

**2<sup>nd</sup> Annual Symposium: Canadian Sports Concussion Project,  
University Health Network.**

**Research on the Concussion Spectrum of Disorders,  
Saturday January 11, 2014  
Summaries of Presentations**

***1. PRESENTATIONS FROM RESEARCHERS IN THE CANADIAN SPORTS  
CONCUSSION PROJECT***

**Leo Ezerins – Executive Director, Canadian Football League Alumni Association.**

***The Importance of Concussion Studies for Retired CFL Players***

The issue of concussion has become a very controversial topic over the last few years. This is nothing new. “Football is on trial. Because I believe in the game, I want to do all I can to save it.” President Theodore Roosevelt, 1905. As former CFL football players we believe it is up to us to support research of the long term effects of concussion for a number of reasons: Our families - “We lived our dreams, our wives and families live our nightmares.” Our families enjoyed the incredible benefits football offered us. Unfortunately many of our families now suffer from the consequences of us having played a violent sport. Ourselves- In order to give back we must understand the issues ourselves. To help others we must help ourselves first. The rules of the game have changed. What has not changed is the long term cognitive decline of many of our guys. The game - “It is not just the game of football it is the game of life.” Through research we believe rule changes will continue to make the game “safer”. Our Community - Hopefully the research will benefit EVERYONE – not only in sports but in the general community as well. We are proud and privileged to do our part in the research under the leadership of Dr. Charles Tator Chair of the Canadian Sports Concussion Project. What we have learned is that patience and persistence are important. In many respects we have come a long way, and at times we feel we have not come that far. The reality is we have a long way to go.

**Robin Green – Senior Scientist, Toronto Rehabilitation Institute-UHN.**

***Initial Neuropsychological Findings from the CFL Study***

In order to provide clinical interventions for individuals who are suffering long-term progressive consequences of multiple concussions, such as chronic traumatic encephalopathy (CTE), we need to be able to diagnose CTE in vivo. At present, diagnosis can only be made through post-mortem examination. We have been trying to identify behavioral pathognomic signs in former professional football players, who are at risk of CTE due to their concussion history. Despite largely normal neuropsychological profiles along with above average intelligence in our cohort of CFL alumni, we found evidence of abnormal neuropsychological test performance in one domain of functioning. Moreover, performance here was much more impaired in this group at risk of CTE than in a group of severely impaired TBI patients, even though the latter were more severely impaired or comparable on all other neuropsychological tests and showed extensive encephalomalacia with other visible lesions, unlike the athlete group. Thus, we observed a double dissociation across populations and test performances. These preliminary findings offer promise of a behavioral approach that is sensitive and specific to the cognitive impairments that

are reported in this cohort of former athletes. The approach might additionally be capturing early manifestations of a progressive disorder in some of the group.

**Karen Davis - Senior Scientist, Toronto Western Research Institute, and Ruma Goswami, Post-Doctoral Fellow, Toronto Western Research Institute.**

***Initial MRI Findings from the CFL Study***

Repeated concussions can have debilitating consequences and may result in a constellation of symptoms including memory impairments, executive dysfunction, apathy and impulsive behaviour. Such affective and cognitive changes may be associated with damage to particular regions of the brain that are associated with those functions. In particular, the connectivity between brain regions may be damaged due to shearing forces that occur upon traumatic impact that disrupts the communication between the brain areas. This study aimed to investigate the relationship between neuropsychological impairments and brain structure in individuals with a history of concussions. Participants included former athletes from the Canadian Football League and healthy control subjects with no history of concussions, matched for age and level of education. A battery of neuropsychological testing including variables of reaction time and number of errors was administered. Neuroimaging (3T MRI) was completed on all subjects and structural analysis of white matter connectivity was performed to assess group differences as well as relationships with cognitive function. We observed white matter abnormalities in the athletes, in part related to abnormal cognitive performance. These preliminary findings suggest that repeated concussions impact brain connectivity that may be linked with cognitive impairments.

**Carmela Tartaglia – Neurologist, UHN Memory Clinic.**

***Clinical Aspects of Former Professional Athletes with Multiple Concussions***

Multiple concussions have been associated with severe behavioural and cognitive changes including dementia. The behavioural changes reported in former athletes having suffered multiple concussions include disinhibition, apathy, loss of social norms, and decreased empathy. These changes may result from damage to frontotemporal regions known for their role in social cognition. Former Canadian Football League athletes and matched healthy control subjects with no history of concussions underwent an interview, neurological exam, neuropsychological assessment and diffusion tensor imaging (DTI). Our results revealed that former players had significantly more cognitive and behavioural complaints than the controls. They reported significant worsening of cognitive as well as motor and sensory symptoms since the time of their last concussion. There was only a trend for worsening of behavioural symptoms while headaches and constitutional symptoms did not worsen. In comparing players who reported worsening of behavioural symptoms and those who were stable or improved since their last concussion no significant difference was detected in white matter integrity of the frontotemporal regions. Preliminary findings suggest worsening of some symptoms in former football players since their last concussion. The white matter integrity in the frontotemporal regions could not differentiate players who complained of worsening behavioural symptoms from those who were stable or improved. Further research is required to understand the neuroanatomical changes that would explain worsening of symptoms in former players having suffered repeated concussions.

**Lili-Naz Hazrati – Neuropathologist, UHN and the Tanz Centre for Neurodegenerative Disease.**

***The Presence/Absence of CTE at Autopsy***

Chronic traumatic encephalopathy (CTE) is characterized neuropathologically by deposition of tau in neurons and astrocytes in different cortical areas and deep brain structures. The tau is mainly localized in neurons situated in superficial layers of the cortex and most often in the depth of the sulci. At the Canadian Sports Concussion Project of the University Health Network, we collected eight brains of retired football players all presenting with different chronic neurological diseases including dementia, Amyotrophic Lateral Sclerosis and Parkinson's disease. Our data showed that CTE-like changes were present in only three of the athletes and co-occurred with other neurodegenerative diseases (mainly Alzheimer's disease). All the others had no CTE but classically signature changes of Parkinson's Disease, Amyotrophic Lateral Sclerosis and Alzheimer's disease. These results may indicate that multiple concussions can be a risk factor for other neurodegenerative diseases, or that not all concussed athletes develop CTE. Moreover, in our case series none of the cases showed progression of CTE over time. In conclusion, we think that concussion may not lead to CTE in all football players.

**David Mikulis- Senior Scientist, Toronto Western Research Institute, and Paul Dufort, Computational Imaging Scientist, UHN.**

***Brief Overview of Current and Planned Analyses of Neuroimaging Data from the Canadian Sports Concussion Project***

Recent advances in both the resolution and sophistication of medical imaging techniques promise significant improvements in our ability to diagnose concussion. Diffusion tensor imaging (DTI) has shown the greatest promise, revealing reductions in measures of white matter integrity in concussed patients versus controls that suggest the presence of long term axonal pathology in this cohort. In our study of 17 concussed patients versus 15 controls, we compared the shapes of fractional anisotropy (FA) histograms derived from all white matter voxels in each participant's DTI scan. The FA values from each subject were sorted into increasing order and the distributions of values at all 5% quantiles from 5 - 95% were compared across groups. The distribution of the quantiles in the 50-80% range were significantly lower ( $p < 0.05$ ) for concussed patients versus controls following adjustment for age, revealing a marked reduction of the highest FA values associated with the cores of deep white matter tracts. The next phase of our work will advance this finding from the group level to enable diagnosis at the individual level by leveraging recent progress in machine learning. The goal will be to detect discriminative spatial "fingerprints" of FA reduction among white matter voxels not visible in global histograms or FA maps.

**Richard Wennberg – Neurologist, Krembil Neuroscienc Centre.**

***The MEG Project Plans***

(Summary not provided.)

**Kieran Murphy – Medical Director, UHN International Strategy.**

***PET Scanning for CTE***

Current neuroimaging modalities such as CT and MRI allow diagnosis of serious brain injury but are usually normal in the setting of concussion or mild traumatic brain injury. Clinicians must therefore rely upon neurological exams and clinical exam in the diagnosis of concussion and subsequent plan for affected patients. Positron emission tomography or PET shows great promise in identifying underlying biochemical changes due to traumatic brain injury in patients who have normal conventional imaging. A new array of PET imaging agents allow us to specifically study Tau proteins that are associated with traumatic brain injury rather than dementia related to other causes. These agents are available to us because of our rapidly evolving molecular imaging infrastructure and collaborations. These advances in neuroimaging have the potential to identify concussion on imaging with increased sensitivity and to help further refine the clinical and long-term management of patients with concussions.

**Chanth Seyone – Founding Director of the Acquired Brain Injury Clinic, Toronto Western Hospital, UHN.**

***Psychiatric Aspects of the Concussion Syndromes***

The common symptoms of concussion are nonspecific and include quasi organic and subjective symptoms. These may be physical, behavioral / emotional or cognitive. However, these symptoms can progress to long term psychiatric sequelae including maladaptive coping, cognitive difficulties, Affective Disorders, Anxiety Disorders, Psychotic Disorders, Sleep Disorders, Personality Disorders (Borderline / Antisocial / Narcissistic), behavioral sequelae, and effects on the family and community.

Psychiatric Disability in these individuals can be better understood if conditions are considered as pre-traumatic, peri-traumatic or post-traumatic. Some pre-traumatic factors include age, alcoholism, mental constitution, genetic vulnerability, previous psychiatric illness, pre-existing psychosocial difficulties, and recent life events. Peri-traumatic factors include extent of brain damage, other physical deformities, the emotional impact of the injury (destruction of the “myth of personal invulnerability”) and circumstances of the accident. Post-traumatic issues that could make an individual symptomatic include intellectual impairments, physical disabilities, onset of Epilepsy, psychosocial difficulties, overprotection from family members, upheaval in family hierarchies, separation, loneliness, financial or occupational difficulties, compensation and litigation, and repeated rehearsal of symptoms.

Management of these individuals is dependent on the time when the patient is first seen. “Do no harm” as iatrogenic causation is quite problematic. Avoid unnecessary investigations. Manage symptoms with rest and psychiatric disability with appropriate treatments. The prognosis in early stages with appropriate and finite management is fair but in later stages with established “disability” and enmeshment of family who have taken on roles of caretaker, poor.

**Hannah Davis- Undergraduate Research Assistant, and Charles Tator, Neurosurgeon, Krembil Neuroscience Centre.**

***Post-Concussion Syndrome in Athletes***

This presentation discussed the clinical features and demography of postconcussion syndrome (PCS) in 138 athletes from a retrospective chart review of consecutive concussed patients seen

by one of us (CHT) at the Toronto Western Hospital. All patients in this study had sports-related PCS based on 3 or more post-concussion symptoms lasting 1 month or longer. The 138 athletes with PCS averaged 22.8 years of age, and 50.7% were 18 years old or less. They averaged 3.4 previous concussions (range of 1 to >12). More than 80% of PCS cases had at least two previous concussions. There was a previous psychiatric condition, ADD/ADHD, learning disability, or previous migraine headaches in 21.0% of the cases. Ice hockey caused the highest number of the most recent concussions at 72 cases (52.2%). Soccer, snow skiing, equestrian sports and basketball were other frequent causes. The average number of persistent symptoms was 7.6, and the median duration of PCS was 6 months at the first examination. The duration of PCS and the number of symptoms were not related to the number of previous concussions, loss of consciousness (LOC), or return to play (RTP). Thus, PCS is a frequent and debilitating condition affecting many athletes. Further research on treatment and prevention of PCS is required.

## ***2. PRESENTATIONS FROM OUR PARTNERS IN THE ONTARIO BRAIN INSTITUTE MULTI-CENTRE CONCUSSION PROJECT***

**Carol DeMatteo – Scientist, *CanChild* Centre for Childhood Disability Research, McMaster University.**

### ***The Epidemiology of a Pediatric Concussion Clinic***

Pediatric Concussion clinics are rare in Ontario and only a few operate across Canada. Most data is related to adults so today some preliminary figures from the prospective clinic database at Hamilton's McMaster University and Children's Hospital will be presented. Four hundred and sixty three children of all ages and all severities of acquired brain injury have been entered since 2012. Eighty-five percent of these children/youth have a MTBI or concussion. The focus for today is two fold: i) gender differences and, ii) multiple concussions. There is minimal difference between boys and girls in overall mean age (15 yr) of clinic population, mean age at 1<sup>st</sup> injury (11.5 yrs), mean age at 2<sup>nd</sup> injury (12.5 yrs), and 3<sup>rd</sup> injury (13 yrs). The trend is that boys are a few months younger at each time point. The mean number of injuries is 3 with 23% having had their second injury within 2 months and 55% within one year. The biggest gender differences noted were in cause of injury with hockey and football being highest for boys and soccer and basketball for girls. Other causes are comparable. Thirty-seven percent of our population have had more than 1 concussion with a range or 2-12. Forty percent of children have symptoms beyond 1 month with 25% still symptomatic beyond 3 months. A decrease in academic standing was experienced by 30% of the total population with more girls affected. Depression screening demonstrated an alarming rate of 23% of youth scoring in the depression range, when compared with a premorbid rate of 4%. Although this is a specialty clinic at a tertiary care centre, the rates of multiple concussion, long symptom duration, depression and perhaps most alarming the young age at which multiple concussions are occurring reinforces the need for more pervasive prevention strategies and more available treatment. We have developed with the support of CIHR funding, child/youth specific, Return to Activity and Return to School Guidelines as well as Guidelines for Toddlers. All are available at [http://canchild.ca/en/ourresearch/mild\\_traumatic\\_brain\\_injury\\_concussion\\_education.asp](http://canchild.ca/en/ourresearch/mild_traumatic_brain_injury_concussion_education.asp).

**Douglas D. Fraser – Director, London Translational Research Centre, Western University.**

***Concussion Research at Western University***

Western University clinicians and scientists have united to investigate concussion. The Western investigators are associated with 4 University Faculties, 3 Research Institutes, 2 Hospital systems and 1 Sports Medical Centre. Thus far, Western Concussion investigators are actively studying concussion biomarkers and outcomes in female varsity athletes, in adolescent male hockey players and in those individuals with multiple concussions suffering chronic symptoms. The investigations focus primarily on biomarkers and include combinations of clinical exams, balance testing, neuropsychological evaluations, brain injury protein measurements, immunological alterations and pathological changes observed on 7T MR imaging. Several laboratory investigators also study concussion using human cadaver cranium, human brain tissues maintained in vitro (cerebrovascular endothelial cells, pericytes and astrocytes) and rodent fluid percussion brain injury models. Concussion epidemiological and mapping studies using data from our South-Western referral region have been completed, and targeted concussion prevention programs are being developed. Generous internal research funding has been obtained from Western University Schulich School of Medicine, London Health Sciences Foundation and the Children's Health Foundation.

**3. PRESENTATIONS FROM INVITED GUESTS**

**Andrew Baker - Chief of Critical Care and Medical Director of the Trauma and Neurosurgery Program, St. Michael's Hospital.**

***Animal Models for Sport and Military Concussions***  
(Summary not provided.)

**Peter Rumney – Physician Director, Holland Bloorview Kids Rehabilitation Hospital.**

***'NeuroCare': A Neurophysiological Approach to Determine Readiness for Return to Activity.***

To establish evidence-based guidelines for the management of mTBI in children and youth, we propose to develop a novel neurophysiological approach (*NeuroCare*) delivered via accessible smart-phone technology. *NeuroCare* allows for the recording and sharing of personal health information between adolescents recovering from mTBI and care providers. It will increase the self-management of physiologic post-concussion symptoms (PCS) in adolescents aged 10-18 years and improve communication between patients and health care providers. The novelty of the approach is based on the recording and analysis of resting state heart rate variability (HRV) as a neurophysiological parameter indicative of readiness for activity following mTBI. HRV at rest has already been demonstrated as useful for prescribing physical activity in an athletic population (and therefore holds high relevance for adolescents returning to sports following mTBI) and Phase 1 of our research plan will focus on determining that HRV is also a good proxy for brain biomarkers (i.e. functional magnetic resonance neuroimaging fMRI) with respect to revealing disruption in brain homeostasis. This approach expands upon current commonly-used measures to include an objective neurophysiological indicator of stress capacity that can be used in conjunction with the individual's reports of cognitive, emotional and somatic symptoms as well as clinician's assessment of balance, strength and cognition.

**Mark Bayley – Medical Director, Brain and Spinal Cord Rehabilitation Program, Toronto Rehabilitation Institute–UHN.**

***Ontario Concussion Guidelines***

(Summary not provided.)

**Todd Jackson – Senior Manager of Insurance and Membership Services, Hockey Canada.**

***Concussion Prevention in Hockey.***

Hockey Canada continues to make safety in the game a priority. If we want to recruit young people to the game and keep them involved, it is essential for us to ensure a safe and positive environment. Basic skill development is the key, and this entails allowing young players sufficient time to learn the core skills of the game and benefit from the Long Term Player Development philosophy. Hockey Canada continues to give coaches the tools they need to properly teach young players the basic skills, and at the same time teach them to play by the rules of the game and with respect. Awareness also plays an integral role in reducing injuries such as concussions and spinal injuries. Hockey Canada drives awareness to the team level through the Hockey Canada Safety Program, which prepares volunteer safety people to recognize and respond to injury, but most importantly to prevent injury from occurring. Through the Safety Program and tools such as the Hockey Canada concussion apps, we continue to communicate with the grassroots of hockey and provide important information that focuses on skill development, respect in the game, rule enforcement and injury prevention as a whole.

**Jayne Morrish – Research Coordinator, Parachute Canada.**

***Preventing Concussions – What’s going on and what we can do?***

Parachute Canada is a national, charitable organization dedicated to preventing injuries and saving lives. Parachute began in July 2012 and unites the former organizations of Safe Communities Canada, Safe Kids Canada, SMARTRISK and ThinkFirst Canada into one leader in injury prevention. Parachute’s injury prevention solutions, knowledge mobilization, public policy, and social awareness efforts are designed to help Canadians reduce their risks of injury while achieving Parachute’s vision of an injury-free Canada where Canadians enjoy long lives lived to the fullest. One type of injury that Parachute is focusing on preventing is concussions, particularly because recent data demonstrates how common these injuries are. Specifically, data from the Public Health Agency of Canada has demonstrated that in the 2010/2011 there were 2,766 concussion related hospitalizations in Canada and in 2009/2010 there were 14,766 concussion related emergency room visits in Ontario. These numbers are the tip of the iceberg in terms of occurrence, with even more concussions going unaccounted for in hospital related databases – such as concussions treated by family doctors and those that are undiagnosed and / or untreated. As such, prevention efforts must work to change the entire environment around concussions, which will aid in shrinking this issue from the bottom-up. Additionally, key pieces of research on concussion prevention need to be included – such as reminding individuals that helmets do not prevent concussions (but are very important pieces of protective equipment for other injuries); coaches, trainers and teachers must to receive education on concussions as they are key for ensuring that safety is being practiced both on and off the field; rule changes and enforcement are essential for reducing injury; and there must be a focus on recognition, treatment and management of concussions in order to prevent the potentially drastic secondary-

effects. Parachute offers various injury prevention solutions: online concussions courses for parents, coaches and players; curriculum based solutions (e.g., Brain Day); online resources through our concussion toolkit; and various campaign pieces. Visit [www.parachutecanada.org](http://www.parachutecanada.org)

**Amy Padro – Manager of Government Relations, Parachute Canada.**

***Media Coverage of Concussion and the Passage of Concussion Education Legislation: How the media and advocacy can work together for policy change?***

Policy and legislation are often the most effective ways to achieve lasting, sweeping changes that have the potential to positively impact injury rates. However, in order to be successful in achieving legislative change, direct advocacy alone is not sufficient. Increasingly, the media is playing a significant role in highlighting issues and shaping public debate around a topic. This is particularly the case in the ongoing debate in the media on sport related concussion.

The presentation highlights the nature of the public debate in the US media prior to the introduction of concussion legislation in a number of jurisdictions. The presentation will demonstrate that the strategic use of the media can encourage favourable public opinion for a policy direction. This is instrumental in gaining the attention of decision-makers with the ability to influence policy and legislation. In highlighting media coverage on concussion, the presentation will demonstrate that public awareness and media coverage of a given topic often precedes government action. If combined with strategic government relations approaches, it is likely that the continuing media attention on concussion will eventually lead to the enactment of concussion education legislation in Canada.

**George Kourtis - Health and Physical Education Program Co-ordinator, Toronto District School Board.**

***Management of Concussions in Elementary and High Schools***

(Summary not provided.)

**Nancy Schad – Safety Consultant, Ontario Physical Health and Education Association (OPHEA).**

***The Ontario Physical Education Safety Guidelines Concussion Protocol***

The Ontario Physical Education Safety Guidelines, [safety.ophea.net](http://safety.ophea.net), provide school boards, (teachers, coaches and intramural supervisors) with the minimum standards for risk management practice for the physical education curriculum, interschool teams and intramural activities. All six of the modules include the Concussion Protocol in Appendices C-1 through to C-4. The purpose of the Concussion Protocol is to provide support in the identification and management of concussion.

Appendix C-1 includes:

- Context and definition of concussion;
- Diagnosis by a medical doctor or nurse practitioner;
- Common signs and symptoms;
- Initial response procedures;
- Return to Learn Plan and educator resources;
- Return to Physical Activity Plan;



- Responsibilities of the school principal;
- Responsibilities of the school collaborative team;
- Documentation procedures for the medical examination and for each step in the student recovery process; and
- Summary Chart 1 provides a visual overview of the steps and roles and responsibilities in suspected and diagnosed concussions.

Appendix C-2 is the Tool to Identify a Suspected Concussion

Appendices C-3 and C-4, document the medical examination, and provide a means of communication between the parent/guardian, school and medical doctor/nurse practitioner to monitor the student recovery process.

**Steve Soroko – Healthy Schools Implementation Coordinator, Ministry of Education, Ontario.**

*Prevention Strategies for Ontario Schools*

(Summary not provided.)

**Brian Levine – Senior Scientist, Baycrest Rotman Research Institute.**

*The Baycrest Brain Health in NHL Alumni Study*

Both unhealthy brain aging and traumatic brain injury (TBI) have been associated with neurodegenerative changes that cause a great deal of human suffering and distress. Previous research has shown that aging and TBI are independently associated with neurocognitive changes that can result in cognitive impairment; however, whether they interact to accelerate such impairments is unknown. Concussions, or mild TBIs (mTBIs) in sport, especially when repeated, have been linked to cognitive impairments in aging (such as Alzheimer’s disease and memory impairments), and have been associated with an earlier onset of cognitive impairments compared to individuals who have not experienced a concussion. This presentation outlines the research model for the Baycrest Brain Health in Professional Athletes Study, a longitudinal examination of the neurocognitive function in members of the National Hockey League (NHL) alumni. Participants are evaluated longitudinally using a comprehensive battery of behavioural, lifestyle, neurological, and neuropsychological measures, as well as state-of-the-art neuroimaging techniques, to assess the long-term effects of repeated TBIs on neurocognitive function and its interaction with aging and other factors that may contribute to brain health outcomes.

**Doug Richards, Sports Physician, University of Toronto, and Paul Comper, Clinical Neuropsychologist, UHN, McIntosh Clinic.**

*The McIntosh Clinic Concussion Research Program*

The MacIntosh Sports Medicine Clinic Concussion Program at the University of Toronto was initiated in 1999; it was one of the first interdisciplinary, comprehensive programs in the country dedicated to concussion management for university level student-athletes. In 2011, service provision was expanded to the community at large. In addition to clinical services, we have also focused on studying many concussion spectrum issues, including but not limited to cognitive dysfunction following injury, physiological determinants of safe return-to-play/return-to-learn,

mechanisms of injury, and the psychological and emotional correlates of concussion. Our efforts to disseminate knowledge about concussion have resulted in many publications over the years. These include systematic and programmatic reviews, prospective studies of return to play guidelines, and other factors (e.g., such as musculoskeletal pain) that might influence cognitive functioning following concussion. Currently, we are studying age related differential concussion recovery rates, the efficacy of exercise (as opposed to rest) as a treatment modality for concussion, and various physiological markers as indices of injury and recovery. We are also currently involved in a study that addresses multiple factors as predictors of concussion recovery, as well as the efficacy of a structured 'return-to-learn' program in a population of adolescent/youths who have suffered concussions.

**Leo Da Costa – Neurosurgeon, Sunnybrook Health Sciences Centre.**

### ***Imaging of Concussions***

Although the majority of patients with mild traumatic brain injury (mTBI) recover in weeks, up to 30% continue to experience persistent neurocognitive symptoms. Despite the persistence of symptoms for many, standard clinical imaging is frequently normal. We used MRI to study cerebrovascular reactivity to CO<sub>2</sub> in patients with mTBI and its correlation with persistent symptoms. Twenty-five patients (mean age = 42.6; 72% males) who sustained a recent mTBI were submitted to CVR testing using BOLD MRI (average 63 days post-injury) and CO<sub>2</sub> manipulation. Symptoms were assessed using SCAT2 questionnaire. Mean CVR indexes were generated for whole brain (WB), grey (GM) and white matter. Spearman coefficient examined the correlation between WB, GM and GM and SCAT-2 scores. WB CVR ( $r=0.4$ ,  $p=0.048$ ) and GM CVR ( $r= 0.4$ ,  $p=0.044$ ) were correlated with SCAT-2 scores, with lower CVR indexes (indicating a state of vasoparalysis in response to CO<sub>2</sub>) correlating to lower SCAT2 scores (more symptoms). Severity of PSC correlates with impairment of CVR on BOLD MRI. Regional variations can be detected by the technique. BOLD CVR needs to be investigated longitudinally as an imaging indicator of severity of injury in seemingly mild injuries.

**Michael Kis – Neurosurgeon, Trillium Health Partners.**

### ***Measurement of Rotational Acceleration is Essential for Helmet Design***

The importance of rotational acceleration in the generation of concussions has long been established. Although there exist anthropometric and biomechanically accurate neck and head models that can be used to simulate concussive injury, the current helmet standards only include linear acceleration in helmet safety testing. Given that the importance of rotational acceleration is firmly established, the reason for this lack of inclusion is the difficulty in simulating reproducible rotational movement that could be standardized as part of safety testing. Our group has developed the Kingston Impact Simulator which is the first device of its kind to simulate reproducible and reliable rotational impacts for helmet testing. Our most recent study examined commercially available hockey helmets and subjected them to concussive level forces and measured rotational acceleration. The key design feature of the machine is the separation of the complex 3D movement into its component vectors to test each axis of movement separately. Our test paradigm provides a bridge between the science of concussion and the engineering of helmet design. Our results demonstrate clear differences in rotational acceleration protection both between different locations in a given helmet as well as between corresponding locations of different helmets. These results were published in the November 2013 issue of Clinical Journal

of Sports Medicine. While it is well established that helmets do a good job of protecting the head against major head impact, their ability to dampen rotational acceleration is variable and as yet not well characterized. Rotational acceleration protection is not assessed in current helmet standards. Our device provides a new way to improve helmet safety and enhance helmet construction. Future research directions will involve testing football helmets and multi-purpose helmets as well as calibrating the role of specific neck muscles in dampening rotational acceleration.

**Matthew Burke – Neurology Resident, University of Toronto.**

### ***Review of Evidence-Based Treatment of Concussion***

Recent systematic literature reviews have concluded that there is minimal evidence to support any specific treatment for concussion, including the fundamental principles of return-to-activity protocols such as type or duration of rest. Consequently, there has been a widespread call for well-designed trials to strengthen the evidence-base for concussion treatment.

Our study utilized data from Clinicaltrials.gov and seven other international clinical trial registries to examine the characteristics of 71 ongoing or recently completed trials investigating the treatment of concussion/mTBI. We found that there are a number of diverse, potentially promising therapies being studied but also several deficiencies, including a paucity of trials addressing return-to-activity principles, small sample size and trial heterogeneity that may threaten the ability of these studies to ultimately influence clinical practice.

**Michael Cusimano - Neurosurgeon, St. Michael's Hospital.**

### ***Concussion Incidence in the NHL***

Athletes participating in contact sports such as ice hockey are exposed to a high risk of suffering a concussion. We determined whether recent rule changes regulating contact to the head introduced in 2010–11 and 2011–12 have been effective in reducing the incidence of concussion in the National Hockey League (NHL). A league with a longstanding ban on hits contacting the head, the Ontario Hockey League (OHL), was also studied. A retrospective study of NHL and OHL games for the 2009–10 to 2011–12 seasons was performed using official game records and team injury reports in addition to other media sources. Concussion incidence over the 3 seasons analyzed was 5.23 per 100 NHL regular season games and 5.05 per 100 OHL regular season games (IRR 1.04; 95% CI 1.01, 1.50). When injuries described as concussion-like or suspicious of concussion were included, incidences rose to 8.8 and 7.1 per 100 games respectively (IRR 1.23; 95% CI 0.81, 1.32). The number of NHL concussions or suspected concussions was lower in 2009–10 than in 2010–11 (IRR 0.61; 95% CI 0.45, 0.83), but did not increase from 2010–11 to 2011–12 (IRR 1.05; 95% CI 0.80, 1.38). 64.2% of NHL concussions were caused by bodychecking, and only 28.4% of concussions and 36.8% of suspected concussions were caused by illegal incidents. We conclude that rules regulating bodychecking to the head did not reduce the number of players suffering concussions during NHL regular season play and that further changes or stricter enforcement of existing rules may be required to minimize the risk of players suffering these injuries (Donaldson L, Asbridge M, Cusimano MD. PLoS One. 2013 Jul 17;8(7):e69122).