Urban–rural differences in pediatric traumatic head injuries: A prospective nationwide study

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Aims: To estimate differences in the incidence of recorded traumatic head injuries by gender, age, severity, and geographical area.

Methods: The study was prospective and nationwide. Data were collected from all hospitals, emergency units and healthcare centers in Iceland regarding all Icelandic children and adolescents 0–19 years old consecutively diagnosed with traumatic head injuries (N = 550) during a one-year period.

Results: Annual incidence of minimal, mild, moderate/severe, and fatal head injuries (ICD-9 850–854) was 6.41 per 1000, with 95% confidence interval (CI) 5.9, 7.0. Annual incidence of minimal head injuries (ICD-9 850) treated at emergency units was 4.65 (CI 4.2, 5.1) per 1000, mild head injuries admitted to hospital (ICD-9 850) was 1.50 (CI 1.3, 1.8) per 1000, and moderate/severe nonfatal injuries (ICD-9 851–854) was 0.21 (CI 0.1, 0.3) per 1000. Death rate was 0.05 (CI 0.0, 0.1) per 1000. Young children were at greater risk of sustaining minimal head injuries than older ones. Boys were at greater risk than girls were. In rural areas, incidence of recorded minimal head injuries was low.

Conclusions: Use of nationwide estimate of the incidence of pediatric head injury shows important differences between urban and rural areas as well as between different age groups.

Keywords: incidence, nationwide, pediatric, prospective, traumatic head injuries, urban-rural differences

Introduction

Traumatic brain injury is a major cause of death and disability in children and adolescents, more so among boys than girls (Kraus et al 1986; Rivara 1994; Arnarson and Halldorsson 1995; Emanuelson and Wendt 1997; Jennett 1998). Young children are at relatively high risk of minimal and mild traumatic head injuries (Rivara 1994; Jennett 1998; Lovasik et al 2001). An increase in the more severe and fatal traumatic brain injuries has been found in late adolescence (Kraus et al 1986; Rivara 1994; Kraus and McArthur 1996; Jennett 1998; Lovasik et al 2001).

Most children receive head injuries. Many slight injuries may never reach the attention of healthcare personnel. Fortunately, most recorded head injuries are minimal or mild with fast recovery and no apparent complications (Kraus and McArthur 1996). Nonetheless, every head injury may have the potential of leading to serious damage (Jennett 1998). Estimating the severity of traumatic head injuries in the acute phase is therefore critical. However, it can be problematic, especially in infants and young children, due to less marked clinical signs and different responses to trauma compared with older individuals (Bernardi et al 1993; Dietrich et al 1993; Quayle et al 1997; Greenes and Schutzman 1998; Savitsky and Votey 2000; Schutzman et al 2001). Pediatric head injuries, even those considered mild, irrespective of cause, may in some cases have debilitating long-term consequences (Jennett 1998). Sometimes the consequences of early brain injury do not fully manifest until adolescence or early

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adulthood (Brooke 1988; Eslinger et al 1992). The previously held assumption that young children recover better from brain injury than older children due to developmental plasticity has not been substantiated. To the contrary, early brain damage disrupts normal maturation and development, and neuronal plasticity may not always lead to optimal outcome (Chapman and McKinnon 2000). Due to unpredictable, hidden, and sometimes serious consequences, prevention of traumatic pediatric head injuries is imperative.

Epidemiological studies are an important step towards goal-directed organized injury prevention. Bearing in mind methodological considerations when comparing results (Rivara 1994; Kraus and McArthur 1996; Emanuelson and Wendt 1997; Jennett 1998), previous studies on the epidemiology of pediatric traumatic head injuries have indicated that each geographical area may have its special characteristics with regard to incidence, age and gender distribution, and severity of injury, important from a prophylactic point of view (Kraus et al 1986; Rivara 1994; Arnarson and Halldorsson 1995; Kraus and McArthur 1996; Emanuelson 1997; Jennett 1998; Lovasik et al 2001).

At the time of the present study, the Icelandic population numbered 262,202. The environment was diverse, with one major urban area, small towns, villages, and farmland.

Because of a social security system, Icelanders have had good access to comprehensive medical services with healthcare insurance for all, including the underprivileged. Standard of living is overall similar to the neighboring Scandinavian countries. However, working days are longer, for both men and women (Olafsson 1990).

Compared with the Scandinavian countries, Iceland has the highest incidence of childhood injuries and pediatric accident mortality rate (Stefansdottir and Mogensen 1997). The mortality rate is higher for rural than urban areas (Stefansdottir and Mogensen 1997). The reasons for the high incidence of childhood injuries are open to speculation. They may be related to less parental supervision, due to long working hours, certain values and views characteristic of the Icelandic population, emphasizing the need for independence and personal freedom, even at a young age, and underestimating environmental hazards (Stefansdottir and Mogensen 1997).

In spite of the high incidence of childhood injuries in Iceland, the annual incidence of hospitalizations due to pediatric head trauma in the Reykjavik area has been comparable with other countries (Arnarson and Halldorsson 1995). Falls have been the most common cause of traumatic head injuries among the youngest children, with an increase in traffic-related injuries with age (Arnarson and Halldorsson 1995).

In the present study, we had the opportunity to collect information for one year on all recorded cases of pediatric traumatic head injuries nationwide. A national sample has the advantage of being geographically representative. The study was prospective, which enhanced the control of data collection, classifications, and recordings. A search of the literature did not reveal any other prospective nationwide studies on the incidence of traumatic pediatric head injuries, with the same inclusion criteria, definitions, and methodology for comparison.

The aims of the study were to estimate the incidence of recorded head injuries by gender, age, severity, and geographical area. The uniqueness of the study is related to its prospective, nationwide scope, including all recorded traumatic head injuries of different severity in both urban and rural areas.

Material and methods

Patients

This study comprised all 550 children and adolescents 0–19 years old, consecutively recorded for head injury, ICD-9 850–854 (World Health Organization [WHO] 1977), at all hospitals, emergency units, and healthcare centers in Iceland during the period April 15 1992 to April 14 1993. The total population in the 0–19 year age range was 85,746. Table 1 shows the population at risk by gender, age, and geographical area.

Although by law, Icelandic adolescents receive most adult responsibilities at 18 years of age, we decided to have the upper age limit at 19 years instead of 17. The majority of Icelandic adolescents do not complete grammar school or trade school until age 20 and are living with their parents and are still reliant on their support during that time, not in the least when traumatic events occur.

Procedures

At the time of the study, the only neurosurgical unit and the only computed tomography (CT) scanners in Iceland were located in Reykjavik. Practically all patients in Iceland diagnosed with or suspected of moderate or severe brain injury (ICD-9 851–854) were brought there by ambulance, helicopter, airplane, or by sea. When the diagnosis and degree of severity was uncertain, expert advice was available by telephone and transport to Reykjavik encouraged.

By the end of the one-year period, all healthcare institutions outside the city of Reykjavik supplied available information from their computerized patient registry

Table 1 Number of Icelandic children and adolescent 0–19 years old in December 1992, by gender, age, and geographical area

	Boys				**Girls**				**Total (%)**
Age in years	**0–4**	**5–9**	**10–14**	**15–19**	**0–4**	**5–9**	**10–14**	**15–19**	
Reykjavik area[a]	6,639	5,559	6,022	5,775	6,377	5,545	5,799	5,611	47,327 (55%)
Rural areas[b]	5,052	4,792	5,177	4,868	4,682	4,440	4,779	4,629	38,419 (45%)
Total	11,691	10,351	11,199	10,643	11,059	9,985	10,578	10,240	85,746 (100%)

Notes: [a]Reykjavik area refers to the city of Reykjavik and the surrounding towns and suburbs from Hafnarfjordur in the south to Mosfellsbaer and Kjalarnes in the north. [b]Rural areas refer to other parts of Iceland, small towns, villages, and farmland.

regarding age, gender, diagnosis, and residence of head injury patients. In the city of Reykjavik, the primary author, through information provided by neurosurgeons, other hospital personnel, and written and computerized hospital records ascertained the information daily. Care was taken not to count twice patients who were transferred from one healthcare institution to another. Private practitioners or health clinics were not contacted, as they did not provide emergency medical services for patients with traumatic head injuries.

Data were collected from the Icelandic Death Register (Statistics Iceland 2001) on patients who received fatal traumatic brain injuries during the same period. Included were patients who died after being admitted to hospital and those who died at the scene or during transport to hospital.

Classifications

All patients were classified according to International Classification of Diseases 9 (ICD-9) (WHO 1977) diagnostic codes 850–854: ICD-9 850 denotes concussion; 851 cerebral laceration and contusion; 852 subarachnoid, subdural, and extradural hemorrhage following injury; 853 other and unspecified intracranial hemorrhage following injury; and 854 intracranial injury of unspecified nature.

Patients with more than one ICD-9 diagnosis were included if at least one of the diagnoses was in the 850–854 range. Patients with more than one 850–854 diagnosis were recorded according to the most serious one.

Physicians diagnosed concussion following traumatic head injury, based on clinical symptoms, such as loss of or reduced consciousness, confusion, dizziness, somnolence, nausea, or amnesia. ICD-9 851–853 diagnoses were made by neurosurgeons, based on cerebral CT findings.

According to Icelandic guidelines, concussed patients with Glasgow Coma Scale (GCS) (Teasdale and Jennett 1974) score 15, no loss of consciousness (LOC) and no signs of skull fracture or other complications, were not admitted to hospital, but discharged from emergency units with head injury instructions. Concussed patients with GCS scores lower than 15, LOC, amnesia, signs of skull fracture, or other complications were hospitalized. Referral to cerebral CT was based on neurosurgical consultation and expert opinion on injury severity and complications.

Concussions (ICD-9 850) treated at emergency units and subsequently discharged were classified as minimal head injuries. Concussions leading to hospitalization were classified as mild head injuries, and nonfatal ICD-9 851–854 diagnoses as moderate/severe injuries.

A distinction was made between patients living in the Reykjavik area, the only major urban area in Iceland, including the city of Reykjavik and the surrounding towns and suburbs (total population 0–19 years: 47,327), and patients living in the rural areas and small towns and villages in other parts of Iceland (total population 0–19 years: 38,419) (see Table 1). The largest town outside the Reykjavik area was Akureyri with total population of 0–19 years: 4,903.

Statistical analysis

A log-linear model with two-way interactions was used for statistical analysis of the data. Inspection of residuals supported the validity of the log-linear assumption and showed no alarming outliers.

Confidence intervals (CI) were calculated for all incidences in Tables 2–4. While total population numbers were high, incidence rates were extremely low. Therefore, confidence intervals were computed with the Wilson score procedure (Agresti and Coull 1998).

Ethics

The Icelandic Data Protection Commission, the Icelandic Medical Ethics Committee, and the medical directors concerned approved the protocol. Permission was obtained from Statistics Iceland regarding use of data from the Icelandic Death Register.

Results

Table 2 shows the annual incidence with calculated confidence intervals of minimal, mild, moderate/severe, and

Table 2 Incidence rates of traumatic head injuries (ICD-9 850–854) per 1000 with 95% confidence intervals by gender, age and severity of injury. Number of injured patients (N = 550) and the total population at risk (N = 85,746) by gender and age. Number and percentage of patients in each injury severity category

	Boys				**Girls**				**Overall**	**Number**
Age in years	**0–4**	**5–9**	**10–14**	**15–19**	**0–4**	**5–9**	**10–14**	**15–19**	**Incidence**	**Injured (%)**
Severity of injury										
Minimal	9.32	3.86	4.20	2.54	6.96	4.11	3.5	2.05	4.65	399 (72.5%)
95% CI[a]	7.7, 11.2	2.8, 5.3	3.2, 5.6	1.7, 3.7	5.6, 8.7	3.0, 5.6	2.5, 4.8	1.3, 3.1	4.2, 5.1	
Mild	1.71	1.93	1.79	1.41	1.36	1.40	1.04	1.37	1.50	129 (23.5%)
95% CI	1.1, 2.6	1.3, 3.0	1.2, 2.8	0.9, 2.3	0.8, 2.2	0.8, 2.4	0.6, 1.9	0.8, 2.3	1.3, 1.8	
Moderate/Severe		0.19	0.36	0.38	0.45	0.20		0.10	0.21	18 (3.3%)
95% CI	0.0, 0.3	0.1, 0.7	0.1, 0.9	0.2, 1.0	0.2, 1.1	0.1, 0.7	0.0, 0.4	0.0, 0.6	0.1, 0.3	
Fatal	0.09		0.09	0.19					0.05	4 (0.7%)
95% CI	0.0, 0.5	0.0, 0.4	0.0, 0.5	0.1, 0.7	0.0, 0.4	0.0, 0.4	0.1, 0.4	0.0, 0.4	0.0, 0.1	
Total	11.12	5.99	6.43	4.51	8.77	5.71	4.54	3.52	6.41	550 (100.0%)
95% CI	9.4, 13.2	4.7, 7.7	5.1, 8.1	3.4, 6.0	7.2, 10.7	4.4, 7.4	3.4, 6.0	2.5, 4.9	5.9, 7.0	
Number injured	130	62	72	48	97	57	48	36	550	
Total population	11,691	10,351	11,199	10,643	11,059	9,985	10,578	10,240	85,746	

Note: [a]Confidence intervals (CI) were calculated with the Wilson score procedure (Agresti and Coull 1998).

fatal traumatic head injury by gender and age. The total annual incidence of head injuries was 6.4 (CI 5.9, 7.0) per 1000 population.

Boys (7.1 per 1000) were more likely to sustain head injury than girls (5.7 per 1000) ($\chi^2 = 9.987$, df = 1, p = 0.002).

There was an interaction between age and severity ($\chi^2 = 24.920$, df = 9, p = 0.003), mainly due to a relatively high incidence of minimal head injuries among the youngest children. The oldest age group was least likely to suffer head injury. This was not statistically significant.

There was a decrease in incidence with increased severity of injuries. Moderate/severe and fatal brain injuries were 4% of all head injuries.

Table 3 provides information on the incidence of traumatic head injuries in the city of Reykjavik and the surrounding urban area compared with the more rural areas of Iceland.

The results show an interaction between place of residence and severity ($\chi^2 = 37.799$, df = 3, p = 0.000). Considering the confidence intervals, there was clear evidence of a significant difference between minimal head injuries in the Reykjavik area and in rural areas. This was not so for mild, moderate/severe, or fatal injuries (Table 3).

In rural areas, age-related differences were less marked than in the Reykjavik area, although not statistically significant. Clinically this rural–urban difference was most striking in the youngest age group and related to minimal head injuries (Tables 3 and 4).

There was no significant two-way interaction. In particular, there was no evidence of different severity by gender.

No three-way interactions of age, gender, severity, and residence were significant.

In the Reykjavik area, 49% of the head injured patients were admitted during the six winter months, October to March. This ratio was 41% in rural areas.

Discussion

In this one-year nationwide sample in the 0–19 years age range, the total incidence of traumatic head injuries was 6.4 (CI 5.9, 7.0) per 1000 population. The national incidence of mild, moderate/severe, and fatal head injuries was 1.8 (CI 1.5, 2.1) per 1000 population. This compared well with the average annual incidence in the Reykjavik area 1987–1991, and in neighboring countries, while the incidence of minimal head injury, 4.7 (CI 4.2, 5.1) per 1000 was considerably lower (Arnarson and Halldorsson 1995).

The incidence of traumatic head injuries was lower in rural (3.7, CI 3.1, 4.3 per 1000) than urban (8.6, CI 7.9, 9.5 per 1000) areas, predominantly due to relatively few recorded minimal head injuries. The incidence of minimal head injuries was 1.9 (CI 1.5, 2.4) per 1000 in rural areas, but 6.9 (CI 6.2, 7.7) in the Reykjavik area. As age differences were less marked outside the Reykjavik area, young head injured children may have been less likely to be brought to medical attention than were older children.

Table 3 Incidence rates of traumatic head injuries (ICD-9 850–854) per 1000 with 95% confidence intervals[a] within parentheses, by severity of injury and residence. Number and percentage of injured patients by injury severity category in each of the two geographical areas (N = 550), and the total population at risk (N = 85,746)

Severity of injury	Reykjavik area Incidence	Reykjavik area Number Injured (%)	Rural areas Incidence	Rural areas Number Injured (%)
Minimal	6.87 (6.2, 7.7)	325 (79.5)	1.93 (1.5, 2.4)	74 (52.5)
Mild	1.52 (1.2, 1.9)	72 (17.6)	1.48 (1.1, 1.9)	57 (40.4)
Moderate/Severe	0.23 (0.1, 0.4)	11 (2.7)	0.18 (0.1, 0.4)	7 (5.0)
Fatal	0.021 (0.0, 0.1)	1 (0.2)	0.080 (0.0, 0.2)	3 (2.1)
Total	8.64 (7.9, 9.5)	409 (100.0)	3.67 (3.1, 4.3)	141 (100.0)
Population		47,327		38,419

Note: [a]Confidence intervals were calculated with the Wilson score procedure (Agresti and Coull 1998).

A low incidence of minimal pediatric head injuries in rural areas was not anticipated. Studies have shown higher rates of the more severe head trauma and fatal injuries in rural compared with urban areas (Vane and Shackford 1995; Triebel et al 1998; Zietlow and Swanson 1999; Reid et al 2001; Eberhardt and Pamuk 2004). As the incidence of mild, moderate/severe, and fatal brain injuries was comparable to the Reykjavik area, it may be inferred that children and adolescents in rural areas with "minimal" head injuries were less likely to be brought to the attention of medical personnel and receive diagnosis and treatment. The reasons for this may be related to cultural, parental, socio-economic status, and seasonal factors, as well as accessibility to healthcare services.

Evidence emphasizes alertness in the case of traumatic pediatric head injuries. Head trauma that seems to be minimal or mild in the acute phase can lead to intracranial injury and long-term consequences (Tulipan 1998; Schutzman and Greenes 2001). These injuries can be difficult to detect in the acute phase, especially in young children and infants, calling for careful observation of clinical signs, and in selected cases radiographic imaging (Greenes and Schutzman 1998; Schutzman et al 2001). Delayed identification of intracranial injuries can lead to secondary injuries due to intracranial hemorrhage, cerebral swelling and elevated intracranial pressure, causing progressive irreversible brain damage, permanent disability, and death (Dietrich et al 1993; Savitsky and Votey 2000). Due to the increased likelihood of delayed emergency services in rural areas (Olafsson and Sigurdsson 2000), medical evaluation is even more urgent than in urban areas.

In the present study, we have no evidence suggesting that a low incidence of recorded minimal head injuries in rural areas led to increased morbidity or mortality. Nonetheless, the findings presented have implications for public healthcare services. In rural areas, there may be increased need for providing information on dangers related to primary and secondary brain injuries and to emphasize preventive strategies. People should be made aware of clinical symptoms, signs of deterioration, and the effects of repeated minimal or mild head injuries. Caregivers should be encouraged

Table 4 Incidence rates of traumatic head injuries (ICD-9 850–854) per 1000 with 95% confidence intervals, by residence, gender, and age. Number and percentage of injured patients by gender and age in each of the two geographical areas (N = 550)

Age in years	Boys 0–4	Boys 5–9	Boys 10–14	Boys 15–19	Girls 0–4	Girls 5–9	Girls 10–14	Girls 15–19	Overall
Reykjavik area									
Incidence	16.27	8.63	8.64	4.50	11.45	6.85	6.04	5.17	8.64
95% CI[a]	13.5, 19.6	6.5, 11.4	6.6, 11.3	3.1, 6.6	9.1, 14.4	5.0, 9.4	4.4, 8.4	3.6, 7.4	7.9, 9.5
Number injured	108 (26.4%)	48 (11.7%)	52 (12.7%)	26 (6.4%)	73 (17.8%)	38 (9.3%)	35 (8.6%)	29 (7.1%)	409 (100.0%)
Rural areas									
Incidence	4.35	2.92	3.86	4.52	5.13	4.28	2.72	1.51	3.67
95% CI	2.9, 6.6	1.7, 4.9	2.5, 6.0	3.0, 6.8	3.5, 7.6	2.7, 6.7	1.6, 4.7	0.7, 3.1	3.1, 4.3
Number injured	22 (15.6%)	14 (9.9%)	20 (14.2%)	22 (15.6%)	24 (17.0%)	19 (13.5%)	13 (9.2%)	7 (5.0%)	141 (100.0%)

Note: [a]Confidence intervals (CI) were calculated with the Wilson score procedure (Agresti and Coull 1998).

to seek medical evaluation regarding acute pediatric head injuries and ensure easy and fast access to services. Because of the possibly long-term consequences of head injuries, healthcare personnel should keep records of medical advice provided via telephone regarding such instances.

There was an increased risk for minimal traumatic head injury in the 0–4 year age range. The reasons for this may be cultural, lack of parental supervision (Stefansdottir and Mogensen 1997), and related to physical characteristics of young children (Brudvik 2000). For mild, moderate/severe, and fatal head injuries, young age was not a specific risk factor, and there was not a marked increase in incidence in the oldest age group, which has been found in the USA (Kraus et al 1986; Rivara 1994; Kraus and McArthur 1996; Lovasik et al 2001). Increased parental supervision, safety awareness and safer environment for infants and young children should be encouraged.

Boys were at greater risk than girls were of sustaining traumatic head injuries. This is a common finding in similar studies, in both Iceland and elsewhere (Kraus et al 1986; Rivara 1994; Arnarson and Halldorsson 1995; Emanuelson and Wendt 1997; Jennett 1998), and may reflect a behavioral pattern and increased exposure to environmental hazards related to the male gender (Rivara 1994). Preventive measures should be adapted to the behavioral characteristics of the two genders.

The data presented show the value of using a nationwide estimate of the incidence of pediatric head injury, to highlight important differences between urban and rural areas as well as between different age groups. These differences, important for public health planning, may be missed in studies relying solely on local samples.

Limitations and future directions

In the present study, information on the causes of traumatic head injuries was not available for the total group of patients. This was also the case for more detailed information on injury severity.

The study took place prior to a formal introduction and implementation of the Head Injury Severity Scale (HISS) (Stein and Spettell 1995) and the Scandinavian Guidelines for the Initial Management of Head Injuries (Ingebrigtsen et al 2000). In the present study, the criteria for hospital admissions following concussion are identical to those suggested by HISS and the Scandinavian guidelines, but due to lack of detailed information related to injury severity for the total group corresponding criteria for mild and moderate head injuries could not be adopted.

In recent years, there has been increased awareness in Iceland regarding the importance of injury prevention and safety measures. In 1999, legislation was passed requiring children under 15 years of age to wear helmets when riding bicycles. In spite of this, there are indications that the annual incidence of moderate, severe, and fatal traumatic brain injuries has been stable in the Reykjavik area from 1990 until 2006.

The design of the present study, including a nationwide sample of all recorded instances of pediatric traumatic head injuries of different severity during a one-year period, provides the opportunity to study the long-term consequences of such injuries.

Conclusion

Care should be taken when estimating nationwide traumatic head injury incidences from local samples. Urban/rural differences are to be expected.

There may be urban/rural differences regarding the discrepancy between actual and recorded traumatic head injury incidences.

The findings of the present study have implications for public health policy and practice in rural areas, where increased awareness regarding "minimal" pediatric traumatic head injuries should be encouraged.

Preventive effort should consider geographical location, age, gender, and cultural and socio-economic factors.

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