Epidemiology of electrical and lightning-related injuries among Canadian children and youth, 1997-2010: A Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) study

Madeleine Böhrer, BSc*; Samuel A. Stewart, PhD†; Katrina F. Hurley, MD, MHI‡¶

ABSTRACT

Introduction: Although death due to electrical injury and lightning are rare in children, these injuries are often preventable. Twenty years ago, most injuries occurred at home, precipitated by oral contact with electrical cords, contact with wall sockets and faulty electrical equipment. We sought to assess the epidemiology of electrical injuries in children presenting to Emergency Departments (EDs) that participate in the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP).

Methods: This study is a retrospective review of electrical and lightning injury data from CHIRPP. The study population included children and youth aged 0-19 presenting to participating CHIRPP EDs from 1997-2010. Age, sex, year, setting, circumstance and disposition were extracted. Variables were tested using Fisher's exact test and simple linear regression.

Results: The dataset included 1183 electrical injuries, with 84 (7%) resulting in hospitalization. Most events occurred at home in the 2-5 year age group and affected the hands. Since 1997 there has been a gradual decrease in the number of electrical injuries per year ($p < 0.01$) and there is an annual surge in electrical injuries over the summer ($p < 0.01$). Forty-six percent of injuries involved electrical outlets, 65% of injuries involved some sort of electrical equipment. Injuries due to lightning were rare (n = 19). No deaths were recorded in the database.

Conclusion: Despite the decrease in the number of electrical injuries per year, a large portion of injuries still appear to be preventable. Further research should focus on effective injury prevention strategies.

RÉSUMÉ

Introduction: Bien que les accidents mortels causés par le courant électrique ou par la foudre soient rares chez les enfants, ce type de blessures est souvent évitable. Il y a une vingtaine d'années, la plupart des accidents survenaient à la maison, causés par le contact de la bouche avec des fils électriques ou par un contact avec des prises de courant murales ou encore par du matériel électrique défectueux. L'étude visait à évaluer l'épidémiologie des cas d'électrisation chez les enfants traités dans des services des urgences (SU) participant au Système canadien hospitalier d'information et de recherche en prévention des traumatismes (SCHIRPT).

Méthode: Il s'agit d'un examen rétrospectif de données provenant du SCHIRPT sur les blessures causées par le courant électrique ou par la foudre chez des enfants et des jeunes âgés de 0 à 19 ans, traités dans un SU participant au SCHIRPT, et ce, de 1997 à 2010. Il y a eu extraction de données sur l'âge, le sexe, l'année, le milieu, les circonstances et les suites à donner. Les variables ont été vérifiées à l'aide du test exact de Fisher et d'une analyse de régression simple.

Résultats: L'ensemble des données comptait 1183 cas d'électrisation, dont 84 (7 %) ont nécessité l'hospitalisation. La plupart des accidents sont survenus à la maison chez les jeunes âgés de 2 à 5 ans, et ils touchaient surtout les mains. Le nombre annuel de blessures causées par le courant électrique décroît progressivement depuis 1997 ($p < 0{,}01$), mais il connaît une recrudescence durant l'été ($p < 0{,}01$). Dans l'ensemble, 46 % des accidents étaient attribuables à des prises électriques et 65 %, à un type quelconque d'appareil électrique. Quant aux blessures causées par la foudre, elles étaient rares (n = 19). La base de données ne comptait aucun décès.

Conclusion: Malgré une diminution du nombre annuel de cas d'électrisation, une bonne partie des accidents semble encore évitable. Il faudrait pousser davantage la recherche sur des stratégies efficaces de prévention des blessures.

Keywords: electrical injury, pediatric, injury prevention, lightning, CHIRPP

From *Dalhousie Medical School, †Medical Informatics, Faculty of Medicine, and the ‡Department of Emergency Medicine, Dalhousie University, Halifax, NS; and the ¶IWK Health Centre Emergency Department, Halifax, NS.

Correspondence to: Dr. Katrina Hurley, Department of Emergency Medicine, the IWK Health Centre, 5850/5980 University Avenue, PO Box 9700, Halifax, NS B3K 6R8; Email: kfhurley@dal.ca

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INTRODUCTION

The morbidity and mortality from electrical injury for the pediatric population in Canada were last reported for the years 1991-1996 by Nguyen and colleagues.[1] Although death and injury due to electrical injuries are rarely reported in this population, most injuries took place in the home[2-4] and were precipitated by oral contact with electrical cords and contact with wall sockets and faulty electrical equipment.[4,5] Low-voltage injuries were most common in the 0-9 year age group, and high-voltage injuries were more commonly seen in adolescents.[4,6] Many of these patients were admitted for observation,[4] and those who required prolonged admission were more likely to have high-voltage injuries, requiring excision, grafting, and amputation.[6] Glatstein et al. reported data from a large pediatric tertiary care centre in Canada and found a higher admission rate for patients with burns resulting from an electrical injury, as compared with the admission rate for burns in general (13% v. 3%-9%, respectively), suggesting a higher rate of vigilance is necessitated for electrical injuries because of concerns about complications.[7]

The purpose of this study was to describe electrical injury trends using data from the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) from 1997 to 2010.

METHODS

Data on all emergency department (ED) visits for children aged 0-19 years related to an electrical injury for the years 1997-2015 were requested from CHIRPP. Because of incomplete or missing data after 2010, the dataset was truncated to ensure appropriate comparisons from year to year. CHIRPP is an injury and poisoning surveillance system that collects and analyzes injuries to people who are seen in the EDs of 11 pediatric hospitals and six general hospitals in Canada. Patients' accounts of pre-event injury circumstances are collected using a questionnaire that is completed during their visit to the ED.[8] An attending physician or other staff adds clinical data to the form, and data coders abstract data from the patients' narratives.[8] The data were de-identified and collected anonymously.

Electrical injury cases were extracted by the data and research manager of the Injury Section, Health Surveillance and Epidemiology Division, Centre for Chronic Disease Prevention and Control in Ottawa. Any records in which any of the three "Nature of Injury Variables" were coded as "electrical injury" were extracted. Additional records with the following keywords, but not containing the "Nature of Injury" variable "electrical injury," were also extracted: plug, socket, outlet, shock, electric (and its variations), current, volt, and spark. Variables extracted for comparison included age, sex, year of injury, setting, injury circumstance, and disposition. Admission to the hospital was used as a surrogate measure of injury severity based on a previous study using this approach.[1] The total number of encounters per year for all injuries, by age group, was also extracted from the CHIRPP database to provide denominators for estimating electrical injury rates.

The patient narratives for each case in the dataset were hand searched by a separate duplicate reviewer to find any cases that did not appear to have an electrical injury (i.e., cases erroneously included). We also searched for the source of current, voltage (low voltage $\leq$1000 volts v. high voltage $\geq$1000 volts), indications of death before or after arrival to the hospital, and details surrounding the circumstances and intentions of the injuries.

Simple summaries of the database variables are shown as frequencies for categorical variables and means with standard deviations for continuous variables. Variables were tested against admission rates using Fisher's exact test, and changes in rates over time were tested using simple linear regression for annual changes and chi-square tests for seasonal effects. Statistics calculated for fewer than five cases are not reported. All analyses were performed using R version 3.2.2.

RESULTS

Based on a hand-search of the patient narrative, we excluded two non-electrical injury cases from the dataset that were erroneously included. Table 1 summarizes the data and compares patient variables with admission rates. Overall, there were 1183 electrical injuries over 13 years of data, with 84 resulting in admission to hospital (7%, 95% CI 6%-9%). Males (n = 685) experienced slightly more electrical injuries than females (n = 498), and events were most likely to take place in the home (n = 864), though events that occurred outside the home were more likely to result in admission ($p < 0.01$). The majority of events affected the

Table 1. Age, context of electrical injury, and affected body area by admission status

Variable	Levels	All	Not admitted	Admitted	*p*-value
Sex					0.57
	Female	498	460 (92%)	38 (8%)	
	Male	685	639 (93%)	46 (7%)	
Age					0.36
	<12 months	71	67 (94%)	4 (6%)	
	12-23 months	180	172 (96%)	8 (4%)	
	2-5 years	427	399 (93%)	28 (7%)	
	5-10 years	218	202 (93%)	16 (7%)	
	10-15 years	181	163 (90%)	18 (10%)	
	15+ years	106	96 (91%)	10 (9%)	
Location					<0.01
	Home	864	818 (95%)	46 (5%)	
	Other	158	139 (88%)	19 (12%)	
Context					0.35
	Work	29	27 (93%)	2 (7%)	
	Sports /Playing	539	511 (95%)	28 (5%)	
	Household	68	65 (96%)	3 (4%)	
	Personal	12	11 (92%)	1 (8%)	
	Activity	228	207 (91%)	21 (9%)	
Primary body part					<0.01
	Head	86	72 (84%)	14 (16%)	
	Spine	1	1 (100%)	0 (0%)	
	Body	14	13 (93%)	1 (7%)	
	Arm	49	44 (90%)	5 (10%)	
	Hand	697	664 (95%)	33 (5%)	
	Leg	26	22 (85%)	4 (15%)	
	Multiple/Systemic	299	272 (91%)	27 (9%)	

hands, and systemic injuries were also common. Head injuries, leg injuries, and systemic injuries were more likely to lead to hospital admission than other injuries ($p < 0.01$).

Injuries due to lightning strikes were rare (n = 19) and mostly because of indirect contact with lightning (n = 15), e.g., lightning hitting the house while touching a doorframe.

Excluding indirect lightning strikes, a total of 14 high-voltage injuries (≥1000 volts) were identified. All but one event took place outside the home. Males (n = 11) experienced the majority of high-voltage injuries, and most patients were admitted to the hospital (n = 9). The high-voltage patients had an average age of 10.2 years (SD 4.8), compared to 6.1 years (SD 5.1) for non-high voltage patients, a statistically significant difference ($p < 0.01$).

Figures 1a and 1b present the electrical injury rates over time, both annually and seasonally, respectively. There has been a decrease in the number of electrical injuries per year ($p < 0.01$), both in terms of raw counts and relative to the number of injuries reported in the CHIRPP database. There was also a surge in electrical injuries during the summer months, as analyzed using a linear regression model that controlled for annual effects ($p < 0.01$).

Table 2 presents a summary of the recorded causes of injury, including overall cases and by admission status. The cause of injury is characterized as a category. A patient can have multiple causes of injury (for example, both "Electrical equipment" and "Lights and Lamps" can be a cause of injury if a child plugged in a lamp and received a shock). Table 2 lists whether a cause was indicated in a record, so the entries in the table are not mutually exclusive. Forty-six percent of injuries involved electrical outlets, but 65% of injuries involved some sort of electrical equipment. There was no pattern of admission associated with cause, and the sample sizes were too small to test any effect reliably.

The most common objects inserted into electrical outlets and receptacles included keys (n = 167), hair clips and hairpins (n = 56), fingers (n = 44), and paperclips (n = 20).

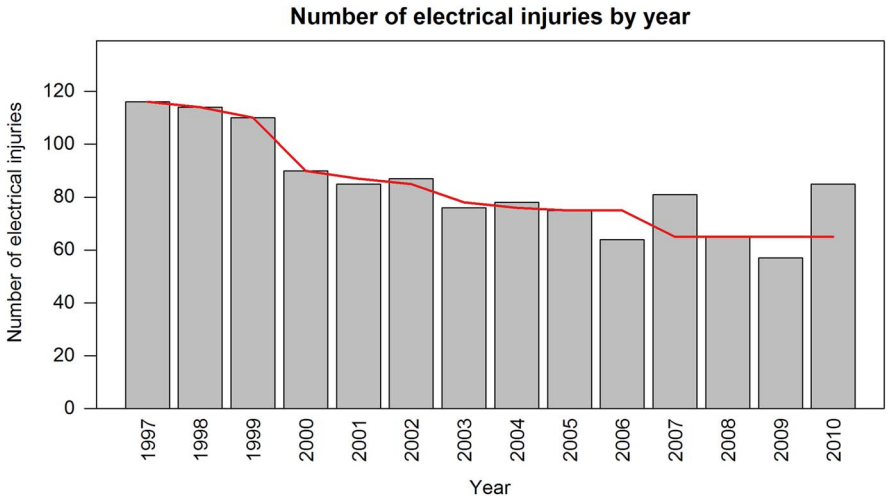

Figure 1a. Annual number of electrical injuries per 100,000 ER visits, 1997-2010.

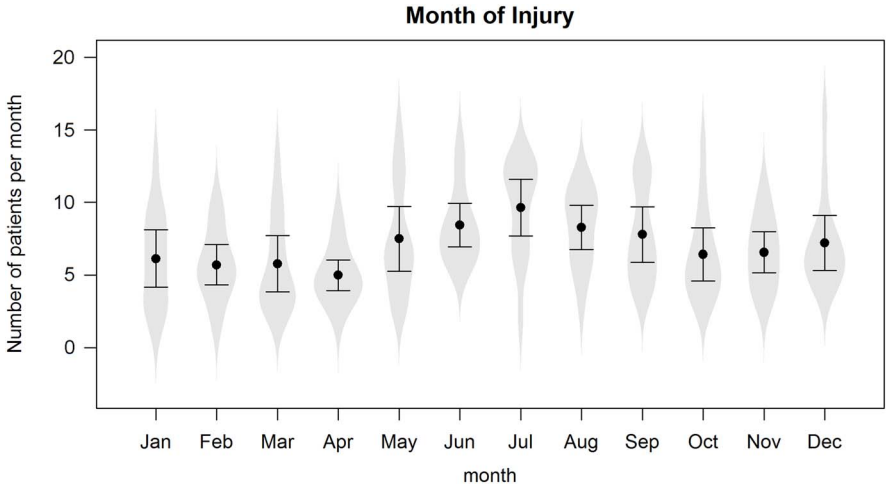

Figure 1b. Total number of electrical injuries per month, 1997-2010.

Table 2. Causes of injury by category for n ≥ 25

	n (%)	Not admitted (%)	Admitted (%)
Electrical equipment	769 (65)	726 (94)	43 (6)
Lights and lamps	78 (6.6)	71 (91)	7 (9)
Audio or visual equipment and accessories	71 (6.0)	68 (96)	3 (4)
Hair products and accessories	68 (5.7)	65 (96)	3 (4)
Office/lab/school equipment and supplies	26 (2.2)	26 (100)	0 (0)
Environmental elements	25 (2.1)	21 (84)	4 (16)

Only two of the 1183 cases were because of intentional self-harm (suicide attempt); one electrical injury was a result of mistreatment by a parent/caregiver, and another resulted from interaction with law enforcement (tasered by police). No prehospital or ED deaths were recorded in the database; for one case, the disposition was recorded as a cardiac arrest resulting from electrical injury with direct admission to the intensive care unit (ICU).

DISCUSSION

We have updated the incidence, causes, and outcomes of electrical and lightning-related injuries in children and youth who presented to Canadian EDs that participate in CHIRPP.

As previously reported by Nguyen and colleagues, the majority of injuries in our study occurred in the patient's home (73% compared with 77% found by

Nguyen et al.) and most commonly involved electrical outlets or receptacles (46% v. 42%, respectively).[1] Lightning strike injuries were rare and mostly because of an indirect electrical injury. The predominance of low-voltage injury occurring in the home is consistent with the results of other studies.[2,4,6,7] Our findings are in contrast to American and Turkish studies that reported higher rates of injury from contact with live electrical cords.[2,5,6,9] Cord biting appears to be more common in the United States; however, these studies were performed more than 20 years ago, thus limiting a direct comparison.[5,9] The types of foreign objects placed in wall sockets are similar to our findings, including keys, pins, fingers, and paperclips.[5]

The male to female ratio for overall electrical injuries was much higher in previous studies with males accounting for up to 83% of electrical injuries.[1,2,6,7] However, the high-voltage injuries identified in this study indicate male-dominated injury patterns as described previously.[2,6,9] Similar to the findings in this study, Rabban et al. found an equal sex distribution in low-voltage injuries but a higher percentage of males sustained high-voltage injuries.[9] The severity of injuries in our study appears to be low based on hospital admission (7%), which was less than that reported by Nguyen et al. (13%) and other reported admission rates.[1,4,7] Surges in electrical injuries during the summer months have also been previously reported.[1,10]

A recent Cochrane review found that safety interventions delivered at home by health or social care professionals were effective in increasing the proportion of families with socket covers on unused outlets.[18] Interventions providing free, low cost, or discounted safety equipment such as socket covers appeared to be more effective in improving safety practices.[18] There is evidence that multifaceted parenting interventions provided to families at risk in the home during the first 2 years of a child's life are effective in reducing self-reported or medically attended injury among young children, along with improving home safety.[19] We were not able to stratify our data by socioeconomic status, but this may be an important factor to consider in injury prevention. Previous risk factors identified for childhood injury and death include the socioeconomic status of the parents and younger parental age.[20] Home safety hazards are strongly correlated with low income, a lower education level, and unemployment.[21]

Overall, the annual number of electrical injuries in children and youth presenting to Canadian EDs participating in CHIRPP has decreased. With most electrical injuries still occurring at home, often involving the insertion of objects into electrical outlets, future injury prevention strategies should target these areas.

LIMITATIONS

Our study has several limitations worth noting. The first is its use of retrospectively coded data with the unavailability of complete data after 2010. Data extraction was performed by a single data extractor and reviewed by a separate reviewer to ensure that included cases were appropriate. We were unable to review whether cases not included in the dataset were erroneously excluded. Therefore, it is possible that some cases were missed. CHIRPP has been validated in terms of its data quality and is thought to be useful for developing injury prevention programs; however, its representation of general youth injury patterns in Canada is controversial.[11-15] As the majority of CHIRPP data comes from hospitals in cities, injuries involving some populations are underrepresented, namely older teenagers, First Nation and Inuit people, and other people who live in rural and remote areas. Fatal injuries are also underrepresented because EDs do not capture data on people who died before they could be taken to the hospital.[16] No deaths were captured in our dataset; therefore, we are unable to comment on the epidemiology of electrical deaths, including lightning, in children presenting to Canadian EDs that participate in CHIRPP. The database does not code for high- or low-voltage injuries, so we had to extract this information from patient narratives. Injuries were also missed if patients refused to complete the data collection forms.[13] Others have indicated that patients with injuries who presented overnight were more likely to be missed.[15] The degree to which CHIRPP captures severely injured children is controversial.[15,17]

CONCLUSION

While injuries caused by electricity are relatively rare in the pediatric population, their consequences may be severe. Research and educational measures should continue to focus on primary prevention.

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REFERENCES

1. Nguyen BH, MacKay M, Bailey B, Klassen TP. Epidemiology of electrical and lightning related deaths and injuries among Canadian children and youth. *Inj Prev* 2004;10(2):122-4.
2. Arasli Yilmaz A, Köksal AO, Özdemir O, et al. Evaluation of children presenting to the emergency room after electrical injury. *Turk J Med Sci* 2015;45(2):325-8.
3. Byard RW, Hanson KA, Gilbert JD, et al. Death due to electrocution in childhood and early adolescence. *J Paediatr Child Health* 2003;39(1):46-8.
4. Garcia CT, Smith GA, Cohen DM, Fernandez K. Electrical injuries in a pediatric emergency department. *Ann Emerg Med* 1995;26(5):604-8.
5. Baker MD, Chiaviello C. Household electrical injuries in children. Epidemiology and identification of avoidable hazards. *Am J D Child* 1989;143(1):59-62.
6. Çelik A, Ergün O, Özok G. Pediatric electrical injuries: a review of 38 consecutive patients. *J Pediatr Surg* 2004; 39(8):1233-7.
7. Glatstein MM, Ayalon I, Miller E, Scolnik D. Pediatric electrical burn injuries: experience of a large tertiary care hospital and a review of electrical injury. *Pediatr Emerg Care* 2013;29(6):737-40.
8. Crain J, McFaull S, Thompson W, et al. Status report - The Canadian Hospitals Injury Reporting and Prevention Program: a dynamic and innovative injury surveillance system. *Health Promot Chronic Dis Prev Can* 2016;36(6):112-7.
9. Rabban JT, Blair JA, Rosen CL, Adler JN, Sheridan RL. Mechanisms of pediatric electrical injury. New implications for product safety and injury prevention. *Arch Pediatr Adolesc Med* 1997;151(7):696-700.
10. Dokov WV. Epidemiology of fatal electrical injuries in children and adolescents. *Acta Paediatr* 2009;98(4):756-7.
11. Pickett W, Brison RJ, Mackenzie SG, et al. Youth injury data in the Canadian Hospitals Injury Reporting and Prevention Program: do they represent the Canadian experience? *Inj Prev* 2000;6(1):9-15.
12. Kang J, Hagel B, Emery CA, Senger T, Meeuwisse W. Assessing the representativeness of Canadian Hospitals Injury Reporting and Prevention Programme (CHIRPP) sport and recreational injury data in Calgary, Canada. *Int J Inj Contr Saf Promot* 2013;20(1):19-26.
13. Mackenzie SG, Pless IB. CHIRPP: Canada's principal injury surveillance program. Canadian Hospitals Injury Reporting and Prevention Program. *Inj Prev* 1999;5(3): 208-13.
14. Herbert M, Mackenzie SG. Injury surveillance in paediatric hospitals: the Canadian experience. *Paediatr Child Health* 2004;9(5):306-8.
15. Macarthur C, Pless IB. Evaluation of the quality of an injury surveillance system. *Am J Epidemiol* 1999;149(6):586-92.
16. Canadian Hospitals Injury Reporting and Prevention Program; 2016. Available at: http://www.phac-aspc.gc.ca/injury-bles/chirpp/index-eng.php (accessed September 14, 2016).
17. Macarthur C, Pless IB. Sensitivity and representativeness of a childhood injury surveillance system. *Inj Prev* 1999; 5(3):214-6.
18. Kendrick D, Young B, Mason-Jones AJ, et al. Home safety education and provision of safety equipment for injury prevention. *Cochrane Database Syst Rev* 2012;9: CD005014.
19. Kendrick D, Mulvaney CA, Ye L, et al. Parenting interventions for the prevention of unintentional injuries in childhood. *Cochrane Database Syst Rev* 2013;3:CD006020.
20. Hong J, Lee B, Ha EH, Park H. Parental socioeconomic status and unintentional injury deaths in early childhood: consideration of injury mechanisms, age at death, and gender. *Accid Anal Prev* 2010;42(1):313-9.
21. Turner JV, Spallek M, Najman JM, et al. Socio-economic distribution of environmental risk factors for childhood injury. *Aust N Z J Public Health* 2006;30(6):514-8.