The epidemiology of traumatic brain injury in the Cree Communities of Eeyou Istchee

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February 2, 2015

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1 Abstract

Background: The effect of traumatic brain injury on populations around the globe is heterogeneous. The literature has described that the incidence rates and risk factors for TBI vary greatly between different rural populations. More specifically, indigenous populations around the globe seem to be disproportionately affected. Given this great variation, experts have recommended that epidemiological studies be conducted on a community-by-community basis to provide insights on prevention that are specific to a given population. In Canada, no such epidemiological analysis of TBI in indigenous populations has been completed.

Methods: A descriptive, retrospective, population-based study of all incident TBI hospitalizations of Québec Health Region 18 (Eeyou Istchee) beneficiaries between 2000-2012 was completed. For the primary analysis, the administrative MED-ÉCHO database was used for case finding. A chart-review of TBI cases in Region 18 was completed for the sub-analysis of risk factors in adults. Statistical analyses were conducted using multiple regression models, multiple imputations for missing data and sensitivity analyses to assess for relevant biases.

Results: There were a total of 172 incident TBI hospitalizations during the study period. The rate of TBI for Eeyou Istchee beneficiaries was 1.86 times (95% CI 1.56 - 2.17) the rate of the rest of Québec. Incidence rates in Eeyou Istchee were higher than in a neighbouring non-indigenous population but lower than in another neighbouring indigenous population. Assaults and off-road vehicle collisions were the leading cause of TBI in the region and their distribution differed significantly from other regions in the province. Protective equipment use predicted higher initial Glasgow Coma Score (GCS) and a better functional outcome. Use of rehabilitation services tended to be systematically more frequent amongst patients involved in motor vehicle collisions in comparison to other mechanisms of injury.

Conclusion: This analysis demonstrates that the occurrence and determinants of TBI are quite different for Eeyou Istchee compared to neighbouring and distant populations within Québec. This type of epidemiologic description is a critical tool for indigenous rural populations that wish to develop relevant TBI prevention strategies.

2 Introduction and knowledge synthesis

2.1 Background

The effect of traumatic brain injury (TBI) on populations around the globe is extremely heterogeneous. Low and middle-income countries are the most severely affected [1]. Rural populations tend to have higher TBI incidence rates as well as having higher mortality and morbidity associated to these injuries [2]. In fact, even the distribution of causes related to TBI differs dramatically in various populations. For example, low-income countries tend to have a greater proportion of TBI related to violence than high-income countries [3]. In terms of risk factors, alcohol abuse and illicit drug intoxication has been consistently linked as an important risk factor for TBI, which was also found to be a predictor for worse outcome in injured patients. With regards to prevention, protective equipment use, such as helmets and seat belts, has been shown to substantially reduce the incidence and morbidity of TBI across the world in traffic-related injuries [4]. These characteristics of TBI demonstrate that there are many determinants of TBI occurrence and outcome that include education, socio-economic status, the environment and access to specialized health care.

In Canada, the literature has described the poorer health status of indigenous peoples compared to the general population of Canada [5]. The analysis of the social determinants underlying the health of these populations has helped to explain why their health status is negatively affected at several levels [6]. Injuries have been shown to be the greatest cause for potential years of life lost in the Canadian indigenous population, and to be four times the overall Canadian rate [7,8]. TBI represents a significant proportion of these injuries in various indigenous North-American populations [9,10]. A large surveillance program conducted in the United States by the Centers for Disease Control showed a higher rate of TBI amongst indigenous populations [11,12]. In addition, the Canadian literature has demonstrated that the Canadian indigenous population has specific risk factors related to the occurrences of trauma. For example, a review of MVC fatalities amongst indigenous patients in British Columbia demonstrated that those individuals were two times more likely to be intoxicated with alcohol at the time of their trauma [13,14]. Desapriya et al. further described that intoxication with other drugs (prescription and illicit) was significantly more common in indigenous patients in Saskatchewan at the time of their injury [15]. Also, the mechanisms of injury related to TBI are quite different when comparing the urban and rural environments where many indigenous populations still live [16].

TBI is an important public health issue leading to substantial mortality and disability in Canadian indigenous populations. There are several determinants related to the more frequent occurrence of TBI in these populations. There are also differences in the mechanisms leading to these injuries. Furthermore, it is known that the proportion and severity of disability amongst different indigenous populations varies greatly after injuries [17]. The literature therefore advises that the appropriate investigation of such community-based problems should be completed on a community-by-community basis [5]. A literature review of published articles on TBI in Canadian indigenous populations was conducted using PUBMED and Google scholar using different search terms including “Surveillance”, “Epidemiology”, “Traumatic Brain Injury”, “Concussion”, “Aboriginal”, “First Nations”, “Inuit”, “Aboriginal” and “Canada”. In addition, the resources from Health Canada, the Public Health Agency of Canada and the public health authorities of each Canadian province/territory were searched on their websites to identify any surveillance projects that were done on TBI in Canada. In short, there has not been any focused epidemiological description of TBI in indigenous communities. The Institut National de Santé Publique du Québec (INSPQ) completed a TBI surveillance study in 2012 on non-intentional TBI hospitalizations in the province of Québec and analyzed the data stratified by different administrative health regions. However, the two northern Québec health regions that represent indigenous communities (Region 17/Nunavik and Region 18/Eeyou Istchee) as well as a non-indigenous region with a similar geographical milieu (Region 10/Nord-du-Québec) were excluded from their analysis [18]. The rationale for the latter were not explained in their report. In such communities, a similar type of analysis is necessary to appropriately develop and use injury prevention and health care resources that are adapted to these populations’ cultural and environmental needs [5].

2.2 Study population

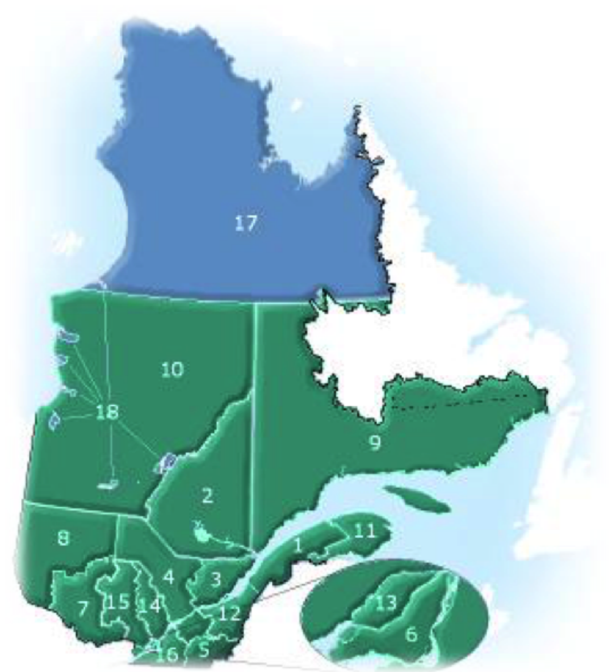

Figure 1: Map of Québec’s 18 administrative health regions. Region 18 (*Eeyou Istchee* - shaded in light blue) is nested within Region 10. A single remote Cree community is nested within Region 17 (*Nunavik* - also shaded in light blue).

This epidemiological analysis of TBI involved the population of Québec’s administrative health Region 18, which includes 8 rural (or semi-remote) Cree communities and 1 remote community within the drainage basin of the James Bay in Québec and the southern Hudson's Bay (Figure 1) [19]. Region 18 is nested within Regions 10 and 17, with designated Cree-controlled lands within their larger traditional territory of Eeyou Istchee. The Cree Board of Health and Social Services of James Bay (CBHSSJB), a Cree-Québec institution created through the James Bay and Northern Québec Agreement (1975) is responsible for regional health administration of Region 18 within the Ministry of Health and Social Services (MSSS in French). The CBHSSJB is an ethnically-based governmental organisation serving everyone residing or visiting within the Cree communities [20]. The CBHSSJB's strategic regional health plan addresses the need to prevent injuries as one of its goals and the regional Public Health Department was interested in collaborating on a surveillance project on head injuries to assess the burden of disease and ultimately develop injury prevention strategies adapted to the needs of Eeyou Istchee [21]. The sub-analysis on injury prevention focussed on the adult subpopulation since the literature has shown that they typically have the highest rates of TBI and subsequent morbidity in indigenous populations [22]. In addition, the severity and outcome measures of TBI are more homogeneously assessed among adults only, excluding children [23].

3 Objectives

3.1 Primary objectives

1. To measure the incidence rate of TBI hospitalizations in a rural and remote Canadian indigenous population (Eeyou Istchee - 9 Cree nations occupying specific lands draining into the James Bay and southern Hudson Bay) and compare them to TBI hospitalization incidence rates of:

a) a neighbouring indigenous community (health Region 17/Nunavik - a predominantly Inuit population);

b) a neighbouring predominantly non-indigenous population (health Region 10/Nord-du-Québec);

c) the entire population of Québec.

2. To draw inferences on the contrasts in rates observed between Region 18 and the above populations by comparing the distribution of mechanisms of injury, age, gender and geographic milieu of the populations.

3.2 Secondary objectives

To describe, in the adult population of Eeyou Istchee,:

a) the risk factors related to TBI in this indigenous population (including mechanisms of injury, alcohol intoxication, and proper use of protective equipment);

b) the severity of TBI in this population;

c) the health care resources used in this population (tertiary, secondary and primary hospitalization as well as rehabilitation services); and

d) the functional outcomes of TBI victims in this population.

The results of this study are to be used for TBI surveillance purposes for the regional public health department and to provide information on priority areas of TBI prevention for the adult subpopulation (aged 15 years or older) of health Region 18.

4 Methods

4.1 Study design

We completed a descriptive population-based retrospective study of all hospitalized incident TBI cases from a single health region of Québec (Region 18) that represented the patients from a single indigenous population (Eeyou Istchee) from 2000-2012. The province of Québec provides universal public health care coverage to all of its residents. As such, all hospitalized patients in the province are registered in administrative health care databases. A provincial hospitalization registry, MED-ÉCHO, which records all hospitalizations in the province and categorizes citizens based on their residence in a specific socio-sanitary region, was used for case finding. In addition, a sub-analysis of adult patients was completed and their hospital charts were audited from all hospital centres where they were treated to collect more information surrounding their injury.

4.2 Case finding and data sources

The incident hospitalized cases of TBI in Québec were identified through the MED-ÉCHO database for the years under study [24]. The database codes hospitalization diagnoses based on the International Classification of Disease (ICD). For the years of 2000-2005, the ICD-9 coding scheme was used, whereas from 2006-2012 the Canadian version of ICD-10 (ICD-10 CA) coding scheme was used. For this study, we used the same TBI definition as the INSPQ to have comparable surveillance data to the rest of the province of Montréal (Table 1)[18]. However, all cases of TBI hospitalization (intentional and non-intentional) were included in this analysis since assaults have been found to be prominent external causes of injury in indigenous communities [8]. Any patient hospitalized with one of the diagnostic codes as either a primary or secondary diagnosis was included in the study.

Since TBI severity/outcome is not homogeneously assessed amongst the paediatric and adult populations, further analysis was completed for the adult population (15 years and above) only [23]. The latter was completed by identifying the hospitals where these patients were treated for their TBI. These patients' charts were subsequently reviewed. The MED-ÉCHO database provides denominalized information on patients with a scrambled unique

ICD-9 (2000-2005)	Diagnostic code
Skull fractures	800.0-801.9 803.0-804.9
Intracranial lesions	850.0-854.1
ICD-10 CA (2006-2012)	**Diagnostic code**
Skull fractures	S02.0-S02.1 S02.7 S02.89 S02.9
Intracranial lesions	S06.0-S06.9 T06.0

Table 1: ICD-9 and ICD-10CA diagnostic codes used for case finding.

identifying number to ensure confidentiality. By using the date of admission/discharge, the age/gender of the patients and their hospitalization diagnoses, we identified the patients nominally at the hospital centres where they were treated with the assistance of the archivists' local databases. Some cases had charts reviewed in only 1 hospital whereas other patients had charts reviewed in up to 3 hospitals and a local community clinic, known in Region 18 as a Community Miyupimaatisiiun ("Being Alive Well") Center (CMC), if they were transferred numerous times between institutions for the same TBI (Figures 2 and 3) [25]. Briefly, Québec has instituted a trauma system to its population that provides 3 lines of service. There are designated primary/stabilization centres, secondary centres with advance trauma care and tertiary centres that are super-specialized with on-site neurosurgeons/vascular surgeons [26]. In Region 18, there is only 1 community hospital, which is a stabilization centre. However, the territory is served, outside the region, by 2 secondary and 1 tertiary trauma centres. The nominalized data permitted the investigators to identify patient charts in their CMC for further data collection, which is described below. If a patient had more than one TBI hospitalization during the study period, only the first (incident) case was included in the study.

4.3 Measured variables

The variables ascertained from MED-ÉCHO included the patient's age, gender, length of hospital stay, external cause of injury, primary and secondary diagnoses of the hospitalization and the patient's Québec health region/municipality of origin. The external causes of injury (mechanisms of injury) were coded in MED-ÉCHO as per the ICD-9 and ICD-10 CA classifications (Table 2) [18]. Mechanisms of injury in the regression models were grouped together such that there were 5 different groups of variables: "off-road vehicles", "assaults", "motor vehicle collisions", "falls" and "other". The additional variables ascertained through the chart review for adults were used to address the secondary objectives of the study. These variables included the: earliest initial post-resuscitation Glasgow Coma

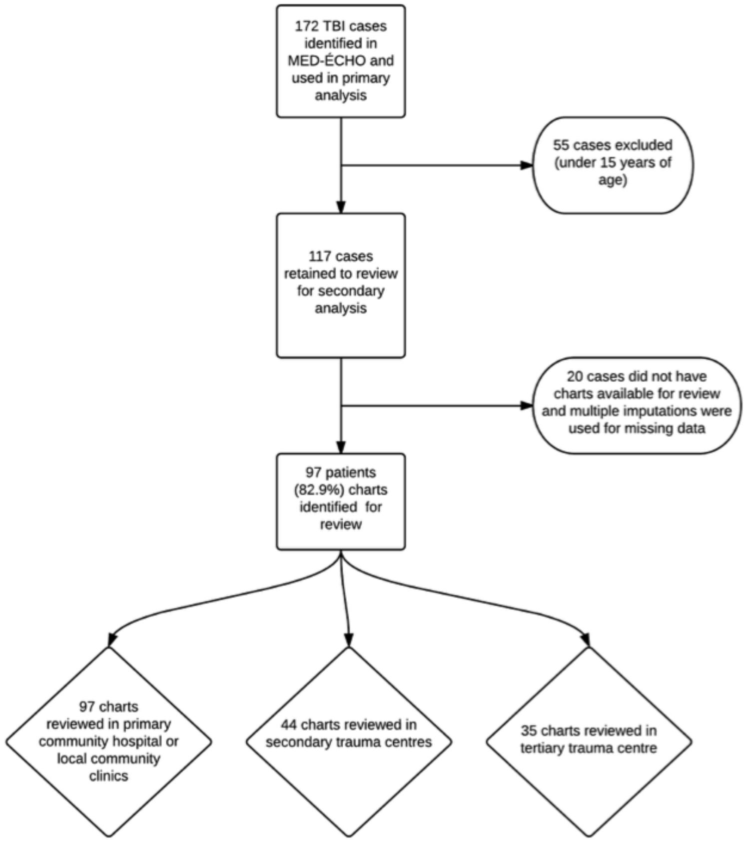

Figure 2: Flow chart of how cases were ascertained in different hospital centres for the chart review (secondary objectives) of the study.

Score (GCS), specific use of protective material (seatbelt or helmet), polytrauma status (defined as any patient incurring a traumatic injury to another body region than the head), comorbidity status (including any patient with 2 or more of diabetes mellitus, dyslipidemia, hypertension, coronary artery disease, history of stroke or psychiatric illness) and intoxication status with alcohol as reported by the note of the first physician assessment (Figure 13 in Appendix). The severity of injury was classified as “mild”, “moderate” or “severe” based on the initial post-resuscitation GCS (GCS of 13-15, 9-12, 3-8, respectively) [27]. If more than 1 chart was reviewed and the information on the variable was available through many sources, the earliest measurement after the injury was used. Functional outcomes were assessed with the first Glasgow Outcome Scores (GOS) of patients at least 6 months after the injury, as noted in the patient’s chart by their family physician at their local CMC [28]. If a GOS score was not available directly, the chart extractor interpreted the clinical notes 6 months after the injury to establish the GOS. Lastly, charts were reviewed to identify the TBI cases that had used inpatient or outpatient rehabilitation services (physiotherapy, occupational therapy, psychology or specialized TBI clinic services). All

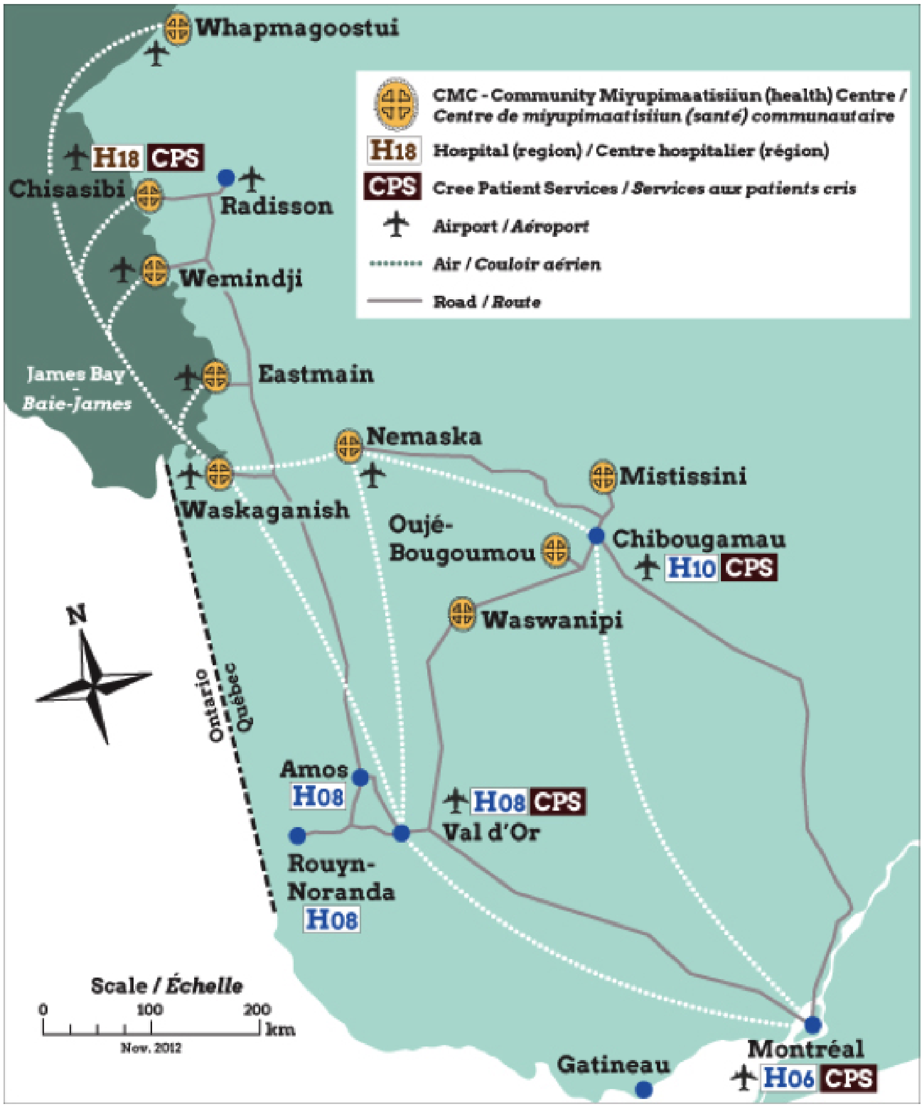

Figure 3: Map of the different hospital centres and clinics serving the communities of Eeyou Istchee.

information ascertained from the charts was conducted by the primary author who has over 5 years of training as a neurosurgery resident and who is experienced in analyzing medical chart information regarding TBI.

4.4 Missing data

For the primary analysis involving MED-ÉCHO data, complete data was available for hospitalizations in Region 10, 17 and 18 except for external causes of injury. A missing indictor variable was used for this missing data. It was assumed that this data was missing at random and was therefore excluded from regression analyses that were subsequently used.

	ICD Revision	
External Cause of Injury	***ICD-9***	***ICD-10 CA***
Motor vehicle	E810-E819 (.0, .1)	V30-V79 (.4-.9) V83-V85 (.0-.3)
Motorcycle	E810-E819 (.2, .3)	V20-V29 (.3-.9)
Snowmobile	E820 (.0, .2, .3, .8, .9)	V86 (0.02)
ATV	E821 (.0, .2, .3, .8, .9)	V86 (0.03, 0.09)
Fall	E880-E882, E883 (.1-.9), E884 (.1-.9), E885, E886.9,	W00-W01, W03-W08, W10-W15, W17-W19, X59.0
Recreational/sports accident	E887-E888, E828.2, E830-E831 (.4, .5), E842.6, E883-E884 (.0), E886 (.0), E902.2, E910 (.0, .1, .2), E917.0, E927.9	V80, V90-V94 (.5,.7,.8), V96, W02, W09, W16, W21, W22 (.0-.7), W51 (.0-.7), W67-W70, X50
Bicycle	E800-E809 (.3), E810-E819 (.6), E820-E825 (.6), E826-E829 (.1), E826.9	V10-V19
Pedestrian	E800-E809 (.2), E810-E819 (.7), E820-E825 (.7) E826-E829 (.0)	V01-V09
Assault	E960-E969	X92-X99, Y00-Y09

Table 2: ICD-9 and ICD-10 CA codes used to identify external causes of injury to the patients included in the study. Adapted from the INSPQ surveillance project on TBI in Québec [17]. In contrast to their surveillance report, both intentional and non-intentional TBI hospitalizations were included in this study.

For the secondary analysis involving the adult population, if charts were not accessible because they were shredded or stored remotely, missing data for GCS, GOS, intoxication status, polytrauma status and rehabilitation services was multiply imputed using "R mi" package, version 0.09-18.03 [29]. Model fit for the conditional models were verified through diagnostic plots included in the package. 30 iterations of 10 multiply imputed data sets were used and all regression models used in the secondary analysis used pooled estimates of the 10 imputed data sets. All of the regression outputs presented in the Results section were produced using this multiply imputed data. These data were assumed to be missing completely at random.

4.5 Data analysis

Descriptive statistics were produced regarding the trends in incident TBI hospitalization rates by year and stratified on age, sex and community of origin within Eeyou Istchee. Region 18 communities were also stratified based on their geography as either "coastal (semi-remote)", "inland (rural and semi-remote)" or "remote" as these communities have built environments that resemble each other (i.e: coastal communities are on the James Bay coast and have distant access to the provincial network of roadways, inland communities are significantly closer to the provincial network of roadways and are not on the James Bay coast, and the remote community has local roadways that are not connected to provincial roadways or other communities) (Figure 3) [25]. Given that the study population is small and there was a small number of total TBI hospitalizations, 5 age categories in years, similar to how provincial surveillance was completed, were used for all descriptive and inferential statistics ("0-14", "15-24", "25-44", "45-64", "65+"). Moreover, to compare the rates from Eeyou Istchee with the other health regions of Québec that were previously measured in a provincial TBI surveillance project, direct standardization of the populations under study to Québec's 1991 population structure was used [17].

For the primary objective of measuring the incidence rate of TBI hospitalizations, the demographic data of Region 18 was obtained from the Ministère de la Santé et des Services sociaux in conjunction with the Institut de la Statistique du Québec based on the 2006 Canadian Census data [30-31]. For the period of 2000-2005, population estimates from these two governmental sources were used and for the period of 2006-2012 projected population figures were used. The demographic information was stratified by age (5-year age groups), gender and year. The same demographic data was also obtained for the entire province and the neighbouring indigenous/non-indigenous populations that were used as reference populations. Crude incidence rates were obtained by using the 13 years of the study populations' person-time contribution and were calculated per 100000 person-years. Adjusted incidence rate ratios (IRRs) were then computed with Poisson regression models between the study population and the 3 other reference populations while controlling for age, gender and year of injury. If the Poisson distribution assumption of having the variance and mean of counts equal was not satisfied, a negative binomial regression model was used instead.

Mechanisms of injury were compared between Region 18 and reference populations with a multinomial regression model. In addition, comparisons of mechanisms of injury within Region 18 were contrasted by geographical zones of communities to identify whether the built/natural environment had an association with the mechanisms of injury. For this last analysis, three Poisson regression models that used robust variance to estimate risk ratios that compared "off-road vehicle use versus other mechanisms", "falls versus other mechanisms" and "assaults versus other mechanisms"were created to identify how mechanism of injury distributions vary by geographical zone. The methodology behind using the robust variance estimator to calculate risk ratios instead of odds ratios is described elsewhere [32].

For the secondary objectives of the study, descriptive statistics on the risk factors of TBI hospitalization in adults were produced (Table 7) using only collected data. Moreover, different regression models subsequently described were used to compute association measures of various risk factors on different relevant TBI outcomes using the multiply imputed data as explained above. For outcome measurements using the GOS, a cumulative odds logistic model was used with covariates of age, sex, alcohol intoxication, use of rehabilitation services, geographical zone of origin, mechanism of injury and polytrauma status as covariates. The proportional odds model was used if valid. Severity of injury using GCS as a continuous variable was also completed using a linear regression model with covariates of alcohol intoxication, age, sex and geographical zone of origin. A sub-group of patients involved in MVCs, off-road vehicle collisions, motorcycle and bicycle accidents were analyzed with two logistic regression models to identify factors that predicted the non-use of protective equipment. Multiple imputations for missing data in this subset was used the same way as described above. Two final Poisson regression models using the robust variance estimator of the risk ratio were used to factors predicting alcohol use at the time of injury and rehabilitation services being offered to injured patients. When protective equipment was a predictor in a model, only a subset of the population was analyzed (i.e.: the subset that had a TBI from an external cause of injury where protective equipment could be used: off-road vehicles and motor vehicle collisions).

Regression model selection was completed based on known confounders of TBI occurrence for the analyses of the primary objectives (age, gender, year and year of injury). For secondary objectives, models were selected based on a forward-backward iterative process using the Akaike Information Criterion (AIC) statistic to select the most parsimonious model along with traditional directed acyclic graphs to ensure known confounders of the associations were being included in the models. The assumptions of linear regression models (normality, homoscedasticity and independence of the errors and linear relationship between the independent and dependent variables) were verified for linear models.

4.6 Sensitivity analysis

Given that the study was conducted in a rural to remote population there was the possibility that more hospitalizations may have occurred for milder injuries compared to an urban centre where hospital beds are proportionately more limited for the larger population it serves. To verify whether this had occurred, a sensitivity analysis was completed by measuring the proportions of mild, moderate and severe TBI hospitalizations in the urban centre of Montréal. Only residents of the socio-sanitary region of Montréal were included.

The TBI database of the trauma centre was used to identify all the moderate and severe TBI patients admitted from their specifically defined catchment area. This database records all TBI hospitalizations along with many variables including the initial post-resuscitation GCS. Obligatorily, these TBI patients are admitted to this specialized centre, whereas all other mild TBI cases are managed in non-trauma centres in the surrounding area. Using the MED-ÉCHO database, all TBI cases in Montréal's socio-sanitary region were identified that are a part of this trauma centre's catchment area (using municipal codes of patients in the MED-ÉCHO database). With this last denominator, the proportions of different severity TBI in this urban population were computed and compared to those of Region 18 to ensure that more severe injuries were not systematically more likely to be hospitalized in the urban rather than rural setting. A Chi-Square test for independence with a significance level of 5% was used to establish whether or not there was a difference in the distribution of TBI severity in urban versus rural settings.

4.7 Precision of estimates and statistical software

For all coefficient estimates from regression models, a 95% confidence interval was calculated. R version 3.0.3 for Mac OS X (R Foundation for Statistical Computing, 2012) and Stata 12.0 for Mac OS X (StataCorp, 2011) statistical software was used for all data analysis.

4.8 Ethics

The institutional research ethics board of McGill University approved this study. The study conformed to the Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans and more specifically research involving First Nations, Inuit or Métis people [33]. In addition, each hospital where a chart review was completed granted authorization from their Director of Professional Services. Finally, the CBHSSJB's public health department collaborated with the study which was approved by the Executive.

5 Results

5.1 Overview and descriptive statistics

From 2000 to 2012 there was a total of 172 TBI hospitalizations in Region 18, with men representing the majority. The crude incidence rate of TBI hospitalization during this 13-year period was 92.1 per 100000 person-years. Mechanisms of injury leading to TBI cases were mainly related to assaults followed by falls, motor vehicle collisions and then off-road vehicles. Table 3 provides these same descriptive statistics for the reference populations that were studied. The main differences noted were that Region 17 had a higher proportion of off-road vehicles as the main mechanism of injury and Region 10/Québec were mainly related to falls. For the majority of the years under study, men had higher rates of TBI hospitalizations and the rates in Region 18 were higher than in the general Québec population (Figure 4). The different geographic environments also showed varying mechanism of injury distributions with the remote community mainly having off-road vehicle collisions and the inland communities primarily having assaults. The remote community had the highest rate of TBI hospitalizations followed by coastal and inland communities (Table 4 and Figure 5).

The Region 18 TBI hospitalization cases tended to be younger than those in Region 10 and Québec. Also, the length of stay in hospital was the longest for the entirety of Québec compared to the three other socio-sanitary regions investigated. More specifically, individuals between 15-24 years had the highest incidence of head injury hospitalizations (Figure 8). The distribution of mechanisms of injury varied by age group with the youngest and oldest having falls as the most common mechanism. The other age group hospitalizations were mainly caused by assaults followed by off-road/motor vehicle collisions (Figure 7). Different geographical zones of Eeyou Istchee had different distributions of external causes of injury (Figure 6).

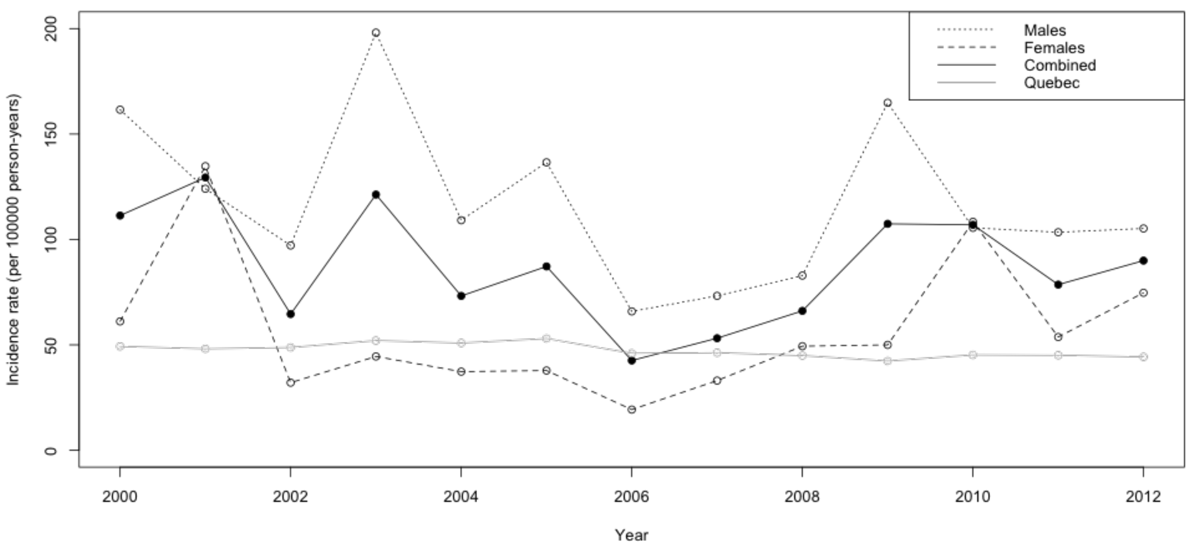

Figure 4: Standardized yearly TBI hospitalization incidence rates in Region 18 standardized to the 1991 Québec population and compared to the province of Québec's hospitalization rates.

5.2 Contrasts of TBI hospitalization incidence rates and mechanisms of injury in the entire Region 18 population

The negative binomial regression was used in the count analysis to calculate adjusted incidence rate ratios since the variance and mean of hospitalization counts were over-dispersed. Region 17 had the highest incidence rate of TBI hospitalizations, followed by Region 18 and 10 respectively. Region 18 had 1.84 times (95% CI 1.56-2.17) the rate of incident TBI hospitalizations compared to the rest of the province of Québec. This rate was similar to the one calculated in Region 10, but was clearly lower than the one estimated in Region 17. Within Region 18, the remote community had a higher rate of

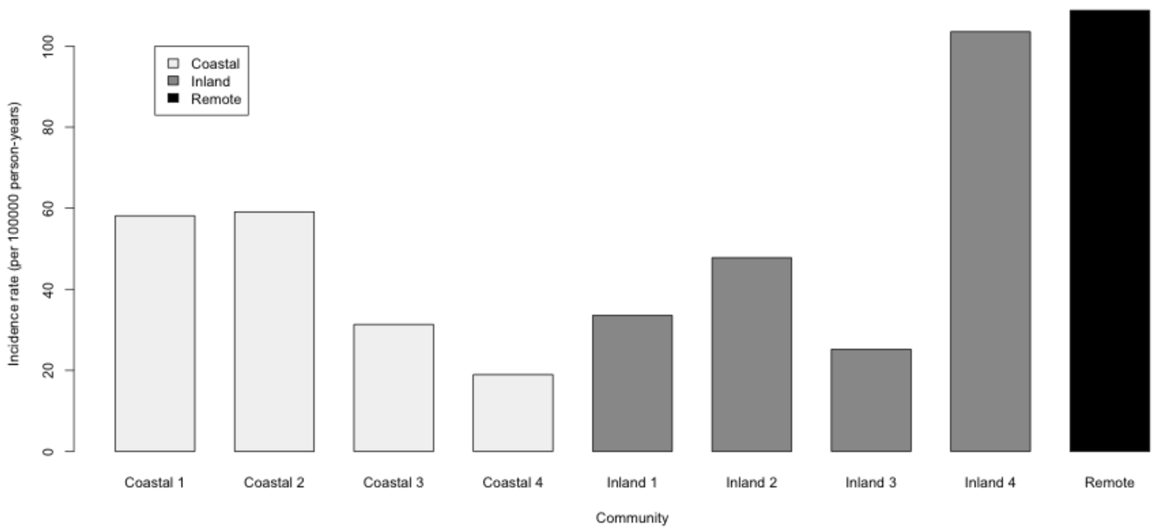

Figure 5: Standardized incidence rates of TBI hospitalization by community in Region 18 from 2000-2012 (communities not named to retain anonymity).

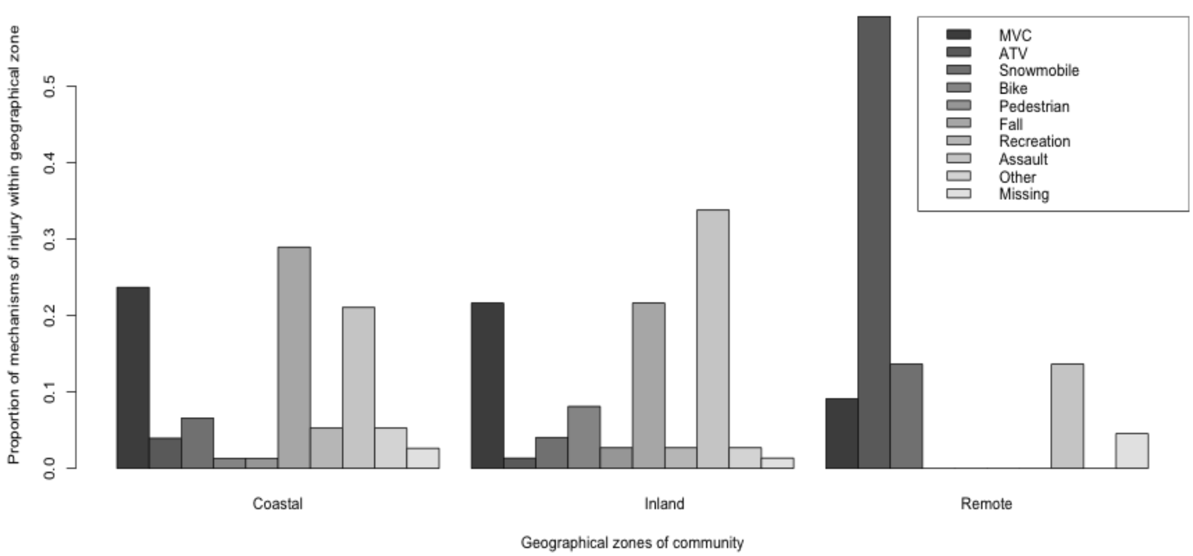

Figure 6: Distribution (proportions) of mechanisms of injury by geographical zone of Eeyou Istchee.

	Region 18	Region 17	Region 10	Québec
Total TBI hospitalizations	172	469	154	50362
Age				
Mean	24.63	23.42	35.32	45.93
Range	0-80	0-86	0-98	0-106
Standard deviation	18.03	16.28	24.44	29.2
Sex (%)				
Male	113 (65.7)	255 (54.4)	100 (64.9)	32041 (57.1)
Female	59 (34.3)	214 (45.6)	54(35.1)	18321 (42.9)
Length of stay (days)				
Mean	10.76	11.19	9.49	16.82
Range	0-128	1-369	1-132	0-2422
Standard deviation	20.11	28.71	16.65	33.1
Mechanism of injury (%)				
Assault	44 (25.6)	76 (16.2)	8 (5.2)	1866 (3.7)
ATV	17 (9.9)	173 (36.9)	15 (9.7)	1243 (2.5)
Snowmobile	11 (6.4)	17 (3.6)	2 (1.3)	150 (0.3)
Fall	38 (22.1)	72 (15.3)	57 (37.0)	24086 (47.8)
MVC	36 (20.9)	41 (8.7)	31 (20.1)	9129 (18.1)
Bicycle	7 (4.1)	9 (1.9)	8 (5.2)	2851 (5.7)
Pedestrian	3 (1.7)	24 (5.1)	4 (2.6)	2365 (4.7)
Motorcycle	0 (0)	12 (2.6)	0 (0)	841 (1.7)
Recreation/sports activity	6 (3.5)	2 (0.4)	1 (0.6)	326 (0.6)
Other	10 (5.8)	43 (9.2)	28 (18.1)	4202 (8.3)
Missing	0 (0)	0 (0)	0 (0)	3303 (6.6)
Total population person-years	186581	142059	198786	100545876
Crude incidence rate per 100000 person-years	92.1	330.15	77.47	50.09

Table 3: Population-level data by region and for the entire province of Québec.

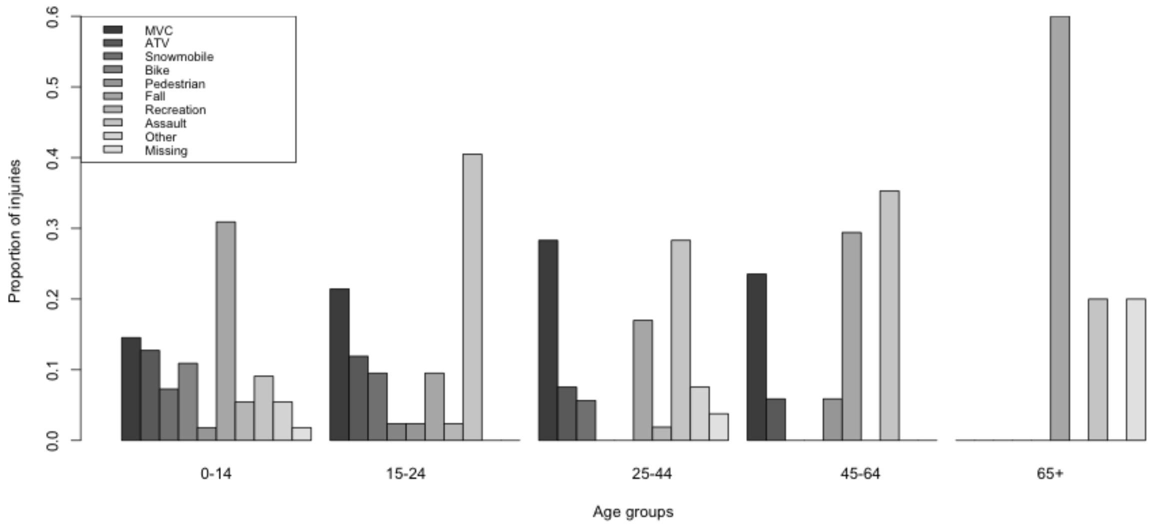

Figure 7: Distribution (proportions) of mechanisms of injury by age group amongst individuals hospitalized for TBI in Eeyou Istchee.

Communities	**TBI hospitalizations**	**Total population person-years contributed 2000-2012**	**Crude incidence rate of TBI hospitalizations**
Coastal	76	105485	72.04
Inland	74	77507	95.48
Remote	22	11000	200

Table 4: Distribution of TBI incident hospitalizations by geographical zone from 2000-2012

TBI hospitalizations as compared to inland/coastal Cree communities. In terms of age, the 15-24 age group had the highest estimated rate of TBI hospitalizations when compared to all other age groups, which was statistically significant. Men had a substantially higher rate of TBI hospitalization that was 1.86 times (95% CI 1.36-2.57) the rate of women (Table 5).

The multinomial regression to establish associations between mechanisms of injury and region of TBI hospitalization revealed that assaults were significantly more associated with Regions 18 and 17 compared to Region 10 and Québec (Relative probability ratios of 10.66, 11.77 and 1.47, respectively). ATV collisions were clearly much more associated with Region 17 than all other populations. Regions 18 and 10 had similar relative probability ratios of these collisions, which were higher than the general Québec population but lower than Nunavik. Similar results for snowmobile collisions were demonstrated. Also, recreational activities in Region 18 were more strongly associated with TBI hospitalizations compared

	Incidence Rate Ratio	95% confidence interval
Québec-wide analysis		
Provincial socio-sanitary regions		
Québec	1	Referent
Region 10	1.55	1.30-1.83
Region 17	6.82	6.06-7.65
Region 18	1.84	1.56-2.17
Sex		
Females	1	Referent
Males	1.86	1.73-2.01
Region 18 sub-analysis		
Within Region 18		
Inland	1	Referent
Coastal	1.32	0.96-1.82
Remote	2.73	1.64-4.27
Sex		
Females	1	Referent
Males	1.86	1.36-2.57
Age groups (years)		
45-64	1	Referent
0-14	1.33	0.80-2.33
15-24	1.95	1.14-3.47
25-45	1.41	0.85-2.48
65	0.83	0.28-2.09

Table 5: Incidence rate ratio contrasts by socio-sanitary region in Québec and by geographical zone within the region 18 sub-population. Two negative binomial regressions were used to obtain these estimates in both populations (covariates adjusted for: sex, age and year of injury).

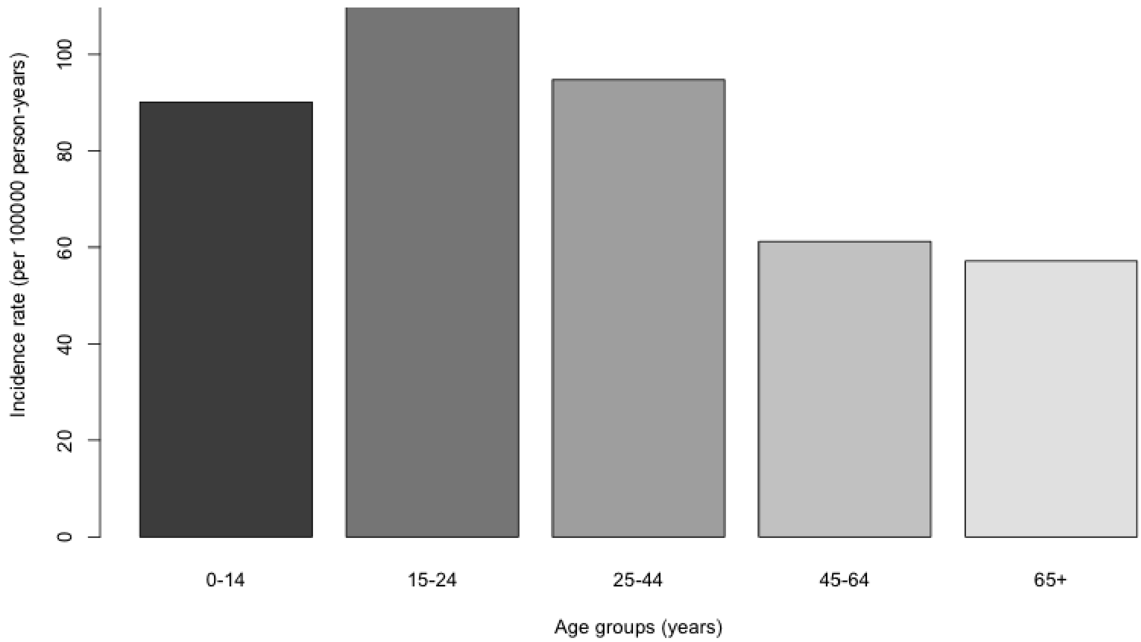

Figure 8: Standardized incidence rates of TBI hospitalizations by age.

Population	Risk Ratio	95% confidence interval
Off-road vehicles vs. other mechanisms		
Inland	1	Referent
Coastal	1.63	0.53-5.02
Remote	14.46	5.74-36.43
Assaults vs. other mechanisms		
Inland	1	Referent
Coastal	0.9	0.51-1.57
Remote	0.44	0.17-1.16
Falls versus other mechanisms		
Inland	1	Referent
Coastal	1.19	0.65-2.17
Remote	NA	NA

Table 6: Risk ratios comparing the association of off-road vehicle collisions, assaults and falls versus other mechanisms by geographical category of Region 18 communities. Three poisson regression models with the robust variance corrector were used that adjusted for age, sex and year of injury.

to the 3 other reference populations. Men were clearly more involved in all mechanisms of injury except for pedestrian and recreation-related injuries. Table 15 in the Appendix shows the multinomial regression output for the model used in this part of the analysis.

Three poisson regression models using the robust variance estimator were also used to describe the association of off-road vehicle collisions, assaults and falls as they are related to TBI hospitalization in different geographical zones. The strongest association was between off-road vehicle collisions in the remote community compared to inland communities (OR = 14.46, 95% CI 5.74-36.43). Also, the remote community had significantly less assaults as an external cause of TBI than the other communities. Table 6 describes these associations in more detail.

5.3 Analysis of risk factors related to TBI hospitalizations in the adult (15 years or older) Region 18 subpopulation

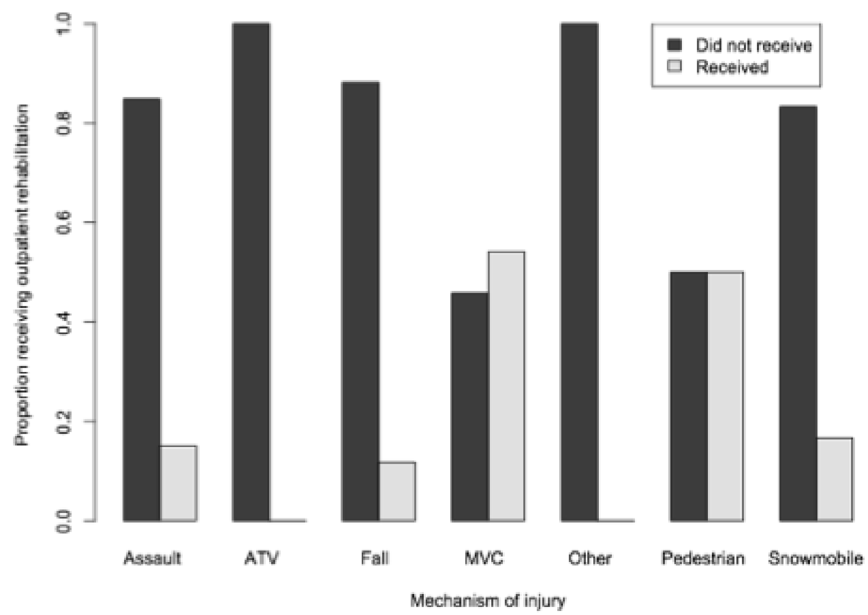

Figure 9: Proportion of individuals (15 years or older) hospitalized for TBI receiving outpatient rehabilitation by external cause of injury.

There was a total of 117 incident TBI hospitalizations of individuals 15 years or older between 2000-2012 (Table 7). In terms of severity of injury, there were mainly mild TBI hospitalizations (80%) followed by severe and then moderate TBI. Most patients were discharged home from their hospitalization and there were no TBI attributable deaths amongst the patients' chart that were reviewed. The GOS varied from severe disability (GOS=3) to a good functional outcome (GOS=5). The GOS calculation was based on assessments that were mainly between 6 months and a year. The range of follow-up time for the GOS calculation varied from 5 months to 14 months. Overall, 34 patients received inpatient or outpatient rehabilitation. Motor vehicle collision victims tended to receive more rehabilitation services than victims of other external causes of injury (Figure 9).

Amongst the 41 patients who were hospitalized with a TBI that was due to an external cause where protection could have been used, only 27% of patients had worn protection. Moreover, just over 55% of patients were reported as having been intoxicated at the time

Total TBI hospitalizations	117
Initial post-resuscitation GCS	
Mean	13.74
Range	3-15
Standard deviation	2.33
TBI severity category (GCS range) (%)	
Mild (13-15)	81 (83.5)
Moderate (9-12)	7 (7.2)
Severe (3-8)	9 (9.2)
Polytrauma (%)	
Yes	43 (44.3)
No	54 (55.7)
Rehabilitation (%)	
Inpatient	12 (12.4)
Outpatient (in community)	22 (22.6)
Discharge orientation (%)	
Home	83 (85.6)
Rehabilitation (inpatient)	12 (12.4)
Deceased	0 (1.0)
Long-term care	0 (0.0)
Other hospital centre	2 (2.0)
Glasgow Outcome Score	2 (2.0)
1	0 (0)
2	0 (0)
3	14 (14.4)
4	52 (53.6)
5	31 (32.0)
Protection (%)	
Yes	11 (26.8)
No	30 (73.2)
Intoxication with alcohol (%)	
Yes	43 (44.3)
No	54 (55.7)
Patients with imputed data (%)	20 (17.1)

Table 7: Summary of additional covariates measured in the adult population of Region 18.

Variables	Coefficient	95% confidence interval
Intercept	13.27	11.53 - 15.01
Age(25-44)	0.42	-1.05 - 1.88
Age(45-64)	0.39	-0.190 - 2.68
Sex: Male	0.18	-1.14 - 1.51
Protection: Yes	1.29	-0.27 - 2.85
Alcohol: Yes	-0.47	-1.87 - 0.93
Mechanism: MVC	0.49	-0.91 - 1.88

Table 8: Linear regression analysis of GCS against variables that potentially have an effect on the severity of TBI amongst individuals with a TBI resulting from a mechanism of injury where protective equipment could be used (off-road vehicle or MVC). Individuals 65 years or older were excluded from the analysis as there were none who sustained a TBI with an external cause of injury where protective equipment could be worn.

Variables	Coefficient	95% confidence interval
Intercept	14.12	12.32 - 15.93
Age(25-44)	0.51	-0.55 - 1.57
Age(45-64)	0.19	-1.25 - 1.64
Age(>= 65)	-0.58	-3.62 - 2.46
Sex: Male	-0.55	-1.60 - 0.50
Community:Coastal	0.01	-1.01 - 1.04
Community:Remote	-2.76	-4.67 - -0.84
Alcohol intoxication: Yes	-1.18	-2.17 - -0.19
Mechanism: Assault	0.65	-0.85 - 2.15
Mechanism: Off-road	1.65	-0.34 - 3.66
Mechanism: Other	0.46	-1.58 - 2.50
Mechanism: MVC	0.78	-0.77 - 2.33

Table 9: Linear regression analysis of GCS against potential determinants of TBI severity in the adult population of Eeyou Istchee.

Variables	Odds Ratio	95% confidence interval
Age(25-44)	1.67	0.35 - 7.99
Age(45-65)	12.27	0.73 - 207.68
Sex: Male	0.52	0.13 - 2.04
Comorbidity: Yes	1.05	0.14 - 7.72
Alcohol: Yes	0.61	0.15 - 2.52
Mechanism: MVC	0.3	0.07 - 1.36
Polytrauma: Yes	1.06	0.21 - 5.25
Protection: Yes	0.17	0.03 - 0.85

Table 10: Proportional odds logistic regression of GOS at 6 months for a subset of patients in a mechanism of injury where protective equipment can be used. The reference category for mechanism is off-road vehicles. The age category of 65 years or older was excluded as there were no individuals of this age group that had such an injury. Individuals 65 years or older were excluded from the analysis as there were none who sustained a TBI with an external cause of injury where protective equipment could be worn.

Variables	Odds Ratio	95% confidence interval
Age(25-44)	2.84	1.05 - 7.66
Age(45-64)	12.47	2.38 - 65.26
Age(>= 65)	99.57	2.98 - 3324.69
Sex: Male	0.37	0.13 - 1.04
Comorbidity: Yes	1	0.24 - 4.09
Alcohol intoxication: Yes	1.1	0.44 - 2.76
Mechanism: Assault	0.66	0.16-2.76
Mechanism: Off-road	2.19	0.42 - 11.38
Mechanism: Other	0.92	0.14 - 5.90
Mechanism: MVC	0.74	0.16 - 3.48
Polytrauma: Yes	1.47	0.55 -3.93
GCS	0.57	0.44 - 0.74

Table 11: Proportional odds logistic regression for outcomes (GOS) at 6 months to a year. Reference category for age is 15-24 and for mechanism of injury is falls.

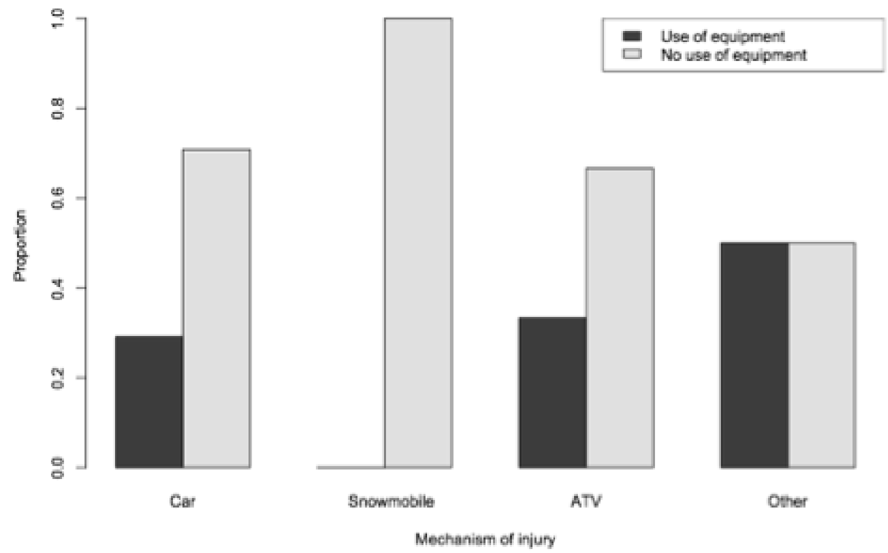

Figure 10: Proportion of individuals (15 years or older) hospitalized for TBI that were wearing protective equipment depending on their external cause of injury.

of their injury. Individuals suffering a TBI from a snowmobile accident were found to never have worn a helmet (Figure 10).

Two linear regression analyses were completed to evaluate TBI severity against several risk factors. The regression outputs of these two analyses are shown in Tables 8 and 9. Amongst the whole cohort of reviewed patients, patients in the remote community had more severe injuries than those in the other communities even after adjusting for confounders such as age, alcohol intoxication, sex and mechanism of injury. On average, amongst the patients who could have worn protective equipment, the individuals wearing protective equipment had an increase of 1.29 in their GCS (95% CI -0.27-2.85).

In terms of outcomes, two proportional odds logistic regression models were designed. Patients wearing protective equipment tended to have a better outcome as assessed by the GOS (Table 10). Generally, older patients had poorer outcomes on the GOS scale than patients in the youngest group (15-24 years old) after adjusting for the confounders mentioned in Table 11.

Finally, two poisson regression models using the robust variance estimator were created to assess factors that predicted which patients used rehabilitation services (inpatient or outpatient) and those that were most likely to have used alcohol at the time of their injury. Regarding rehabilitation, patients in older age groups tended to receive more rehabilitation than those in the youngest group. This was particularly significant for the 45-64 age group (Table 12). In addition, patients in MVCs had 3.79 times the probability of receiving rehabilitation services than those with a mechanism of fall. A similar finding was concluded when they were compared to those suffering TBI from an assault. Victims of off-road vehicle collisions and other mechanisms (bicycles and recreational activities) were not significantly different from the other groups. In terms of alcohol consumption at the time of injury, older patients had lower probabilities of being intoxicated compared to the youngest age group (Table 13).

Variables	Risk Ratio	95% confidence interval
Age(25-44)	1.75	0.82 - 3.74
Age(45-64)	2.55	1.07 - 6.02
Age(65+)	2.44	0.38 - 15.55
Sex: Male	0.93	0.53 - 1.62
GCS	0.86	0.78 - 0.96
Comorbidity:Yes	1.18	0.65 - 2.17
Community:Coastal	0.74	0.40 - 1.34
Community:Remote	0.56	0.15 - 2.11
Mechanism: Assault	1.06	0.33 - 3.38
Mechanism: Off-road	1.69	0.38 - 7.54
Mechanism: Other	2.49	0.89 - 7.02
Mechanism: MVC	3.79	1.53 - 9.33

Table 12: Poisson regression with robust variance correction of hospitalized TBI patients that received post-injury rehabilitation against potential factors influencing the decision to receive rehabilitation. Reference category for age is 15-24, for mechanism of injury is falls and for community is Inland.

5.4 Sensitivity Analysis

Table 14 breaks down the different severity TBI in Region 18 and compares it to the distribution in Montréal in a specific territory covered by 1 trauma centre. The distributions of injury severity are similar and the Chi-square value is quite low, which excludes any significant difference in TBI severity distributions.

6 Discussion

6.1 Summary of findings

The results of the primary objectives of this study revealed that Region 18 had a significantly elevated TBI hospitalization rates from 2000-2012 compared to the rest of the Québec population. Region 17 was the population with the highest rates. Region 10 had similar rates to Eeyou Istchee. The 15-24 year-olds of Eeyou Istchee had the highest occurrence of TBI hospitalizations and men were at a higher risk in all age categories.

Variables	Risk Ratio	95% confidence interval
Age(25-44)	0.92	0.66 - 1.30
Age(45-64)	0.51	0.23 - 1.11
Age(65+)	NA	NA
Sex: Male	0.91	0.64 - 1.28
Community:Coastal	1.03	0.73 - 1.44
Community:Remote	0.63	0.27 - 1.49
Mechanism: Assault	1.70	0.80 - 3.59
Mechanism: Off-road	1.74	0.76 - 3.99
Mechanism: Other	1.21	0.46 - 3.19
Mechanism: MVC	1.46	0.67 - 3.13

Table 13: Poisson regression with robust variance correction of hospitalized TBI patients that consumed alcohol at the time of injury against potential variables that may influence alcohol consumption. Reference category for age is 15-24, for mechanism of injury is falls and for community is Inland.

	Severity of TBI (%)		
Population	*Mild*	*Moderate*	*Severe*
Region 6	5467 (83.6)	388 (5.9)	681 (10.4)
Region 18	81 (83.5)	7 (7.2)	9 (9.2)
Significance testing	$\chi^2 = 0.38$	df = 2	p = 0.83

Table 14: Test of homogeneity in distribution of different severity TBI between Region 18 and an urban population (Region 6 - Montréal)

Compared to the rest of Montréal, Eeyou Istchee's TBI hospitalizations were mainly related to assaults, MVCs and off-road vehicle collisions, which is significantly different than the rest of Québec and the other reference populations of this study. Within Region 18, there were differences in rates and mechanisms of injury based on geographical locations of communities, where the remote community had the highest rate of TBI hospitalizations along with a strong predominance for off-road vehicle collisions being the external cause of injury.

The sub-analysis of adults TBI hospitalizations revealed that injury severity was significantly affected by use of alcohol at the time of injury, as well as by geographical zone of the community where, on average, cases from the remote community were more severe. There was a potentially clinically significant increase in initial GCS provided to individuals wearing protective equipment, but this did not reach statistical significance. Moreover, functional outcomes of hospitalized patients were improved in patients wearing protective equipment and in younger age groups. Rehabilitation services tended to be systematically provided to individuals with MVCs more so than to those with falls or assaults even with other similar situations around their injury. Also, older age groups tended to be referred and receive rehabilitation more so than the youngest age group. In general, older hospitalized patients had lower risks of consuming alcohol at the time of their injury than the younger adult population.

6.2 Interpretation of TBI epidemiology results for Eeyou Istchee

6.2.1 Hospitalization rates, population-based risk factors and mechanisms of injury

There have been epidemiological descriptions of TBI in many different populations across the globe, with varying rates reported due to differences in case definitions, data sources and evidently risk factors for the populations under study [34-36]. In the United States, the CDC conducted TBI surveillance with reported incidence rates for emergency discharges. Similar to the study we conducted, they used ICD-9 codes to identify TBI cases for 1 year in 1997 with a reported rate of 69.7 per 100000 person-years [11]. In their report, there were significant variations in TBI hospitalization rates between states under investigation. Moreover, other surveillance studies with similar methodology in other high-income countries, such as Scotland and Finland, revealed once again varying rates of TBI [37,38].

In Canada, the provinces of Ontario and, as previously referred to, Québec both completed surveillance studies on TBI hospitalizations using ICD coding from administrative databases [18,39]. Ontario reported hospitalization incidence rates that fell from 83.1 to 50.4 over the period of 1992 to 2002. In Québec, the incidence rates fell from 50.4 to 42.9 in the period of 1991 to 2009. Eeyou Istchee had an age-adjusted incidence rate (directly standardized identically to the reported rates in Québec) of TBI hospitalizations that varied on a yearly basis from as low as 42.6 to as high as 129.4 per 100000 person-years (Figure 4). The rates in Eeyou Istchee did not tend to decrease over time as they did in Québec, Ontario and even in the United States (mainly due to high variability) [11,18, 39]. Men and young adults in Eeyou Istchee had a significantly higher rate of TBI, which is a finding that has been consistently found in populations across the globe [11,18, 36-40]. Briefly, these varying rates across populations emphasize the need for surveillance to be completed on very specific populations with similar methodology to be able to monitor trends over time and to appropriately adapt public health prevention planning to the community.

The findings of this epidemiological investigation clearly documents that rural environments in Québec tend to have higher rates of TBI hospitalizations. The Québec TBI surveillance report in 2009 alluded to this when they compared rates of TBI hospitalization stratified by region [18], although Regions 10, 17 and 18 were not included in the analysis. These findings have been replicated elsewhere in the literature in different rural populations [16, 41]. Typically, investigators attribute these differences to the higher rate of transport-related accidents in the rural setting [41]. In Eeyou Istchee, Nunavik and even Nord-du-Québec regions, there were clearly higher rates of off-road vehicle collisions than in the rest of the province. These associations were the strongest for Nunavik followed by Eeyou Istchee and Nord-du-Québec. Furthermore, within Eeyou Istchee, there was clearly a predominance of transport-related accidents in the remote geographical zone compared to the coastal and inland communities. The remote community of Eeyou Istchee, as well as all the communities of Nunavik, are not connected to Québec's provincial road network. As such, the use of off-road vehicles is very common to travel around the communities on often-unpaved roads. In addition, these communities tend to use these vehicles to participate in traditional activities such as hunting along their trap lines [42]. Interestingly, the inland/coastal communities of Eeyou Istchee and Region 10, which are connected to provincial road networks, had lower rates of TBI hospitalizations related to these types of collisions, which likely reflects less dependence on the use of off-road vehicles. This finding supports the idea that the varying geographical environment within rural areas is a significant determinant of TBI occurrence. Hence, these distinct geographical attributes are important to consider when conducting TBI surveillance in rural environments.

The other striking difference was that the other eight Cree communities had assaults as the main external cause leading to TBI hospitalizations. In Nunavik, there was also a significantly higher rate of assaults related to TBI compared to the rest of Québec, which was not found in Region 10. A TBI study in New Zealand found similar findings when comparing the main causes of TBI amongst indigenous and non-indigenous populations and a study in Alberta on severe trauma in status Aboriginals also replicated these findings [8,16]. In contrast, a study completed on TBI rehabilitation patients in Saskatchewan found no such association [10]. Hence, generalizations of ethnicity towards the risk of TBI hospitalization do not seem substantiated. There may be socio-economic factors that explain these differences in the Northern Indigenous population of Québec. Finally, falls have been documented to be a leading cause of TBI, specifically in aging populations [18, 34]. The indigenous populations of Québec, such as Eeyou Istchee, have a very young population, with about 40% of the population being under the age of 18 [30-32]. The latter being the rationale explaining why falls are not as prominent of an external cause of injury in these populations. The main conclusions of the surveillance studies in Québec and Ontario were to concentrate public health efforts on the prevention of falls to prevent head injury hospitalizations [18, 39]. Our findings clearly demonstrate that head injury epidemiology within populations is heterogeneous and that large-scale surveillance studies do not necessarily apply to all population clusters.

6.2.2 Risk factors, rehabilitation and outcomes

The main factor increasing the initial severity of TBI was the remote geographical zone. As previously mentioned, the epidemiology of TBI is heterogeneous across populations and is affected by many determinants. The reasons behind the increase in severity in this population was adjusted for the evident confounders of the association, which leaves us with the question as to why is it increased. Although mechanism of injury was controlled for as a confounder, there is likely residual confounding of this association. The amount of kilometres or time driven in this more remote and isolated community is likely substantially higher than the coastal/inland communities. As it was previously shown, Nunavik has a substantially higher IRR of TBI hospitalizations compered to Québec, Nord-du-Québec and Eeyou Istchee. As such, there are clearly uncontrolled factors in our analysis that are contributing to this trend, which may be related to the environment (road access), cultural and socio-economic factors that were not analyzed in this study but that have been shown to be crucial in other reports [43].

Alcohol use at the time of injury was clearly a factor in reducing the initial post-resuscitation GCS and 44% of the head-injured patients had used alcohol at the time of their injury. In keeping with these findings, most population-based studies report that 30-50% of TBI cases are associated to use of alcohol [44-46]. The issue of alcohol use and TBI has been extensively visited in the past and reports have shown that use of alcohol increases the probability of TBI through all mechanisms of injury [47]. However, alcohol use at the time of injury has not been shown to reduce the overall outcome of TBI patients [48]. As discussed below, reducing the use of alcohol in certain settings have been proposed as a prevention strategy to reduce TBI related to assaults and motor/off-road vehicle collisions where there was a possibly strong, although non-significant/imprecise, association between alcohol use and these external causes of injury (Table 13).

This study focused on risk factors impacting the severity of injury and the outcome of patients with TBI. Nonetheless, there have been many other reviews that have investigated how these similar risk factors contribute to the occurrence of TBI. For example, a population-based study in the United States confirmed that use of helmets in all-terrain vehicle riders strongly reduces the likelihood of any TBI in addition to lowering the severity of TBI [49]. Unhelmeted riders had 1.62 times the odds of incurring a TBI and had 3.19 times the odds of having a moderate/severe TBI compared to a mild one. Moreover, a Canadian study clearly showed that the rates of paediatric hospitalizations for head injuries was lowered by 45% after bicycle helmet legislation was enforced [50]. A case-control study in France found that helmeted cyclists had a significantly lowers odds of head injuries compared to unhelmeted cyclists, which was further validated by a Cochrane review in 2009 [51,52]. Interestingly, the protective effect of helmets was stronger in the rural setting than in the urban one. In terms of seat belt use, there is data from the United States reporting a decrease in TBI related to transportation crashes by 40% over the past 3 decades [53]. In short, the use, or non-use, of protective equipment has a clear effect on the primary and secondary prevention of TBI.

In terms of functional outcomes between 6 to 12 months after the injury, the GOS scores of the adult hospitalized patients tended to be in higher categories for individuals wearing protective equipment. These findings are consistent with what was just previously mentioned. The multivariate analysis we conducted showed that older age groups, even after adjusting for rehabilitation (although not used in the final model shown in Table 11 because of our model selection criteria), tended to have worse outcomes than the youngest age group that was analyzed (15-24 year olds). This finding is consistent with other reports in the literature [54]. As expected, the patients in the study with lower initial GCS had a higher odds of receiving rehabilitation services. In general, older age is a risk factor for poorer outcomes after any severity of TBI. To add to this disparity, younger patients tended to receive rehabilitation services less so than older patients and patients in MVCs had a higher odds of receiving rehabilitation than those with assaults or falls. This disparity is troubling considering that rehabilitation services across the spectrum of different severity TBI has been clearly shown to improve victims' functional outcomes [55].

6.3 Traumatic Brain Injury prevention strategies for adults (15 years or older) of Eeyou Istchee

Please refer to Appendix II (Section 16) that contains this separate document.

6.4 Strengths and limitations

This study had many strengths in terms of comparing two different and neighbouring indigenous populations to the greater population of the province where they reside, which has not been previously completed [8, 9, 33]. Typically, a single indigenous rural population is compared to an urban non-indigenous population. By employing our strategy we were able to partially control for confounders of environment, socio-economic status and cultural differences, which may explain differences in TBI occurrence [9-11,16,41]. Although, two indigenous populations do not necessarily have the same cultural or socio-economic situations, there is more similarity between them as opposed to the general non-indigenous population. In fact, by using a neighbouring non-indigenous population as a third reference population, more inferences on the determinants of TBI for the population of Region 18 could be elicited. As previously mentioned, the main determinant of TBI in the rural setting is often attributed to differences in methods of transportation. Our analysis reproduced this finding but by comparing different populations with similar built environments, further details of the determinants could be sought. Region 18 clearly has more off-road vehicle collisions than the rest of Québec but it also has many more assaults related to TBI than the neighbouring region of Nord-du-Québec, after adjusting for the evident confounders of age and sex. A similar finding with Nunavik was found as well even though there rates of off-road vehicle collisions related to TBI were significantly higher. Hence, the public health issue of violence related to traumatic injuries becomes a priority as outlined in the prevention strategies we were targeting. More generally, the methodology we used suggests that violence related to TBI seems to be a particular problem for the two indigenous populations of Québec that were studied in this report (Eeyou Istchee and Nunavik).

This study also completed very meticulous and detailed data collection, which expanded beyond the use of only administrative databases, which have little information on the overall severity and outcomes of TBI patients. By completing chart reviews in multiple hospital centres, we ensured that the most accurate information was obtained regarding the evolution of patients' injuries. By reviewing all of the adult charts in the first-line hospital where they were evaluated, there was a better chance of obtaining the most accurate post-resuscitation GCS as this could easily vary after transferring the patient to a secondary or tertiary centre. In addition, the details on the use of alcohol and use of protective equipment are thought to be more accurate when taken from the earliest source of information since this is before any information exchange between clinicians can modify the original clinical history.

The sensitivity analysis of our data helped exclude the possibility of over-hospitalization of Region 18 patients. Previous research has shown that there is a higher proportion of moderate/severe compared to mild TBI cases because of limited hospital resources in urban centres [75]. Given that there was a similar proportion of different severity TBI in Montréal as in Eeyou Istchee, it seems plausible that our estimates are unbiased when comparing them to the rest of Québec and the other reference populations we used for our analysis.

Several limitations of this study relate to the fact that case finding relied on administrative databases using ICD coding from two different iterations (ICD-9 and ICD-10 CA), which can alter case definitions during the study period. Using ICD codes has also been known to be less sensitive at identifying mild TBI cases and therefore this population may be underestimated in our analysis [76]. As previously mentioned, it becomes difficult to compare different reports of TBI hospitalization rates because of differences in case definitions [34-36]. For example, our definition of cases, which resembles the one used for Québec surveillance, likely underestimates TBI hospitalizations compared to the Ontario study where a broader definition was used [18, 39]. In addition, the TBI surveillance study by the INSPQ excluded intentional injuries. The latter explains why our study's TBI incidence rates are slightly higher for the entire province of Québec. As such, comparability to other populations must be completed with caution. Nonetheless, for the purpose of generating inferences regarding determinants of TBI within Québec, this study remains suitable. Also, our study only concentrated on TBI hospitalizations and therefore many milder injuries were excluded [76]. Similarly, mortality cases that were never hospitalized were not included in this analysis, which again underestimates mortality figures and overall TBI incidence rates. Lastly, the GOS was used based on information provided by physicians in the charts of patients in the local CMCs. Furthermore, the follow-up periods were short (up to 12 months) and varied (between 5-14 months) which may cause some misclassification of patients' outcomes. Moreover, the latter may have caused the outcomes to appear worse than if patients were followed and evaluated at a further time point after their injury. Nonetheless, this information still provides critical information on individuals who have a particular risk of having poorer outcomes compared to other TBI victims.

7 Conclusions

TBI is a clinically heterogeneous problem that affects individuals of all ages. Clearly, it is also a problem that affects populations around the globe in a heterogeneous way. Diagnosing the severity of TBI is as simple as using the GCS. Diagnosing the problem of TBI at the population level is not as straightforward. The literature and this study clearly shows that nearby populations have very varied rates, risk factors and outcomes related to TBI. Community-based investigations are critical to properly address the pitfall of provincial/nation-wide surveillance studies that group together many heterogeneous population clusters. For example, in Québec, falls prevention was the main area of focus to reduce the incidence of TBI [18]. Based on this investigation, it is clear that violence prevention, off-road/motor vehicle collision prevention and prevention of falls are all areas that need to be targeted. Also, it is important to note the importance of the natural, built and social environments on TBI occurrence in similar, yet distinct, rural communities. In short, the population affected by TBI in Region 18 is young, left with sequelae and unlikely to receive rehabilitation services. Programs, developed within the community, that target TBI determinants are required to prevent these injuries.

8 References

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9 Appendix

9.1 Traumatic Brain Injury prevention strategies for adults (15 years or older) of Eeyou Istchee:

This study shed light on the main mechanisms and determinants of TBI in the population of Region 18 and more specifically in adults where a more in-depth sub-analysis was completed. As such, injury prevention strategies can be developed to target these determinants and eventually lead to a lower rate of TBI in this subpopulation. Typically, the CBHSSJB Public Health Department uses the Québec provincial rates of diseases as a reference and goal for their own population [56]. As such, the rates of TBI hospitalizations would need to be decreased by a factor of 2 to reach this goal. Based on our findings in the adult population, the main mechanisms of injury that would need to be targeted are assaults (interpersonal violence), off-road vehicle and motor vehicle collisions. Falls were also a common mechanism of injury leading to TBI in the adult population. The CBHSSJB has developed injury prevention strategies for falls previously and therefore this analysis does not cover this topic any further [57]. Moreover, a focus on young adults between the ages of 15-25 would be justified since they are at the highest risk of TBI hospitalizations. The Haddon matrix, developed by Dr. William Haddon Jr, is a widely used tool to develop ideas on injury prevention of many types [58]. It focuses on the spectrum of primary to tertiary prevention to help populations reduce the disease burden of injuries. The epidemiological study we completed provides information on the three phases of prevention, which will be adapted to the injury prevention models that are developed subsequently. The following section details different injury prevention strategies, using the Haddon matrix and best practices identified through public health organizations/literature that can thereafter be adapted to TBI prevention programmes in Eeyou Istchee.

9.2 Ensuring culturally appropriate injury prevention strategies:

Many injury prevention initiatives targeting indigenous populations in Canada have been started by various organizations over the last two decades [59-63]. Indigenous populations have been progressively gaining more leadership experience into running these initiatives at the local community level, which is a fundamental step to ensuring culturally appropriate strategies are employed [64]. More importantly, for these injury prevention strategies to be effective, they need to be culturally appropriate [5]. The province of Alberta developed a strategic plan for injury prevention in the province's aboriginal population [65]. As a part of this strategic plan, an "Aboriginal Injury Prevention" model was developed. This model emphasized the need for education, research, partnerships and communication to develop injury prevention strategies while having overarching indigenous values guiding their development. More specifically, they mandated that all strategies must be self-determined, empowering, intergenerational and transparent.

9.3 Injury prevention strategies for priority mechanisms of injury in Eeyou Istchee:

9.3.1 Assaults/interpersonal violence:

Assaults were the dominant external cause of TBI in adults (¿=15 years) in the communities of Eeyou Istchee, mainly concentrated in the 8 inland/coastal communities and in the age groups of 15-64 years of age (Appendix A-B). All of these assaults involved blunt types of trauma. The WHO separates interpersonal violence by family/intimate partner violence and community violence, the difference being whether or not the individuals engaging in violence are related [66]. Given that it was mainly youth and young adults that had assaults as their main mechanism of injury, the following suggestive prevention strategies concentrate on individuals aged 10-35 years as defined by the WHO in their youth violence chapter on violence prevention. This specific population is the most affected by violence and it is thought that community violence at later ages is a consequence of violence during the youth of individuals [67].

The reasons why violent behaviour occurs in individuals is difficult to explain and involves individual, relationship, societal, cultural and environmental factors. As such, an ecological model of violence was built to explain that individual violence arises from multiple levels of influence from relationship, community and societal factors [68,69]. As such, injury prevention strategies for interpersonal violence target these domains at different levels. Extensive research has been completed on which prevention strategies are effective in reducing interpersonal violence. Some interventions previously developed to prevent violence have been shown to be ineffective and are not presented here [67]. Nonetheless, many potentially effective strategies have not been thoroughly investigated but may still be considered in the context of violence prevention. The ecological model presented above can be effectively adapted to the Haddon matrix for primary injury prevention (e.g.: the "pre-event" row of the matrix). The Haddon matrix presented in Figure 11 outlines potential violence prevention strategies that may be used in Eeyou Istchee along with an indication as to whether there is evidence that the intervention is effective. In the following matrix, the host and agent share several primary prevention strategies since both parties tend to be lacking protective factors against violence when an event occurs.

9.3.2 Off-road vehicle collisions and motor vehicle collisions:

MVCs and off-road vehicle collisions were the second most common mechanism of injury in the adults of Eeyou Istchee and they were substantially higher when compared to the entire population of Québec. More specifically, the remote community was the most affected by TBI hospitalizations caused by off-road vehicle collisions. As previously mentioned, the environmental milieu of Eeyou Istchee likely explains why so many TBI hospitalizations occurred from these mechanisms of injury. Nonetheless, the secondary sub-analysis did indicate that many individuals were not wearing protective material and that alcohol intoxication was a common finding at the time of injury. Consequently, there are prevention measures that can be taken to prevent these injuries.

The INSPQ completed a surveillance project on off-road vehicle collisions causing hospitalization or death in 2011 [70]. Their main findings were that the Northern populations of Québec (including Regions 17 and 18) were at a particularly high risk of such injuries. There report did not focus on factors related to these injuries such as protective material use, alcohol intoxication status or accessibility to designated routes for these vehicles. The main victims of these injuries were in the 15-45 age range, which is the same target population this report is focusing on. In Québec, the legal age to drive these off-road vehicles was raised from 14 to 16 years in 2006 with the intention to reduce injuries in the young population [70]. Furthermore, the youth aged 16-17 years of age must have a competency certificate to drive these vehicles. The INSPQ reviewed the literature and legislation in other jurisdictions to establish whether requiring individuals over the age of 18 to have these certificates would reduce the rates of injuries [71]. Their conclusion was that there was not enough evidence to support such new legislation. The Québec Transport Ministry (MTQ) also held public consultations with the northern indigenous populations of Québec in 2006 when modifications to various provincial off-road vehicle programmes were taking place. The Eeyou Istchee consultation group raised the issue that they would like to be involved in the planning of designated routes for these vehicles and training for young drivers. In addition, this consultation group emphasized that Cree trappers would not need to have a license to ride on roads that are on their trap line and that traditional sleds would not need to conform to security regulations [42].

Given that Eeyou Istchee and other aboriginal groups depend on these vehicles to complete daily commutes and traditional activities, changes to provincial programmes would need to be adapted to their local community needs. Hence, the MTQ recommended that regional security committees be formed to address regional needs. In terms of prevention, the literature has consistently demonstrated that wearing helmets (which is mandatory in Montréal), avoiding alcohol consumption while driving, driving on paved roads and using vehicles with smaller engine size to limit excessive speeding all reduce the risk of injury [70-73].

In terms of motor vehicle collisions (mainly passenger vehicles), there have been extensive reviews on risk factors and prevention strategies to reduce the occurrence and severity of injuries. The WHO has developed a training manual for road traffic injury, which provides evidence-based strategies for MVC injury prevention [74]. Their evidence also includes many prevention strategies that apply to both MVCs and off-road vehicle collisions. As such, a single Haddon matrix for all motorized vehicles was created to help in formulating strategies for TBI prevention from these external causes in Region 18 (Figure 12).

	Host (injured victim)	Agent (Motor vehicle, off-road vehicle)	Physical environment (community infrastructure)	Social environment (policies, social programs, laws, etc...)
Pre-event	Avoid alcohol and drugs while driving[1] Avoid excessive speed Avoid driving in hazardous weather conditions[1] Avoid driving during darkness[1] Ensure vehicle has undergone routine maintenance[1] Respect routes designated for off-road vehicles[1] Avoid driving while fatigued[1]	Ensure vehicle has undergone routine maintenance[1] Avoid using three-wheeler off-road vehicles[1] Use daytime lights on vehicles[1] Ensure roads are kept clean and safe from slipping during snow/ice storms[1]	Encourage building paved road infrastructures[1] Develop designated off-road vehicle routes[1] Properly identify speed limits and road hazards with traffic signs[1]	Enforce laws on drunk driving[1, 2] Enforce laws on seatbelt and helmet use[1, 2] Regulate the engine size of off-road vehicles[1, 2] Enforce laws on the mandatory age/certification of off-road vehicle users[1, 2] Set legal blood alcohol levels to lower levels for youth[1] Enforce graduated driver licensing systems[1] Enforce speed limits[1]
Event	Wear seat belts or use helmets [1, 2]	Ensure cars have airbags[1] Ensure cars have a crash-protective design[1]	Build guard rails near ravines and ditches[1]	
Post-event	Ensure rapid transfer to adequate medical facilities for required care[1] Ensure appropriate rehabilitation services[3]	Ensure vehicles are built to easily extract victims[1] Ensure vehicles have protection against fire[1]	Ensure adequate staff and equipment for extraction of victims[1] Ensure adequate pre-hospital care[1] Ensure rapid transfer to hospital care and trauma centre if necessary[1]	Encourage lay bystanders to assist collision victims and transport to medical care if no ambulance is available[1] Develop compensation/support programs for victims of motor/off-road vehicle collisions[1] Build partnerships with specialized neurotrauma centres that can provide outpatient support to TBI patients

Figure 11: Haddon matrix addressing potential prevention strategies to reduce community violence in Eeyou Istchee (blunt trauma). The strategies identified with a superscript number from 1-5 have an associated reference indicating there is evidence for their effectiveness in preventing interpersonal violence. References 6 and 7 were used to adapt other prevention strategies, with weaker evidence for their effectiveness, to this Haddon matrix. Superscript references: 1. [77-82], 2. [83], 3. [83], 4. [82], 5. [84-85], 6. [66], 7. [67], 8. [55]

	Host (community members - victims)	Agent/vehicle (community members - perpetrators)	Physical environment (community infrastructure)	Social environment (policies, social programs, laws, etc…)
Pre-event	Social development programmes (i.e. bully prevention)[1] Provide incentives for youth to complete secondary schooling[2] Academic enrichment programmes[3] Vocational training[6] Mentoring programmes[4] Foster care programmes[6] Programmes to strengthen ties to family and jobs to reduce involvement in violent behaviour[6] Establish job creation for unemployed[6]	Social development programmes (i.e. bully prevention)[1] Provide incentives for youth to complete secondary schooling[2] Academic enrichment programmes[3] Vocational training[6] Mentoring programmes[4] Foster care programmes[6] Programmes to strengthen ties to family and jobs to reduce involvement in violent behaviour[6] Establish job creation for unemployed[6]	Create safe routes from school/recreational activities/work to home[6] Reduce media violence[6]	Extra-curricular programmes[6] Train health care workers to identify and refer youths at high risk for violence[6] Reduce the availability of alcohol[5] Deconcentrate poverty[6] Reduce income inequality[6] Public information campaigns[6] Strengthen and improve police and judicial systems[6] Establish job creation programmes[6] Establish youth and adult recreational programmes[6] Programmes to mitigate the effects of rapid social change[6]
Event	Self-defense training Promote seeking medical attention for milder injuries[8]	Increase police surveillance/vigilence[6] Facilitate reporting of violent activity to the authorities[7]	Increase police surveillance/vigilence[6] Facilitate transfer of patients to specialized care in difficult weather conditions	Encourage reporting of violent activity to the authorities[7] Sensitize the public to the effects of mild head injuries[8]
Post-event	Improve adherence to rehabilitation programs [8] Ensure proper psychological support of victims[7] Ensure proper community re-integration [8] Address substance abuse[6]	Rehabilitate offenders to prevent repeat offences Address substance abuse[6] Protection orders to prevent perpetrators from contacting victims[7]	Improve access to community rehabilitation services and facilities [8] Adapt working environments for the disabled Ensure the community has means to transport the disabled Provide shelters to victims of violence requiring refuge [7] Improve emergency response[6] Improve trauma care and access to health care[6]	Improve community re-integration[8] Public information campaigns[6] Encourage the public to report violent behaviour when information is obtained in a delayed fashion[7] Develop compensation programs for victims of criminal acts[7] Develop programmes to identify victims of interpersonal violence[7] Build partnerships with specialized neurotrauma centres that can provide outpatient support to

Figure 12: Haddon matrix for potential injury prevention strategies leading to TBI in Eeyou Istchee with motor and off-road vehicle collisions (ATVs and snowmobiles). The strategies identified with a superscript number from 1-2 have an associated reference indicating there is evidence for their effectiveness in preventing vehicle collisions. Superscript references: 1[74], 2[42, 70-73], 3[55]

Coefficient	Relative Risk Ratio	95% confidence interval
Intercept: Assault	0.08	0.07 - 0.09
Intercept :ATV	0.07	0.06-0.08
Intercept : Bicycle	0.25	0.23-0.27
Intercept :Motorcycle	0.04	0.03-0.05
Intercept :MVC	0.84	0.79-0.89
Intercept :Other	0.35	0.32-0.37
Intercept :Pedestrian	0.21	0.19-0.23
Intercept :Recreation	0.05	0.04-0.07
Intercept :Ski	0.01	0.00-0.01
age: Assault	0.98	0.97-0.98
age:ATV	0.97	0.97-0.98
age : Bicycle	0.97	0.97-0.97
age :Motorcycle	0.98	0.98-0.99
age :MVC	0.98	0.98-0.98
age :Other	0.97	0.97-0.98
age :Pedestrian	0.99	0.99-0.99
age :Recreation	0.98	0.97-0.98
age :Ski	0.98	0.97-0.98
regionqc10: Assault	1.47	0.69-3.11
regionqc10:ATV	4.11	2.28-7.38
regionqc10: Bicycle	0.93	0.44-1.97
regionqc10:Motorcycle	0	0.00-Infinity
regionqc10:MVC	1.18	0.75-1.84
regionqc10:Other	1.45	0.84-2.50
regionqc10:Pedestrian	0.62	0.22-1.71
regionqc10:Recreation	1.03	0.14-7.50
regionqc10:Ski	4.66	1.12-19.37
region17: Assault	11.77	8.4-16.48
region17:ATV	38.06	28.40-51.00
region17: Bicycle	0.75	0.38-1.51
region17:Motorcycle	4.23	2.28-7.87
region17:MVC	1.06	0.72-1.56
region17:Other	1.4	0.88-2.23
region17:Pedestrian	2.4	1.51-3.83
region17:Recreation	1.13	0.27-4.63
region17:Ski	32.77	18.59-57.78
region18: Assault	10.69	6.81-16.80
region18:ATV	6.06	3.38-10.87
region18: Bicycle	1	0.44-2.25
region18:Motorcycle	0	0-Infinity
region18:MVC	1.71	1.08-2.72
region18:Other	0.71	0.32-1.60
region18:Pedestrian	0.6	0.18-1.94
region18:Recreation	5.88	2.29-15.13
region18:Ski	34.2	16.97-68.94
Sexmale: Assault	3.95	3.47-4.49
Sexmale :ATV	3.09	2.69-3.56
Sexmale : Bicycle	2.18	1.99-2.39
Sexmale :Motorcycle	2.69	2.27-3.19
Sexmale :MVC	1.28	1.21-1.35
Sexmale :Other	1.86	1.72-2.00
Sexmale :Pedestrian	0.79	0.73-0.86
Sexmale :Recreation	0.57	0.46-0.71
Sexmale :Ski	3.12	2.14-4.54

Table 15: Output of multinomial regression model with falls as the reference mechanism of injury and all of Québec as the population reference category.

MED-ECHO RAMQ number (randomly generated to preserve anonymity):

Age:

Sex:

Community in Eeyou Istchee where TBI occurred:

Date of injury:

Date of hospitalization:

Hospitalization length of stay (days):

Hospital centres where patient was treated (in sequential order):

Mechanism of injury (MVC, snowmobile, assault, all-terrain vehicle, other):

Use of protection documented in any chart reviewed (Yes/No/NA):

Initial Glasgow Coma Score (as documented by first physician assessment at first health centre on trauma sheet):

Polytrauma (i.e.: was more than 1 organ system involved. Yes/No):

Documentation of alcohol use in any chart (Yes/No/NA)

Hospitalization length of stay (days):

Discharge orientation (home, rehabilitation (inpatient or outpatient), long-term care, deceased, other acute hospital centre):

Glasgow Outcome Score at 6 months (or closest assessment after 6 months) as assessed by rehabilitation physician or family physician in the community (NA if not assessed):

Comorbidity (CAD, diabetes, hypertension, psychiatric illness):

Figure 13: Sample data extraction sheet used during chart review