. The paper that initiated the litigation was a paper written by Dr.Bennet Omalu [11,12]. it is true that American football is a high-velocity contact sports and it is not hard to imagine that players can suffer from irreversible chronic brain injury. However, it is also true that most players do not suffer from long term after-effects following brain concussions. Dr.Omalu examined one player (Mike Webster) and came to the conclusion that American football was to blame for his patient's chronic traumatic encephalopathy (CTE). It must be said, however, that his evidence is rather weak. The author should also look as the patient's lifestyle prior to becoming a professional athlete.

I have been working as a neurosurgeon for 31 years and experienced many patients who suffered from brain concussion. I feel that we, the sports physicians as a whole, are becoming too worried about the illness, and the regulations that the players need to follow following a brain concussion has become too strict. In certain cases of brain concussion, the patients recover much faster than the current regulation deems safe. I have worked as a team doctor for the Free Blades for 9 years, and I have allowed patients to return in

as early as 3 days. The incidence of brain concussion in one season is 2.0. That is not very many, and it does not cause much stress to the attending doctor. Given that brain concussion is such a broad disease in terms of symptoms and severity, a single regulatory protocol cannot provide a satisfactory management plan. Recently, there have been discussions about the "second impact syndromes". This syndrome still remains to be understood, yet the governing body has already started discussing further restrictions to prevent this unknown disease. This can potentially harm the player's professional career. School children suffer from brain concussion all the time. Should we start restricting these children with regulations every time they suffer from a brain concussion?

As for spinal cord concussions, because the incidence is much lower compared to brain concussion, there is no guideline that informs physicians on when the players can return to play. When looking back on the ice hockey player that suffered from 2 episodes of SCC and a subsequent retirement from the sport; had the patient not suffered a similar injury on 2 consecutive days, he may not have had to retire.

SCC often results in patients who has a coexisting spinal cord stenosis. When you watch boxing matches, boxers get punched in the head hundreds of times over their careers, yet only a fraction of these punches results in them being knocked out. Perhaps one could argue that only those punches that land at a certain vector results in the boxer collapsing (pinpoint energy trauma). Something similar could be the case with SCCs. Developmental stenosis points to a condition where the spinal canal/vertebral body (SC/VB) ration is less than 0.8 in several spinal levels(Fig.6)[8]. In six of the patients that suffered from SCC that did not have any radiological signs, evidence of developmental spinal stenosis was noted between C3-C7(Table 2). Therefore, these patients were probably prone to SCC (Fig.3). It was not possible to assess the Space available for the cord (SAC) in our patients to look for other possible causes of repeated SCC because of the limited number of patients Table 4).

This concept of pinpoint energy trauma may also apply for LC. LC remains to be very difficult to diagnose and guidelines are unclear. Blunt trauma to the head resulting in the sudden movement within the semicircular canal causes many of the typical symptoms associated with LC.[3].

Brain concussion, SCC and LC can occur simultaneously [4-9]. In 2 cases of brain concussion in the free blades players, 2 complained of tinnitus following the injury. The high school wrestler was also diagnosed with brain concussion. Therefore it is very important to differentiate and think about these 3 types on concussion when examining patients.

One of the biggest reasons why doctors have become overly cautious when treating patients with brain concussion is because there is not an objective method to accurately diagnose this disease. The patient's subjective symptoms is the only thing that physicians can use to gauge the severity.

Conclusion:

Three types of concussion seen in sports injury were described. Note that they can co-exist from the same injury. Sports doctors should always be present during the match to accurately diagnose the illness.

Compliance with Ethical Standards

Fundings; No- funding was received for this research.

Conflict of Interest: The authors declare that they have no conflict of interest.

All co-authors have seen and agree with the contents of the manuscript.

For this type of study formal consent is not required.

Informed consent: "Informed consent was obtained from all individual participants included in the study."

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institution or practice at which the studies were conducted."

This study have been approved by our institutional and/or national research ethics committee and have been performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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