Traumatic Brain Injury Care Systems: 2020 Transformational Challenges

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Abstract

Traumatic Brain Injury (TBI) care systems are those that deliver care services to reduce mortality and morbidity rates, risks and incalculable human suffering from neuro-traumatic events. These care systems seek positive cognitive, functional and physical outcomes and social reintegration for TBI patients. Current TBI care systems are fragmented and operate in silos, each with diverse clinical and resource priorities and supported through disparate information systems. Paradoxically as each silo attempts to sustain life and mitigate the impact of patho-physiological aspects of TBI, the systemic sustainability of the entire TBI care system is compromised. This paper explores the implications for the future systemic sustainability of TBI care through regionalization, intelligence systems, virtual environments and transformational leadership.

Keywords: Care system, Collaborative network, Effectiveness, Leadership, Sustainability, Systems performance, Transformation, Traumatic brain injury

1. Introduction

Traumatic Brain Injuries (TBI) continues as a 21st century that remains subterranean and mostly invisible scourge in our societies. War conflicts, structural malfunctions, risk behaviours firearms, violent assaults, vehicular dependence, high risk sports participation and public values and choices have contributed to this population health challenge with dire implications for health care costs and quality of life of its victims and society. Traumatic Brain Injury (TBI) care systems are those which efficiently and effectively integrate all of the key care service components on multidimensional system levels. TBI care systems have a mission to reduce mortality and morbidity rates, risks and incalculable human suffering from neuro-traumatic events that directly impact on the structure, physiology and biochemistry of the human brain. These systems seek to promote primary and secondary prevention and assure positive tertiary and rehabilitative care outcomes, full cognitive and physical functionality and social reintegration. Its fundamental strategies include the creation of social ecologies which mitigate the risk of TBI, the provision and delivery of appropriate and timely TBI and rehabilitative care effectively. Traumatic Brain Injury (TBI) care systems operate largely in silos, each with diverse clinical and resource priorities and disparate information support systems. This paper probes the pathophysiological aspects of TBI and its concomitant care systems. The implications for future systemic sustainability and leadership imperatives are underscored.

2. The Traumatic Brain Injury (TBI) scourge

Traumatic Brain Injuries (TBI) are externally-inflicted assaults that affect cognitive, functional and physical outcomes. TBI are neither a unique 21st-century problem, nor are the neuropsychiatric consequences a recent phenomenon (Vaishnavi, Rao & Fann, 2009).TBI is the most common global cause of death and disability in people under 45 years of age and poses major health and socioeconomic challenges, which affect all societies internationally (Imhof & Lenzlinger, 2005). Basic neuroscience research has greatly advanced medical and clinical knowledge; however, translating research advances into patient benefit presents challenges (Hulme, 2008; Von Wild, 2005).

With an estimated incidence of TBI is 200/100,000, there are 46 461 200 new TBI cases annually in Canada, the EU nations and the USA (Langlois, Rutland-Brown & Wald, 2006). Of these over 75% tend to be males under 30. TBI carry a mortality rate of 11%, most of which occur within 48 hours. In Canada, the European Union and

the USA, traumatic brain injury (TBI) is a leading cause of permanent disability and results from motor vehicle accidents (MVA)-related events (60%), sports-injuries (15%), work-related injuries (15%) and violent assaults and suicides (10%) (Cole, 2004; Hopkins & Jackson, 2006; Park, Bell & Baker, 2008). TBI is the leading cause of death and disability in adolescents and young adults and approximately 16 100 000 Canadians, Europeans and Americans face TBI-related disabilities which require life-long assistance. The estimated annual health care costs and life years lost due to TBI death and disability in amount to over $7 billion in Canada, $97 billion in the European Union and $60 billion in the USA in 2009 alone.

Traumatic brain injury (TBI) is the "signature wound" of NATO troops serving in the wars in Afghanistan and Iraq (French & Parkinson, 2008; Hayward, 2008; Okie 2006). There is a significant and growing literature on the casualties of war conflicts, particularly in the Iraq and Afghanistan theatres, which underscore the long-term societal impacts of TBIs, particularly from blast trauma (Bhattacharjee, 2008; Girard, 2007; Keltner & Cooke, 2007; Kocsis & Tessler, 2009; Lux, 2005; Warden and French, 2005). In the USA military, rates of concussion vary between 10 and 20 per cent with over 20,000 confirmed TBI cases in 2009 alone with up to 40 per cent of these experiencing symptoms beyond three months (Jaffee, Helmick & Girard, 2009). Improvised Explosive Devices (IED) causing blast trauma is the principal cause of mortality and morbidity of civilians and military personnel in war theatres (Warden, 2006). Traumatic brain injuries from blast traumas are qualitatively different from injuries incurred in MVA- related injuries and sports injuries (Wolf, Bebarta & Bonnett *et al.* 2009). In conflict regions, such as Afghanistan, Angola, Chechnya, Congo, India, Iraq, Israel, Lebanon, Pakistan, Palestine, Spain, the UK and Vietnam, blast traumas account for at least 35 per cent of all TBI injuries. Nor are such casualties restricted to these areas, given the rise in urban warfare tactics by terrorist and paramilitary groups in the rest of the world (Almogy & Rivkind, 2007).

Blast traumas which directly linked to TBIs are classified as: 1.primary, with barotraumas associated with rapid ambient pressures and ensuing blast waves resulting in concussion, diffuse axonal injury, gaseous embolisms, infarctions and subdural hematomas; 2. secondary (penetrating injuries) with brain penetration of fragments from projectiles resulting from blast waves; and 3. tertiary (impact injuries) resulting from ejections and blast wind velocity into stationary objects (DePalma, Burris & Champion *et al.*, 2005). TBI are also classified as either open, or closed, penetrating intracranial wounds. Closed TBI which are the result of blunt trauma caused by IEDs have a different pathophysiology penetrating TBI, which involve the violation of external objects through the dura mater. Penetrating head injury typically carries high mortality rates, often from suicide involving firearms.

Aside from causation, TBI are classified on the basis of severity, and whether open or closed (penetrating). Clinical screening tools, such as the Glasgow Coma Scale (GCS), assess severity on the basis of visual, motor and verbal functioning. The determinants of poor prognostic TBI outcomes are diverse, but patient age; a GSC of fewer than 5; poly-trauma, such as fractures, abdominal and thoracic injuries; and delays in access to care predominate (Mathias &Wheaton, 2007). Severe TBI is a leading cause of death and morbidity in Canada, the European Union and the USA with 90 per cent of the mortality cases occurring within 48 hours (Bryant, 2008; Chan, 2005; Winslade, 2007)**.** Moreover, mild Traumatic Brain Injuries (m-TBI) are difficult to identify and often under-diagnosed with the resulting complications and neuro-worsening, as evidenced in cases of “talk and die” syndrome (Deb & Burns, 2007; Ruff, 2005).

Mild Traumatic Brain Injuries, known as m-TBI, are difficult to identify and run the risk of under-diagnosis, which poses major clinical management challenges for care providers. For the most part, the skull absorbs much of the energy of crush injuries and focal blows assaults, brain damage may remain superficial, even with depressed skull fractures. Delays in diagnosis and treatment complicate the clinical picture and prognosis for TBI patients, evidenced in cases of “talk and die” syndrome (Hoge, 2006; Snell & Halter, 2010). Physical and cognitive symptomatological manifestations associated with TBI include: aggression, amnesia, anxiety, ataxia, confusion, depression, headaches, impaired executive functions, such as disordered thinking, focus, problem solving and decision making, insomnia, irritability, loss of consciousness, mood labiality, photosensitivity, sympathetic storming, tinnitus, and vertigo (Lemke, 2007). TBI is often associated with poly-trauma injuries, such as fractures and abdominal and thoracic injuries in about 35 per cent of cases, which increase the risk of secondary brain damage, due to coagulopathy, hypoxia, hypotension, hypoxia and pyrexia. About 10 to 15 percent of m-TBI patients experience chronic, persistent symptoms for more than one year, known as persistent, or post-concussive, syndromes. Severe TBI continues to be a leading cause of death and morbidity in Canada, the European Union and the USA (Maas, Stocchetti & Bullock, 2008).Traumatic intracranial hematomas occur at least 25 per cent of patients with severe TBI and up to ten per cent of moderate TBI. Among patients who die from traumatic brain injury, about 90 per cent die within 48 hours of injury, usually due to uncontrolled raised

intra-craniaI pressure (ICP). Complications in critically ill patients or life support withdrawal decisions account for many delayed deaths (Finkel, 2006).

TBI creates significant clinical challenges for critical care nurses, emergency physicians, general practitioners, neurologists, neurosurgeons, occupational therapists, paramedics, psychologists, psychiatrists, physiatrists, physical therapists and palliative care providers, as well as significant challenges for family caregivers. Physiological and psychological consequences of TBI impact a person's psycho-social and occupational life and ultimately that of all of society. Cognitive recovery from TBI is clinically complex, individualistic and unpredictable, making it a silent epidemic. Its neuropsychiatric sequelae is manifested through amnesia, clinical depression, cognitive dysfunctions, hyperarousal, insomnia, memory and learning problems, mood labiality and post-traumatic stress disorder (PTSD), which affect over least 40 per cent of the TBI population with significant consequences for their social re-integration. Moreover, increased rates of psychiatric sequelae from TBI are associated with substance abuse and present a risk factor for homelessness, which in turn exposes this vulnerable population to higher rates of victims of violence. Table 1 provides an estimated summary of the total number TBI cases in 2010 in Canada, the European Union (EU) and the USA.

3. TBI care system imperatives

The goals of Traumatic Brain Injury (TBI) care systems are to optimize cognitive, functional and therapeutic outcomes for patients with traumatic brain injuries, be they m-TBI, moderate, or severe TBI. In essence, the care mission is to sustain life as a biological entity and recover quality of life in terms of physical, mental, social and spiritual well-being. A TBI care system is the integration of care agents and processes that response to traumatic brain events, which impact on the cognitive, functional, physical and social integrity of a person. These care systems are by nature complex adaptive systems, which are cross-functional, cross-organizational and cross-systemic.

TBI patients present important medical, clinical and systemic management challenges. These challenges focus on identifying and reversing factors that contribute to poor prognostic outcomes of TBI patients. The care of TBI patients forms an integrated and effectively managed continuum from emergency field care systems through to full social reintegration. TBI care systems seeking to identify and mitigate the risk of poor outcomes of TBI patients through a myriad of critical TBI clinical processes. From the extant literature, TBI care systems are which depend on the effectiveness of seven discernable care imperatives.

3.1 Effective field screening and care interventions

Paramedics with Advanced Trauma Life Support (ATLS) skill sets and competencies assess suspected TBI cases and deploy their clinical expertise, so as to recognize the "talk and die" syndrome and prevent progressive damage, or neuro-worsening. Other key paramedic functions include hemorrhage control; prevention of hypotension and hypoxia; intracranial pressure (ICP) monitoring; monitoring of cerebral functions and neuro-worsening monitoring; oxygenation and ventilation. Field clinical screening of TBI manifestations is crucial. Although early identification of TBI and interventions for optimal recovery are paramount, many TBI injuries still go undetected and untreated (Okie, 2005). Clinical screening tools are instrumental in assessing severity of TBI and include the: Glasgow Coma Scale (GCS) score; length of time of Loss Of Consciousness (LOC) or Alteration Of Consciousness (AOC); duration of Post-Traumatic Amnesia (PTA) and Military Acute Concussion Evaluation (MACE) tools, which assesses cognitive orientation, concentration and memory recall. The GCS is a universally recognized classification system, which categorizes TBI as mild, moderate, or severe, through the assessment of visual, motor and verbal functioning. Table 2 provides an estimated total of patients with m-TBI, moderate and severe TBI in 2010 for Canada, the European Union (EU) and the USA. When combined GCS, LOC, PTA and, in the case of the military MACE scores provide information relating to cognitive performance. These screening techniques complement a plethora of clinical guidelines and standards for triaging, diagnosis and treatment from the Brain Trauma Foundation, the American Association of Neurological Surgeons (AANS) and the Congress of Neurological Surgeons (CNS).

3.2 Effective logistical planning and transit care management

TBI patients present logistical and transit care management challenges, which compound the important clinical, medical and systemic management ones. Clinical challenges of TBI patients require that critical care paramedics focus on symptom management, aggressive ICP monitoring, brain oxygenation and pulmonary functions, which complicate flight and land transit strategies. Optimal recovery from TBI depends on rapid assessment, early and efficient clinical intervention, safe and effective evacuation to specialized neuro-intensive care centers usually via base hospitals. In transit care management, effective logistical planning for evacuation and transport to specialized centers is a priority, as is the multidisciplinary care coordination across spatial and temporal

dimensions. For example, American military personnel with severe and penetrating TBI are aero-evacuated from the war theatres to highly specialized centers, such as Landstuhl Regional Medical Center in Germany then once stabilized are aero-evacuated to the Andrews Air Force Base in the USA, before being transferred within 36 hours to preselected final destinations, such as the Walter Reed American Medical Center, or the National Naval Medical Center in Washington, DC. for long-term intensive neuro-trauma care and neuro-rehabilitation (Brooks, 2008). Effective aero-evacuation of TBI patients require the skill sets and clinical competencies of critical care air transport teams, consisting of paramedics**,** emergency physicians, intensivists and neuro-care nurses.

3.3 Effective emergency TBI care units at base hospitals

Further screening, triage and stabilization occur at emergency care units at base hospitals. The clinical emergent priorities of fluid resuscitation, ICP monitoring and the prevention of hypotension and hypoxia continue to be important. Emergency care units at base hospitals usually have access to computer tomography imaging and more advanced diagnostic and treatment resources, which are instrumental in the fight against adverse TBI prognostic outcomes. Clinical studies confirm that age, GCS motor score, pupillary response, and CAT scan characteristics as the most powerful independent prognostic variables for TBI patients. Blood chemistry variables (hemoglobin, glucose and platelets); GCS eye and verbal scores, hypotension, and hypoxia are also important in prognosticating outcomes (Menon & Harrison, 2008). At the same time, base hospitals do not necessarily have the panoply of care resources, skill sets and competencies essential for moderate or severe TBI patients. Thus, these units provide critical holding stations to stabilize the clinical picture of TBI patients and resolve logistical issues for evacuation to tertiary specialized neurotrauma care units.

3.4 Effective neuro-intensive care at specialized neurotrauma centers

The transfer of TBI patients to neurotrauma centres with specialised neuro-intensive capabilities is paramount to improved therapeutic outcomes and their survival. Given the heterogeneity of TBI deficits, care coordination, knowledge management and multidisciplinary collaboration across professional domains, such as neurology, neuropsychology, neurosurgery, physical medicine and psychiatry, is essential (Bigler, 2008). Non-survival rates of severe TBI increases 2 to 15 times when patients are treated in non-neurosurgical centres versus neurosurgical centres (MacKenzie, Rivara & Jurkovich *et al*. 2006).Specialized neurotrauma centers offer the advantage of access to more effective functional neuroimaging tools, such as magnetic resonance imaging or position emission tomography technologies which are more informative than CT scans in providing cogent diagnostic information for neurologists and neurosurgeons. A major focus for neuro-intensive care is to prevent and limit progressive brain damage and provide the best conditions for natural brain recovery. Artificial ventilation, cerebral perfusion pressure monitoring, clinical microdialysis, early and extensive decompressive craniotomies, glycemic control and nutrition, ICP monitoring and control, osmotherapy, oxygenation, sedation and temperature homeostasis, are all part of the clinical protocol processes in neuro-intensive care environments (Blackbourne, 2008). Neurosurgical interventions range from pre-emptive surgery to debridement, dural matter closures and conservative techniques together with high levels of infection control. TBI patients often present with poly-trauma and/or critical illness, which compounds the risk of further neurologic dysfunction and poor neurological outcomes (Sigford, 2008)**.** Neuro-trauma centers have poly-trauma services to attend to these complex traumatic cases (Lew, 2005).

3.5 Effective and comprehensive rehabilitative care

TBI patients face a dichotomy of therapeutic outcomes, including favourable ones, such as complete recovery, moderate disability and life independence, or unfavourable ones, such as severe disability, long-term comatose, permanent vegetative states and death (Winslade, 2007). Early and intensive rehabilitation is important in achieving the best possible functional and therapeutic outcomes of TBI patients. Timely and well-coordinated involvement of ancillary services, such as audiology, behavioural therapy, cognitive rehabilitation and remediation, occupational therapy, optometry, physical therapy, pharmacological therapy, physiatry and psychiatry minimize physical and mental health complications, improve patient satisfaction and well-being and maximize functional recovery (Gutman,2009; Kokiko & Hamm,2007; Phipps & Richardson, 2007). The effective identification and follow-up of neuro-cognitive impairment sequelae of TBI patients is very important. The consequences of such impairments are substantial, far-reaching and contribute to potential long-term decreased quality of life with limitations in performance of daily activities, driving skills and abilities to manage personal affairs (Petchprapai & Winkelman, 2007). In the USA, caregiver support amounts to an associated $18 billion annually (Hopkins & Jackson, 2006). Moreover, studies have suggested that many care providers, particularly of general practitioners, fail to recognize the neuro-cognitive impairment consequences of TBI in 35 to 90 per cent of cases. Raising awareness and education of care providers of clinical manifestations of

neuro-cognitive impairments in patients would lead to better identification and increased referrals to and interventions of, neuropsychologists, occupational, physical and speech therapists (Blum and Fee, 2008).

3.6 Effective care of TBI psychiatric sequelae

TBI patients represent a very vulnerable population, as they often suffer from diverse psychiatric sequelae, such as bipolar disorders, clinical depression, generalized anxiety disorders, post-traumatic stress disorders (PTSD) and significant personality changes (Deb & Burns,2007; King,2008). TBI patients with PTSD typically exhibit symptoms of acute anxiety disorder, avoidance behaviours, hyper-vigilance, insomnia and nightmares- all of which impact on functional work and social capacity over prolonged periods with risks of homelessness (Keane, 2008; Neatherlin & Fox, 2006; Stein & McAllister, 2009). From the literature 23 to 40 per cent of TBI patients, who meet the criteria for major depressive disorder, generalized anxiety disorder, or PTSD actually sought mental health care. Stigmatization remains a great barrier to seeking necessary assistance. TBI patients often manage distressing symptoms through panoply of substances abuse, which propagates a cycle of increased addiction dependency, neuro-worsening, and alcohol-related brain injuries. This often triggers domestic violence, social isolation and more serious levels of clinical depression. Suicidality becomes an ideation and sought as an option for many (Simpson & Tate, 2007)**.** To counter this, early psychological and psychiatric intervention is essential. Such care includes symptomatic recognition, monitoring and clinical management through psychological counselling, peer support and pharmacologic treatment and in some cases, residential care. Care coordination, community service providers and supportive environments for patients with TBI with psychiatric sequelae is critical for psychosocial healing (Keltner & Dowben, 2007).

3.7 Effective TBI social reintegration strategies

TBI patients invariably face a myriad of physical, cognitive and behavioural challenges that result in physical impairments and cognitive, emotional and behavioural dysfunctions. These consequences affect all aspects of life, including the development and maintenance of interpersonal relationships and social functioning. Social reintegration strategies are aimed at maximizing individual strengths and creating supportive environments for individuals with TBI for productive work and integrated family and social life.Comprehensive assessment tools, such as quality of life in brain injury (QOLIBRI), objectively identify the social environments in which these patients reintegrate into. Home care environments for TBI patients raise daunting challenges for families, who face complex processes of adapting, coping and grieving, while reintegrating as a family unit (Daggett, Bakas, & Habermann, 2009). Education on the TBI manifestations and caregiver responsibilities for family members is crucial. TBI rehabilitation teams, including mental health professionals, occupational therapists, physiotherapists and social workers, have competencies and skills sets that enable TBI patients to reintegrate effectively into their family lives and communities (Wheeler and Bragin, 2007). Much of the literature on social reintegration, however, assumes that family and work units are integrated, supportive and are themselves healthy. The reality is that many family structures are fragmented and their integrity as a unit challenged in times of financial hardships when there are extra demands of any member with an injury or illness. The importance of stable resources and the provision of necessary emotional and financial support are essential for TBI members and their families.

4. The sustainability paradox of TBI care systems

The paradox of TBI care systems is essentially this: as more care, clinical, financial and human capital resources are deployed to sustain and promulgate life and quality of life at each level of the TBI care system, the systemic sustainability of the entire TBI care system, from a holistic perspective, is at risk of compromise. To be sustainable in the light of diminishing resources and growing cohorts of TBI patients, the system needs to be reengineered and transformed to reduce waste and minimize iatrogenic risks of misdiagnosis, under-diagnosis, redundancy of clinical tests and overexposure to radiation (Brenner & Hall, 2007). Each care subsystem and transition entails risks and losses which include inaccessibility and unavailability of care resources, travel costs, opportunity costs, time costs and coordination issues. In the face of growing numbers of TBI patients, the effectiveness and sustainability of current modalities of TBI care system will be questioned. Moreover, increasing caseloads of a myriad of other afflictions, such as carcinomas, cardiovascular diseases, infectious diseases and psychiatric disorders will place unbearable strains on the entire sustainability of current modalities of health care systems. In the face of sustainability questions, there are health care system management alternatives that hold promise. These are discussed below.

4.1 Towards effective TBI collaborative network integration

The weak links in the TBI care processes are the transition points where TBI patients are physically transferred from one subsystem to another as such transfers entail a concomitant transition of accountabilities. Each transfer point entails a transition of responsibilities and poses risks that continuity of care for TBI patients will be

compromised. Horizontal integration of TBI care systems is essential. Regionalization and centralization of TBI resources and specialized TBI care centers is instrumental in reducing redundancy and making the optimal use of scarce and diminishing resources. This requires clear clinical governance arrangements regarding personal, medical, and specialist care needs of TBI patients. It also underscores the need and role of TBI care coordinators to advocate and shepherd TBI patients and their families through the TBI care systems from the pre-hospital care to complete social reintegration. TBI care coordinators work with integrated multidisciplinary care provider teams to present care options and strategies for symptom management, ongoing clinical consultation, counselling and support to patients and family members (Lew, Cifu & Sigford *et al*., 2007). The lack of integrated accountability for TBI patients through designated care coordinators greatly complicates the recovery processes.

Cogent regionalization also implies vertical integration of pre-hospital, tertiary care and rehabilitative care through regional health authorities. Such regional integration across fractured jurisdictions would work to promote effective care and priority management and performance monitoring to evaluate progress towards defined and specific TBI care goals and objectives (Kondro, 2008).Moreover, regional management authorities would be enablers of the formation and evolution of TBI collaborative networks with leadership accountability for systemic sustainability and TBI care performance. For example, such TBI networks might collectively decide to collaborate in designing and implementing strategies to decrease regional TBI rates by 10 per cent annually. These collaborative networks would be multi-disciplinary and engage regional chiefs of fire and rescue, paramedical and police services, as well as representatives from the emergency physician, neuro-nursing, neurosurgeons, public health, social work, occupational and physical rehabilitation therapy and mental health professional communities.

Strategic control and management at regional levels are important to the continued effectiveness and systemic sustainability of effective TBI care systems. Effective regional management increases the likelihood that human capital, operational resources and care services will focus on TBI care delivery to reduce mortality rates and its sequelae risks efficiently and cost effectively. Strategic control of regional TBI networks requires well-defined goals, objectives and accountability structures. In Canada, the ultimate accountability for quality TBI care services still remains largely at the care facility level. Regional health bodies in the many European Union nations and some Canadian provinces exert some important coordinating roles, but have limited real authority and do not yet promulgate collaborative networks. Stable financial and resource support and clear legislative powers from governance sources is essential for regionalization of TBI care systems and the sustainability of TBI care. In the USA, the TBI Act of 2008 has made appropriation funds available to continue funding TBI model systems focused around leading national brain research centers. This system model approach is still largely institutionally- based and by no means makes TBI care available universally, nor uniformly on a regional basis.

4.2 Towards integrated TBI intelligence architectures

Integrated TBI intelligence architectures are technological facilitators and conduits through which TBI care systems are reengineered, transformed and ultimately improved. They form the basis for effective regional TBI care collaboration networks, which would have access to monitor and share system performance and outcome intelligence to mitigate TBI risks and reduce mortality and morbidity rates effectively. The vital fuel in the regional TBI care management is quality information using intelligence systems. Although the extant literature on integrated regional models of information systems remains limited (Lee, 2006), TBI intelligence systems have the potential to support TBI care networks by meeting the management information needs of care coordinators, participants of TBI collaborative networks and leaders (Jaffee, Helmick & Girard, *et al*. 2009). The development of cloud computing services and regional intelligence systems has the potential to promote system efficiency and effectiveness in TBI care management, while minimizing the need to invest heavily in ICT. Such systems have the potential to support leaders and regional collaborative networks in monitoring regional TBI objectives and performance outcomes, using query and analytical capabilities, data mining, intelligence reporting, forecasting and integrative reporting. Regional intelligence systems hold promise in monitoring epidemiological patterns of TBI and clinical performance. All this is with a view to foster continuous improvement of all TBI care levels and to refine primary and secondary prevention strategies. These systems require compatible telecommunication standards and common data definitions in order to interoperate effectively on wireless communication platforms. Without regionalized support through integrated and interoperable intelligence systems regionally, the long-term sustainability of current TBI care modalities will be increasingly open to question.

To realize the full potential of intelligence system technologies requires the implementation of portable electronic smart cards, which should be the modus operandi across health care systems in Canada, the European Union and perhaps the USA by the year 2020. System challenges of data integrity, data definition commonality, ICT platform standardization, interoperability, security and privacy must be first met. As effective leadership

enablers, integrated intelligence systems are the basis for more appropriate resource allocation and greater quality TBI care, all to the ultimate advantage of public and service communities.

4.3 Towards effective pathways to virtualized care environments

The increase in IED-related blast trauma in war theatres has spawned the drive for more effective tele-medical systems providing neurological assessment, neurosurgical treatment, psychiatric intervention, behavioral therapies, occupational and physical rehabilitation. TBI care systems world of the future will include cloud computing, robotic neurosurgery, tele-consultation, tele-neurosurgery, tele-rehabilitation and tele-home care. Virtualized and pervasive TBI care systems will be increasingly important in integrating care processes to optimize cognitive, functional and physical outcomes of TBI patients. Pervasive care systems will support TBI tele-monitoring, regardless of spatial and time constraints, through the deployment of integrated wireless architectures, intelligent emergency care applications, and location management systems and mobile networks (Varshney, 2005).

TBI classification systems will continue to evolve to reflect the inherent heterogeneity of the TBI population. Advanced diagnostics based on biomarkers and genotyping will promote effective identification and monitoring of pathophysiological changes associated with the range of manifestations of traumatic brain injuries. Prognostic risk classification will continue to evolve, as will quality assessment tools and evidence-based international and national guidelines. Neuro-protective technologies will minimize the intensity of physical insults on the brain and prevent harmful cascades of biochemical events inherent in TBI. Developments in neurobiology focusing on neuroplasticity, regeneration and replacement of lost neuronal cells and circuits hold great promise. Interactive video-teleconferencing (IVTC) and remote cognitive assessment systems will rapidly assess reaction time, memory and mood variations and will facilitate tele-neuroconsultations. These technologies will bring the neuro-intensive care teams to the field and assist paramedics to identify TBI and post-concussion syndrome (PCS) through tele-diagnosis. The systemic advantages underscore effective efficient and sustainable access to TBI care; greater continuity of care over geographical constraints; and the prevention of unnecessary and risky aero-evacuations. Videoconferencing and tele-neurosurgical mentoring will also enhance care coordination and integrate onsite medical units with poly-trauma specialists internationally. Tele-education and tele-monitoring in home environments will facilitate recovery, rehabilitation and reintegration within social communities. TBI care management for blast trauma and MVA victims with neuro-cognitive field testing will accelerate the rate of positive clinical response and prevent neuro-worsening.

The clinical frontiers in research in molecular and gene therapy, pharmacology and neuroscience hold substantial promise in mitigating TBI and its patho-physiological sequelae.The challenge will be to move neuro-intensive care technologies to the field as much as possible. Here ICT developments hold the key. Intelligence systems will facilitate, internationalize and virtualize TBI care systems. Allowing virtual international consultations on atypical TBI cases opens the door to the possibility of outsourcing neuro-medical care. Tele-medical applications in TBI are part of the evolving future e-health care systems, including surgical robotics, thought-controlled prosthetics, handheld and wear-technologies with screening algorithms and neuro-cognitive test batteries linked to patient history. Home tele-health will expand the reach of visiting nurses, who will monitor TBI patients remotely through monitoring devices. These systems will assist TBI patients in meeting cognitive, physical and social challenges.

4.4 Towards transformational leadership imperatives

Systemic sustainability of the TBI care systems requires the horizontal and vertical integration of strategies of regional stakeholders to mobilize and effectively deploy limited care resources. This requires the explicit collaboration of governance agencies, neuro-intensive care centers, paramedical, police, fire and rescue services, social agencies, professional associations, care providers, institutional suppliers and service communities. Moreover, collaborative decision-making is posited on effective regional intelligence systems evolve through open professional environments which foster trust and promote intelligence sharability. The responsibility and accountability for regional collaborative networks rests with transformational leadership. Proactive vision and strategic leadership unlocks the power of intelligence technologies to transform TBI care delivery systems for TBI patients. Proactive vision and transformational leadership of TBI care systems holds the key to the continued sustainability and effectiveness of TBI care systems. Governance agencies need to facilitate and provide the necessary leadership and the essential resources to galvanize regional development of TBI intelligence networks and care systems. The fostering of strategic partnerships through transformational leadership between governance, TBI care providers and organizations and the private sectors, particularly in ICT and intelligence system development hold the key to future systemic sustainability. The establishment of national TBI intelligence system

guidelines would be a first step to foster positive dialogues between leaders and care providers.Traumatic brain injuries pose serious population health challenges. The current sustainability of care delivery for TBI patients will be increasingly questioned in the face of growing health care demands and decreased resources. Faced with societal challenges, humans always find ways to meet them and adapt in innovative ways. It is posited in this paper that regionalization of TBI care supported by integrated intelligence systems and the implementation of virtual care environments through innovative clinical and ICT research provide part of the solution ahead. In doing so, transformational leadership is a sine qua non.

5. Conclusion

The leadership imperatives above are indeed transformative and present adaptive challenges of a high–order to assure future systemic sustainability. And yet there is an even more fundamental yet crucial challenge to assure systemic sustainability that perhaps only future generations will appreciate. This lies beyond the realm of conventional thinking in Canada, the EU and the USA with its emphasis on safety awareness and education, the creation of safe environments and neuro-protective devices. The challenge in question requires a more fundamental evolution towards new societal values and norms. In the dawn of the 21st century, we remain essentially a violent society, one which inherently tolerates alcohol and substance abuse, firearms, health destructive behaviours, violent contact sports, war conflict, vehicular dependence and a blood-lust media culture, which is bounded and constrained only to an extent by legislative and regulatory measures prompted by occasional public outcries through controlled media outlets. The bottom line is that current TBI care systems form a safety net for what is an essentially violence-tolerant society. Draconian prevention and health promotion strategies for TBI with zero-tolerance policies for destructive health behaviour are not part of societal dictum or vision. Our current culture does not yet universally and explicitly regard health and well-being as a critical and valued resource, a right of every human being and an investment in people. Rather health continues to be associated with "sickness care" and financial drains with interminable costs to the society. That health is a good in itself and promulgates socio-economic integrity and viability of human ecologies still conflicts with the prevailing market and economic dictums of our societies. Economic and vested interests in violent cultures and societal impoverishment are still part of the social ethic and ecology may not change for generations to come. Only social and psychological transformations on societal levels will change this (Williamson, 2006). TBI care systems will continue to present social ecological challenges until such time when humanitarian values of peace override propensities towards values that foster violence and destructive behaviours, until catastrophic war conflicts are resolved through peaceful resolution and the right to health and well-being is unquestioned. What with our current Realpolitik of TBI care systems, we have reached the fork in the road. To be sustainable the TBI care systems will have to be leveraged through regional management, the deployment of intelligence systems, the design and implementation of virtual technologies through transformational leadership. This until such time that societies embrace new value dictates of non-violence.

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Table 1. Estimated TBI cases and costs in Canada, the European Union and the USA for 2010

Total estimated 2010	*Canada*	*European Union*	*USA*
Population	34 125 000	501 300 000	309 400 000
Total numbers of TBI cases	192 000	2 754 000	1 700 000
Number of m-TBI cases	112 900	1 619 352	999 600
Number of moderate TBI cases	40 704	583 848	360 400
Number of severe TBI cases	38400	550 800	340 000
Number of pre-hospital TBI deaths	4 440	62 160	38 480
Number of hospital deaths	1 560	21 840	13 520
Emergency unit visits of TBI cases	158 000	2 268 000	1 400 000
TBI hospital admissions	32 000	446 000	275 000
Discharged cases with TBI disabilities	9 000	130 000	80 000
TBI mortality cases	6 000	84 000	52 000
Population living with TBI disabilities	670 000	9 600 000	5 900 000
Direct and indirect costs (US$)	$ 6 760 000 000	$97 200 000000	$60 000 000 000

The above table shows estimated TBI cases and costs in Canada, the European Union and the USA for 2010.

Table 2. TBI severity parameters, assessment tools and total annual cases in Canada the European Union (EU) and the USA for 2010

Severity of TBI	*Loss of Consciousness (LOC)*	*Post-Traumatic Amnesia (PTA)*	*Glasgow Coma Score (GCS)*	*TBI Cases (%)*	*Total annual cases in Canada, the European Union, the USA (2010)*
m- TBI	<30 minutes	24 hours	13-15	58.8%	2 732 000
Moderate	>30minutes	1-6 days	9-12	21.2%	985 000
Severe	24 hours	7+ days	3-8	20.0%	929 000

The above table shows the TBI severity parameters, assessment tools and total annual cases in Canada the European Union and the USA in 2010.