

The Canadian Concussion Centre



Speaker Presentations

1. Canadian Concussion Centre: Progress Report

C.H. Tator

The Canadian Concussion Centre was initiated in 2000 as the Canadian Sports concussion Project, and adopted its new name in 2015 to indicate its broadened scope to include concussions in motor vehicle crashes, falls at home and workplace injuries. Many research projects have been completed or are in progress. The full range of conditions comprising the concussion spectrum of disorders have been examined including acute concussion, second impact syndrome, postconcussion syndrome (PCS) including depression and anxiety and chronic traumatic encephalopathy (CTE). Fifteen neuroscientists comprise the active group of investigators, and there are 18 members of the Advisory Board. There is a concussion fellowship, the first offered in Canada, and a search is underway to appoint the Soloway Concussion Chair, the first in Canada. More than 4M\$ has been donated to the CCC in addition to research grants from several agencies. More than 300 PCS patients have been entered into clinical research studies including almost 100 professional athletes, mainly CFLAA retired players. The research involves neurological, neuropsychological, and imaging assessments with MRI, MEG and PET. Twenty brain donations have been received and approximately half have had CTE. Two treatment trials have also begun for PCS, and there is an education/support group that meets regularly to help PCS patients.

2. MEG in the Diagnosis and Prognosis of Concussion

R. Wennberg, Y. El-Rahimy, N. Shampur, L. G. Dominguez

Abnormalities in neurophysiologic function underlie the deficits in cognitive processing caused by concussion. It is hoped that magnetoencephalographic (MEG) measures of the brain's cortical activity might reliably document the presence of dysfunction caused by concussion, as well as track neurophysiologic recovery. Three potential measures with sound theoretical bases and preliminary data include: (1) the middle-latency somatosensory evoked field (SEF) M60, normally present 60 milliseconds after stimulation of the median nerve at the wrist, representing the first intracortical stage of neuronal processing of external somatosensory input to the brain; (2) the middle-latency auditory evoked field (AEF) M50 ratio, which shows suppression of the cortical response normally present at 50 milliseconds to the second of paired auditory stimuli presented 500 milliseconds apart, reflecting the brain's auditory gating of multiple sensory stimuli; and (3) the presence of intermittent low frequency activity in the background "resting state", representing deafferentation of cortical grey matter secondary to subcortical white matter dysfunction. We present data from a small initial series of patients showing measurable differences at the individual subject level between patients with acute concussion and controls in M60 SEF latencies and M50 AEF suppression ratios, as well as within subject changes during recovery in the weeks after concussion.

3. How often are Abnormalities Detected on Conventional MR Imaging in Patients with the Clinical Diagnosis of Concussion?

D.J. Mikulis, P. Dufort, A.P. Crawley, C.H. Tator

The diagnosis of concussion is based on clinical criteria alone and assumes that the neurological manifestations are purely functional without structural changes. However, advanced imaging techniques have shown group differences in structural metrics (controls vs. patients), but the ability to identify these alterations in single subjects has not yet been achieved. Therefore, most patients with concussion do not undergo MRI as part of the diagnostic assessment. The question nevertheless remains, "How effective is the clinical examination in excluding gross structural brain injury in "concussed" subjects?" In light of this, we conducted a review of conventional MRI scans in patients with the clinical diagnosis of concussion as well as controls who were enrolled in a provincial multicenter concussion study sponsored by the Ontario Brain Institute. A total of 45 patients and 31 controls were recruited from the University of Toronto, McMaster University, and The University of Western Ontario. Conventional MRI scans were reviewed by an experienced neuroradiologist who identified any abnormality that was then

categorized as either likely traumatic vs non-traumatic in nature. The results of this study revealed that there is evidence of traumatic brain injury in the concussed group on conventional MRI. The impact of these findings on the diagnosis of concussion as well as the implications on research studies will be discussed.

4. Regional Brain Volumes Correlate with Behavioural Symptoms in Individuals with Post-Concussion Syndrome.

K. Misquitta, J. Chung, M. Eizenman, A. Ebraheem, A. Tarazi, N. Multani, M. Khodadadi, R. Goswami, R. Wennberg, C.H. Tator, R.E. Green, B. Colella, D.J. Mikulis, M. C. Tartaglia

Individuals with post-concussion syndrome (PCS) experience a range of behavioural symptoms that can persist for months or years following injury. Previous research shows that brain atrophy can occur following a concussion and may contribute to post-concussive symptoms^{1,2}. Visual Attention Scanning Technology (VAST, EL-MAR Inc., Toronto, ON, Canada) is an eye-tracking technology that measures individuals' free scanning behaviour when viewing images from different themes. This study assesses the relationship between cortical and subcortical volumes and behaviour measures (aggression, apathy and depression) using VAST in patients with PCS. Forty-four patients (mean 35.5 years) with post-concussive symptoms after multiple concussions and an average of 4 concussions and 9 controls (39.6 years) participated. Cortical and subcortical brain segmentation was completed using FreeSurfer. Visual scanning parameters were measured using VAST and correlated with cortical and subcortical volumes. Brain volumes and VAST performance were not significantly different between patients and controls. Lower left hippocampal volume was related to depression ($r=-0.264$, $p=0.033$) and total hippocampal volume to aggression ($r=-0.344$, $p=0.008$) measured with VAST. Lower amygdala and putamen volumes were associated with apathy ($r=-0.273$, $p=0.029$; $R=-0.268$, $P=0.031$, respectively). Smaller volumes of limbic structures and putamen were related to behaviour in PCS patients. Atrophy may be implicated in the behavioural changes seen in PCS. Financial Disclosure: Prof. Moshe Eizenman is a director in EL-MAR Inc.

5. Application of Deep Learning to the Detection of White Matter Damage in Diffusion Weighted Imaging of Concussion Patients

P. Dufort

Despite ongoing and intensive efforts, diagnostic neuroimaging protocols capable of reliably detecting damage associated with concussion have remained elusive. It is now well established that standard CT and MR protocols have little diagnostic value in this context. Advanced diffusion tensor imaging (DTI) metrics like

fractional anisotropy and mean diffusivity have revealed group differences between patients and controls in some studies, but many others continue to report a complete absence of significant findings. Diffusion weighted imaging scans possess millions of variables with the potential to embody complex nonlinear patterns, yet contemporary methodology employs relatively few simple measures to elucidate them. Emerging machine learning techniques, deep learning in particular, have the potential to reveal more complex patterns by disentangling the independent sources of variation that generated them. In this talk, we will provide a high-level overview of deep learning, and describe its potential application to the analysis of diffusion-weighted imaging data for the detection of white matter damage from concussion. Rather than focusing on the standard tensor model, we will show how deep learning can be employed to mine patterns from the fiber orientation distributions produced by state-of-the-art diffusion tractography software.

6. Let's ChAT Deeply about Hockey: Uncovering the Neurochemistry of CTE

L.N. Hazrati

Chronic traumatic encephalopathy (CTE) is a progressive neurodegenerative disease associated with repetitive concussive and sub-concussive head injuries. This disease has become a popular topic due to its close association with sports involving repetitive and high impact collisions such as football and hockey.

Post-mortem pathological analysis has defined CTE as a Tau-pathology with neurofibrillary tangles (NFTs) accumulating in both neurons and astrocytes. It is believed that these pathological abnormalities result in progressive deficits in cognition, behavioral, mood and motor function.

CTE has been neuropathologically classified into four stages according to the location and spread of NFTs. As early as the stage II of the disease, NFTs are noted to involve deep-seated groups of neurochemically diverse brain structures (cholinergic, dopaminergic and serotonergic). These deep and discrete neuronal groups often show few NFTs and there is no obvious evidence of neuronal death. However, the extent of the loss of their projections to their main targets is not known. Any loss of these biochemically varied projections to the cortex would seriously affect the function of cortical neurons in general and lead to neurological and psychiatric deficits.

In this study we have examined the fiber densities of cholinergic (ChAT+), serotonergic (5HT+) and dopaminergic (Th+) fibers in the cortex of our cohort of young hockey players with neuropathologically proven CTE. Our results indicate significant deficits in all three systems in different cortical areas (with and without tau pathology). These findings indicate that multiple head traumas induce important brain biochemical imbalances that extend beyond the areas of tau

deposits and can be suspected to cause more directly the behavioral and mood disorders associated with CTE.

7. Tau and Neurofilament Light (NFL) in Blood – Promising Biomarkers for Acute TBI

K. Blennow

Evaluation of patients with mild traumatic brain injury (mTBI) is an important medical problem in the emergency ward. Awareness of the risks associated with repeated mTBI in high-impact contact sport athletes has also increased, mainly driven by reports on the of the long-term clinical consequences, a neurological condition called chronic traumatic encephalopathy (CTE).

Diffuse axonal injury (DAI), i.e. shearing of fragile axons by acceleration/ deceleration forces from the trauma, is a central pathophysiological mechanism in TBI. Clinical studies suggest that the neuronal proteins tau and neurofilament light (NFL) in cerebrospinal fluid (CSF) are candidate biomarkers for acute TBI, but CSF sampling on TBI cases is difficult to implement in the clinical situation.

Thus, blood biomarkers would be valuable, with several potential implications, including as diagnostic tools to identify and estimate the severity of, or rule out, neuronal damage; to predict prognosis in patients and guide return-to-play decisions in athletes; to monitor treatment effects on neuronal damage in clinical trials; and to study TBI pathophysiology directly in patients. However, development of blood biomarkers for brain injury has been hampered by the lack of assays sensitive enough to adequately quantify brain-specific proteins in blood, or have limited specificity for brain damage due to peripheral expression of the protein (e.g. S100B).

The novel ultra-sensitive analytical technique, Single Molecule digital Array (Simoa) is a bead-based fluorescence imaging immunoassay with digital quantification, which gives an extraordinary increase in analytical sensitivity. We have developed novel Simoa assays for measurement of tau and NFL in blood samples. These assays are sensitive down to 1-2 pg/mL, and able to measure the proteins in all samples, also from healthy people.

In a pilot paper, we show that tau in plasma (in samples taken 1 hour after the trauma) can predict outcome of mTBI/concussion in ice hockey players. The NFL assay was evaluated in a study on severe TBI patients. Blood samples were taken at admission and up to 12 days after injury and at 1-year follow-up. Serum NFL at admission yielded an AUC of 99% vs. 96% for S-S100B, and increased to 100% for S-NFL vs. 65% for S-S100B at day 12. Serum NFL was significantly higher in non-survivors than in survivors, with high sensitivity and specificity figures. High NFL levels were also related to poor functional outcome at one-year follow-up,

while S100B did not relate to functional outcome. These results suggest that measurement of tau and NFL in blood show promise as biomarkers for TBI, both for diagnosis and prediction of prognosis.

8. Use of Cognitive-Motor Integration to Track Function Following Concussion in Youth

L. Sergio

A prominent health issues facing Canadians is the impact of concussion (mild traumatic brain injury) on young athletes. Further, the current metrics used to assess safe return to play/learn/work are not comprehensive. Whether caused by trauma or degenerative disease, the effect of mild brain insult on one's functional abilities is not well understood. This talk will review our research to date which shows that "cognitive-motor integration", or tasks which rely on rules to plan a movement (such as "push the computer mouse forward to move the cursor up"), is impaired in both elite and non-elite young athletes following mild traumatic brain injury. Dr. Sergio will also discuss the development of a clinical cognitive-motor assessment tool to assess brain function following concussion.

9. Assessing Symptoms of Depression and Concussion in Adolescent Athletes Devoid of Concussion Injury

T.Renton , A. Colantonio, N. Reed, J. Topolovec-Vranic

The study aimed to: i) investigate the prevalence and establish normative data for depressive and concussion-like symptoms by sex among adolescent athletes, ii) investigate the relationship between self-reported symptoms, demographic characteristics and medical history (e.g. history of concussion, depression, anxiety or learning disability) This was a cross-sectional study of athletes. Individuals were recruited from i) community level sport organizations or ii) participating in baseline testing conducted by a concussion management clinic in the GTA. Participant demographics and medical history as well as The Post-Concussion Scale (PCS) and The Mood and Feelings Questionnaire (MFQ) were collected.

83 male and 80 female athletes participating in all sports and levels of competition were recruited. Results showed elevated rates of depression and other post-concussion symptoms among girls versus boys ($p < 0.05$) despite absence of concussion injury. Multivariate analyses showed that sex was a predictor of higher concussion and depressive symptomology.

Despite absence of injury, concussion-like symptoms were present in athletes particularly among girls. Findings suggest the need to further understand the

meaning of “symptom-free” in terms of return-to-play concussion management strategies and gendered management strategies.

10. Return to School vs Return to Play; Are they Compatible?

C. DeMatteo

In a CIHR funded 3 year prospective study presently underway of children/youth 5-18 years with concussive injury, we will endeavor to answer the question: does adherence to the “Return to Activity” (RTA) and “Return to School” (RTS) guidelines, improve outcomes as measured by the duration of symptoms and prevention of repeated injuries? Four main factors are being examined to measure ‘compliance’ or adherence to guidelines. These are: i) Symptoms – every 48 hours, ii) Actigraph accelerometers and log, iii) Cognitive activity scale, iv) Stage of guidelines. Timing of return to school versus return to play along with symptom status will be presented from the first 68 participants. Preliminary analyses, shows that on average youth are returning to school with accommodations by 8 days post injury and fully back to school by 1 month. Sixty two percent of youth report problems at school with 20% reporting a drop in grades. Significant correlations with school problems and certain symptoms are evident; particularly symptoms of sleep problems, fatigue and sadness. The biggest finding remains that youth return to school faster than they return to play despite symptom profiles. And adherence with return to school guidelines appears to be less than Return to Activity/Play guidelines.

11. Contributions of Functional MRI and Event-Related Potentials to Mild Traumatic Brain Injury/Concussion Evaluation

A. Ptito

The goals of the talk will be to present the clinical picture of concussion and mild head injury with an emphasis on sports and motor vehicle accident victims. Functional magnetic resonance imaging and event-related potentials data obtained from athletes with persistent post concussive symptoms, particularly depression, will be described. Serial functional neuroimaging studies suggestive of recovery will also be introduced. Data obtained with children aged 10-17 will be discussed and compared to those of adults. Individual functional magnetic resonance imaging and event-related potentials data will also be presented to illustrate the potential of these tools in a clinical setting. In addition, new data on potential new treatments with neuromodulation (rTMS and stimulation of the tongue) in mild TBI and multiple sclerosis will be presented.

12. Insomnia in Patients with Mild Traumatic Brain Injury/Concussion

T. Mollayeva , A. Colantonio

Insomnia, the complaint of inadequate sleep despite adequate opportunity, is commonly reported by patients with mild traumatic brain injury (mTBI)/concussion. It can lead to serious impairments of daytime functioning, impede the rehabilitation process and the return to productive life. Ongoing sleep problems can also contribute to the development of new or exacerbation of pre-morbid medical and psychiatric disorders, constituting additional burden to the already compromised brain and bodily functions of the impacted individual. In reviewing the pathophysiology of post-traumatic insomnia in mTBI/concussion, no single mechanism has been found to be responsible for disordered sleep and wakefulness after injury to the brain. The goal of this presentation is to emphasize the importance of a multifaceted approach to dealing with insomnia in patients with mTBI/concussion. In due course, insomnia in this population must not be viewed as a singular diagnosis but as a manifestation of a complex interaction of socio-demographic, medical, psychiatric, behavioural, and environmental factors.

13. The Potential for Phytocannabinoids and Terpenoids to Treat Concussion Sequelae without Psychoactive Adverse Effects

N.K. Jha, B. DeBenedictis, G. Cheung, J. Bailes, L. Grinspoon

Concussions are TBIs (Traumatic Brain Injuries) that present with physical, cognitive, emotional, and/or sleep-related symptoms that do not require loss of consciousness, impact to the head, or positive findings on routine neuroimaging. Currently, concussion management focuses on moderate amounts of physical and cognitive rest, avoiding levels of physical/cognitive activity that exacerbate symptoms, and protection from re-injury while symptomatic. Despite these guidelines, a significant proportion of concussed individuals develop Post-Concussive Syndrome, where symptoms can last months or even years. To date, no pharmaceutical or nutraceutical compound has been shown to be effective in preventing or treating concussion through a double-blind, randomized, placebo-controlled clinical trial. The ideal outcome of research in this area would be to develop a formulation of cannabinoids and terpenoids that is effective in improving patient outcomes following concussion without causing adverse effects. Basic science research has shown that a multitude of compounds in cannabis, including CBD, THC, and terpenoids, may work synergistically to provide neuroprotection and anti-inflammatory effects without causing any psychoactive effects. While much research has been put into the potential therapeutic use of cannabinoids, well-designed studies with objective measures of patient improvement are lacking

regarding the efficacy of cannabinoid use for TBI. This abstract outlines the basic science rationale for a proposed formulation of cannabinoids and terpenoids to treat concussion sequelae.

14. Concussion Research at Western University

D. Fraser

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 on biomarkers and interventions. The former include combinations of clinical exams, balance testing, neuropsychological evaluations, brain injury metabolite measurements, immunological alterations and pathological changes observed on 7T MR imaging. The latter include a RCT of early exercise intervention with and without the use of a weighted compression vest. 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 have been developed. Our focus on concussion research and awareness at Western University recently culminated with the third annual “See the Line” event, chaired by retired professional hockey player Eric Lindros, and included a Concussion Symposium and Gala/Dinner (www.seetheline.ca).

15. Characterizing Retired CFL Players with a History of Multiple Concussions: An Update

A. Terpstra , B. Colella, R.E. Green

In retired CFL players with a history of concussion, understanding (i) whether there are core and cross-cutting cognitive and neuropsychiatric impairments and if so, (ii) the characteristics of such deficits, would permit early and targeted therapies. Previously, we examined 20 retired CFL players with a history of multiple concussions and found significant group differences between players and matched controls on a go-no-go task, and on indices of mania and aggression, providing preliminary evidence for compromise to the latent variable of inhibitory control. Here, we provide an update to these findings. The objectives were (i) to replicate the original findings in a second and larger sample of patients; (ii) to

provide evidence that the findings cannot be fully explained by a “cohort effect” (i.e., attributed to premorbid traits selected for in elite, professional football players). 30 new (plus 20 previously assessed) retired CFL players were administered a cognitive and neuropsychiatric battery; results were correlated with concussion and play history. We replicated the original findings, and, further, demonstrated poorer inhibitory control in those who played for longer and/or had sustained more concussions. While hypomania and elevated aggression may be pre-morbidly higher in those drawn to professional football, these characteristics appear to be exacerbated by multiple concussions. These symptoms should be early targets of therapy not only for symptom relief, but also to remediate or mitigate underlying brain dysfunction, and to prevent further exacerbation of symptoms through accelerated aging.

16. Motor Deficits in Former CFL Players with Multiple Concussions

A. Tarazi, A. Ebraheem, M. Khodadadi, C.H. Tator, R. Wennberg, M.C. Tartaglia

Concussion (mild traumatic brain injury) is common in contact sports, including boxing, hockey, and football. Repeated concussions have been implicated in dementia pugilistica (DP), a syndrome described in boxers that included motor, cognitive and behavioral deficits. Recently, chronic traumatic encephalopathy (CTE), usually presenting with cognitive and behavioral symptoms but no motor symptoms has been described in former professional football players with repetitive concussions. Some have proposed that these two syndromes are the same. We investigated the incidence of motor impairments in former professional Canadian Football League (CFL) players. We assessed motor symptoms and signs (including UPDRS-Part3) in 46 former CFL players (mean age 53.4) with a history of multiple concussions and 25 healthy controls (mean age 50.0) with no history of concussion. There was no significant difference in UPDRS in both groups. The mean for CFLs was 0.52 and for controls was 0.16 ($p=0.135$). One CFL had mild dysmetria on heel-shin test. Motor signs were not found in former CFL players.

Motor impairments including Parkinsonism, weakness or gait difficulty were not common in former CFL players with a history of multiple concussions. This is a major difference between CTE and DP and warrants further investigation. Differences in mechanism of injury could be responsible for the differences in signs and symptoms between DP and CTE.

17. The Baycrest Brain Health in Professional Athletes Study

B.Levine

The Baycrest Brain Health in Professional Athletes Study protocol provides a comprehensive assessment of neuropsychological, behavioural, and brain function in retired professional and university alumni hockey players. This talk will focus on neuropsychological and behavioural findings and their relationship to detailed structural and functional neuroimaging results. Discussion will focus on the challenges of interpretation of brain and behavioural findings in this unique sample

18. Developing Interventions to Mitigate Symptoms and Prevent Deterioration in Retired CFL Players

B. Colella ,L. Ruttan, S. Lombardi, C. Saverino ,L. Miguel-Jaimes, L. Meusel, R.E. Green.

Retired CFL players and their spouses often report a constellation of cognitive and neuropsychiatric changes that in some cases interfere with day to day functioning. These include increased irritability and stress, as well as elevated anxiety, depression, and executive dysfunction. In our studies characterizing this population, we have found similar such changes through a combination of performance-based and self-report measures. Therefore, the overall aim of the clinical research arm of our study has been to develop an intervention protocol and delivery platform to treat and remediate dysfunction, while delivering therapy to the participants (i.e., retired players) through their participation in research. Here we will present preliminary feasibility findings of face-to-face and remotely delivered combination therapy that is designed to dually treat symptoms and to prevent further deterioration. We will also present preliminary efficacy findings for mood, stress and cognitive dysfunction.

Poster Presentations

19. Neuroanatomical Correlates of Visual Working Memory and Visual Attention as Measured by Perceptual- Cognitive Task in Post-Concussion Syndrome

M. Ozzoude, K. Misquitta , J. Faubert, A. Ebraheem, A.Tarazi , N. Multani,

**M. Khodadadi, R. Goswami, R. Wennberg, C.H. Tator, R.E. Green, B.Colella, D.J. Mikulis
M. C. Tartaglia**

Concussion is a pathophysiological process that causes somatic, behavioral, and cognitive symptoms that usually resolve but in 10% of patients can persist for months, years and indefinitely as post-concussion syndrome (PCS)¹ especially

after multiple concussions. We aim to examine the use of a visual working memory test for detecting the effects of repeated concussions and as a possible diagnostic biomarker for PCS. Thirteen former professional athletes with multiple concussions and Thirteen age and education matched controls underwent a perceptual-cognitive task (NeuroTracker™), MRI, and neuropsychological evaluations. Task-specific regions investigated were: middle/superior frontal, parahippocampal, superior/middle/inferior temporal, precuneus, lingual, superior parietal, pars triangularis, pars orbitalis, and pars opercularis ². We investigated group differences in NeuroTracker scores and the relationship between NeuroTracker, neuropsychological performance, and freesurfer derived cortical thickness (<http://surfer.nmr.mgh.harvard.edu>). There was no significant difference between controls (mean age=41.70, mean education=16.3) and athletes (mean age=48, mean education=16.7) on NeuroTracker performance ($p=0.833$). The NeuroTracker score correlated with Rey Visual Design Learning Test trial 1-5 ($r=0.500$, $p=0.013$), right parahippocampal thickness ($r=0.408$, $p=0.048$) and right precuneus thickness ($r=0.410$, $p=0.047$). NeuroTracker performance may be a good measure of visual working memory deficits and relate to neuroanatomical areas important for encoding and recognizing environmental scenes (parahippocampal gyrus) and visuospatial attention (precuneus gyrus).

20. Resting-State Functional Connectivity in a Group of Individuals with Post-Concussion Symptoms Compared to Non-Concussion Controls: Preliminary Findings

R.Shafi, A.P. Crawley, M.C. Tartaglia, C.H .Tator, A. Colantonio, D.J. Mikulis

Concussion may result in cognitive, neuropsychological and behavioural sequelae well beyond the one year post-injury period. The literature contains conflicting results concerning resting-state functional connectivity in subjects experiencing post-concussive syndrome, but there is evidence that traumatic brain injury can disrupt connectivity within and between the salience, default mode and executive brain networks [1]. We collected behavioural and 3T MRI data from a sample of 34 individuals (17 males, mean age 34 years) who reported a history of multiple concussions (range 2-18) and 22 participants (9 males, mean age 36 years) with no known history of concussion. ROI-to-ROI and Network –to-ROI analyses were used to assess within and between connectivity in the salience, default mode and executive networks using the Functional Connectivity (CONN) toolbox [2]. When comparing subjects reporting a history of concussion with their age-matched controls, our preliminary results reveal, 1) an increased connectivity between the left Supramarginal Gyrus (SMG) and the bilateral cuneal cortices, and 2) a decreased connectivity between the right inferior frontal gyrus (pars triangularis)

and the cerebellum. Consistent with the literature, our findings suggest a preservation of the large-scale network connectivity with albeit disruptions at local networks. These disruptions may thereby interference with higher-order cognitive processes and explain the persistent symptomatology in the postconcussion population.

21. The Impact of Age and Gender on Mechanism of Concussion: a Retrospective Cohort Study

B. Varriano, C.H. Tator, A. Tarazi, A. Ebraheem, M.C. Tartaglia

Post-Concussion Syndrome (PCS) develops in approximately 10% of patients who have suffered concussion and can last weeks, months or even indefinitely. PCS is most often described after concussion from contact sports, falls, motor vehicle accidents (MVA) and trauma. It is unknown whether gender and age influence cause of concussion. This is a retrospective analysis of patient-reported concussions from the Canadian Concussion Centre Clinic, Toronto Western Hospital. Variables considered included gender, age (young vs. old: cut-off 50) and cause of concussion for 462 cases (F:177;M:285; <50:406; 50+:56). Concussion from MVA was more common in females than males (17.5% vs. 8.4%, respectively;p<0.01). Concussion from falls was more common in older than younger people (32.1% vs. 10.8%, respectively;p<0.01). Concussion from MVA was more common in older than younger people (30.4% vs. 12.6%, respectively;p<0.01). Concussion from sport was more common in younger than older people (62.8% vs. 24%, respectively;p<0.01). There are age and gender differences in concussion cause. MVA is a more common cause of concussion in females and the old. Concussion from falls is more common in the old while sport is a more common cause in the young. These results demonstrate that age and gender are associated with different mechanisms of injury for concussion and thus have implications for concussion prevention strategies.

22. Does the Mechanism of Injury Affect Symptom Prevalence in Postconcussion Syndrome Patients?

A.Gasser, A. Haggart, C.H. Tator

To determine whether the mechanism of injury affects symptom prevalence in PCS patients. This study was a retrospective cohort study of 285 patients where the mechanism of injury was a result of sports and recreation, MVA, or a fall. 201 of these patients met inclusion criteria of at least three symptoms persisting at least one month, and did not involve a more severe head injury.

The cohort included 125 males (62.2%) and 76 females (37.8%). The mean age at the most recent concussion was 27.9 years, and the average number of previous

concussions was 2.7. The average number of symptoms was 7.8, and the most prevalent persistent symptom in the cohort was headache (85.1%). The difference between different mechanisms of injury and the resulting prevalence of symptoms was not statistically significant except for loss of appetite and vertigo between sports and recreation and MVA, as well as vertigo between MVA and falls.

The prevalence of symptoms for the entire cohort is consistent with literature, where headache was the most common persistent symptom. It was suggested that the prevalence of symptoms does not differ for a given mechanism of injury, except for vertigo and loss of appetite.

23. The Feasibility of Non-LCD Screen Technology as a Computer-Interface for Patients with Postconcussion Syndrome: a Pilot Study

A.Mansur, T. Hauer, C.H. Tator

LCD screens refresh at a rate of 60 times per second, which is tolerable for a healthy individual, but a concussed individual who suffers from photosensitivity has a lower critical flicker frequency threshold. The backlighting of the screen can also stress individuals who experience photosensitivity and can cause cognitive fatigue, headache, and eye strain. In addition, flashing and motion can make individuals recovering from a concussion nauseated and can delay their recovery. A non-LCD backlit computer system could relieve individuals of some of the discomfort they feel while using a computer during their recovery. These screens use magnetized polymers to create shapes on the display, as opposed to light modulating liquid crystals on an LCD screen. They also do not need to constantly refresh their image and are not backlit, unlike LCD screens. In addition, they only refresh once the content on the screen changes. We are conducting a cross-over study on 50 patients with postconcussion syndrome and photosensitivity. After performing a reading task for a maximum of 30 minutes, we will compare the symptom exacerbation scores and the time it takes to elicit symptom exacerbation between the LCD and non-LCD groups using the SCAT3 scoring system. We hypothesize that the non-LCD screen will provide a less exacerbating reading experience.

24. An Examination of Policy Addressing Student Concussion in the Context of Best Practices for Prevention, Recognition, and Management of Concussions

S. Mylabathula, C.H. Tator

Concussions are the focus of much concern and policies have been developed in many jurisdictions to lower concussion incidence and minimize its effect on school-aged children and adolescents. However, little is known about the impact of

these policies, and whether they are making any difference on the incidence or management of this potentially serious brain injury. The present study involves three parts examining policy that addresses student concussions. The first part is a systematic review of current concussion policies world-wide that affect elementary schools, high schools and universities, as well as the associated non-school-based sports organizations in which students participate. The second part is an examination of health administrative data of the Ontario student population aged 4-18 prior to and after the implementation of a new concussion policy targeting Ontario students, called PPM 158. The aim of this part is to understand if PPM 158 has impacted incidence in its early implementation. The third examines the impact of PPM 158 by surveying all principals in Ontario public schools to gauge the successes and challenges of implementation at the school level.

25. Using [18F]T807 PET to Image Tau in Former Canadian Football League Players

C. Burke, A. Tarazi, P. Rusjan, K. Misquitta, S. Houle, A. Wilson, M. Khodadadi, R.E. Green, B. Collela, N. Multani, C.H. Tator, M.C. Tartaglia

Chronic traumatic encephalopathy (CTE) is a slowly progressing neurodegenerative disease associated with repeated concussions. CTE is a post-mortem diagnosis based on detecting abnormal protein tau deposition in distinct areas. Currently, in vivo diagnosis is not possible. The novel positron emission tomography (PET) tracer [18F]T807 has strong affinity for abnormal tau in vivo. Six former professional Canadian Football League players aged 31-84 with multiple concussions underwent a PET scan using [18F]T807. The subjects reported on symptoms memory, executive function, and behaviour. The standardized uptake value ratio (SUVR) of [18F]T807 in regions relative to the cerebellum was assessed in relation to age, number of concussions, and symptoms. Three of the six subjects had $SUVR > 1$ in the temporal or frontal lobes with tracer uptake greatest in the sulcal depths. All three had symptoms in multiple cognitive domains. Two subjects showed low tracer uptake and had no symptoms while one player showed low uptake but had symptoms in multiple domains. Preliminary data suggests [18F]T807 can detect tau pathology in vivo in former professional athletes at risk for possible CTE. This ongoing study will determine the utility of [18F]T807 to detect tau in vivo and thus become the first diagnostic test for in vivo CTE.