

Injuries Experienced by Infant Children: A Population-Based Epidemiological Analysis

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ABSTRACT. *Objective.* Injuries to infant children are an important health concern, yet there are few population-based analyses from which to develop prevention initiatives. This study describes the external causes, natures, and disposition from an emergency department of infants with injuries for a geographically distinct population in Eastern Ontario.

Methods. Epidemiologic analysis of emergency-based surveillance data (1994–2000) for infants (<12 months old) from the Kingston sites of the Canadian Hospitals Injury Reporting and Prevention Program.

Results. A total of 990 cases of injury to infants were identified, of which 217 (21.9%) required significant medical intervention. Leading causes of injury were falls (605/990; 61.1%), ingestion injuries (65/990; 6.6%), and burns (56/990; 5.7%). Common types of falls experienced were: from furniture (229/605; 37.9%), being dropped (92/605; 15.2%), in car seats (73/605; 12.1%), down stairs (63/605; 10.4%), or in a child walker (42/605; 6.9%). The observed patterns of injury changed according to the ages of the children. Vignettes are used to illustrate recurrent injury patterns (falls, physical vulnerability, burns and ingestions, equipment injuries).

Conclusion. The results indicate the relative importance of several external causes of injury and how these vary by age group. This population-based information is also useful in establishing rational priorities for prevention, and the targeting of interventions toward responsible authorities. *Pediatrics* 2003;111:e365–e370. URL: <http://www.pediatrics.org/cgi/content/full/111/4/e365>; *infant, injury, trauma, case series, emergency department, prevention.*

ABBREVIATIONS. CHIRPP, Canadian Hospitals Injury Reporting and Prevention Program; PY, person year; CI, confidence interval.

Injury is an important cause of death and morbidity during childhood,¹ yet there are few focused studies of injury in infant children. In Canada, an estimated 965 children were killed and 40 675 hospitalized due to unintentional injuries during 1997.² Forty-one deaths and 1 693 trauma-related hospitalizations occurred to infants under 12 months old.²

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Deaths and hospitalizations represent only a small fraction of the injury control problem. In our region of Canada, for every death that is observed in our full population there are ~19 hospitalizations and 300 presentations to an emergency department and an unknown (but presumably larger) number of medically treated injuries.^{3–5}

Infants are unique in that they are under the immediate care of an adult and most injuries can be prevented by the undivided attention of a responsible caregiver. Most infant injuries happen in the home and this has been attributed to lapses in attention, the presence of household hazards, and enhanced mobility of older infants as they develop.^{6–8} In terms of external causes, accidental falls have been documented as the leading type of infant injury.^{6,9–12} Common natures of infant injury include lacerations, burns, poisonings, choking, and other soft tissue injuries.⁷ Head injuries are a particular concern because infant skulls are malleable and susceptible to fracture and intracranial injury.¹⁰ Ongoing observation of infant head injuries with regular computerized tomography scans is now being advocated by some, even for asymptomatic injuries.^{13–14}

There are few epidemiologic studies of injuries within the infant age group, and none that describe these experiences on a population basis. The present analysis attempts to fill this void. Our research setting in Kingston, Ontario is a site of the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP).¹⁵ CHIRPP is an ongoing national emergency department-based, injury surveillance program. We used this system and opportunity to conduct one of the first population-based studies of infant injuries in North America. Our objectives were to describe the external causes, natures, and disposition from the emergency department of these injuries, and to identify common patterns in their occurrence over a 7-year time period. This provides fundamental data from an extremely large and population-based case series that informs the development of focused injury prevention efforts for the very young.

METHODS

CHIRPP is an ongoing computerized injury surveillance program that operates in the emergency departments of selected Canadian hospitals.¹⁵ The dataset is maintained by the Child Injury Division of the Bureau of Reproductive and Child Health, Health Canada. CHIRPP began operation in 10 Canadian pediatric hospitals in 1990, and has since been expanded to include 6 general hospitals. Information on the circumstances leading to

each injury is provided by the patient or an accompanying adult who completes a 1-page self-administered CHIRPP questionnaire. Clinical information is provided by the attending physician or is abstracted from the patient's medical chart by a research nurse.

Kingston is a Canadian city in Eastern Ontario with a population of ~120 000 that lives in the city proper and surrounding rural areas. It is home to 2 universities and a major health sciences complex. The Kingston General and Hotel Dieu hospitals have the only 2 emergency departments in Kingston. Since 1993, injury data from these hospitals have been collected and entered into the national CHIRPP database. The Kingston site is unique in the CHIRPP surveillance program because of its complete community coverage (all injuries requiring emergency care for its entire population are captured; this does not occur at other CHIRPP centers). The catchment area for the 2 Kingston hospitals has long been assumed to include residents of the city of Kingston, as well as Frontenac, Lennox, and Addington counties. Kingston General Hospital is also a regional trauma center.

Intensive efforts are made to obtain records for all injuries seen in the Kingston CHIRPP hospitals. To facilitate this process, at registration in the emergency department patients or their guardians are asked, "are you here due to an injury?" A CHIRPP surveillance form is generated automatically when an affirmative response is provided. The patient log for all emergency department visits is also reviewed to ensure that injury cases were not missed at registration. There are sometimes extenuating circumstances when the patient is unable to complete the form at registration (eg, severe trauma, eye injury). These CHIRPP forms are completed by research staff based on direct interviews with patients or review of the medical record. Clinical information is available for 100% of injury cases based on information from the medical record. Descriptions of the circumstances surrounding injury are provided by the patient or guardian 80% to 85% of the time, and the remaining descriptions are abstracted from the medical chart, as available. Revisits for the same injury event generally represent small proportions (<1%) of cases and are not excluded from this analysis. Based on occasional audits of internal patient records, the Kingston site has identified virtually 100% of all presenting injuries (K. Bowes, Kingston CHIRPP nurse coordinator, personal communication, 2002).

Records of all injuries occurring to children <12 months old (up to 1 day short of a year) during the calendar years 1994 through 2000 were abstracted from the Kingston CHIRPP dataset. Available descriptors included: patient demographics (age in months, sex), nature of injury, and treatment received. The CHIRPP classifications of cause of injury ("breakdown event", mechanism of injury, and context) are generic for all age groups, and were rather noninformative for the infants. Written descriptions of the circumstances surrounding each injury event are also compiled as part of the data collection process. These text descriptions were used to develop a new classification system to describe common circumstances leading to infant injuries.

Analysis

Overall and sex-specific rates of injury were calculated per 1000 person-years (PY), with population figures for the infant age group being obtained from the 1996 Canada Census of Population. The hospital catchment area is approximated by the census population of the City of Kingston, and Frontenac, Lennox, and Addington counties.¹⁶ Associated 95% confidence intervals (CIs) were

calculated using the normal approximation of the binomial.¹⁷ The injury records were then divided into 4 age groups (0–2 months old, 3–5 months old, 6–8 months old, 9–11 months old) meant to correspond with different levels of child development and mobility. Descriptive statistics (frequencies and cross-tabulations) were used to characterize injuries within age groups by nature, circumstance, and disposition. Common circumstances of injury were then illustrated qualitatively via the use of short vignettes. Age-related injury patterns were compared with published norms for child growth and development.¹⁸ All data management was conducted in Excel 97 (Microsoft, Richmond, WA, 1997) and statistical analyses were performed in SPSS (SPSS Inc, Chicago, IL).

RESULTS

A total of 990 injury records met the inclusion criteria, an average of 141 per year, or 76.1 (95% CI: 71.5–80.7) per 1000 PY. The annual rate estimated for male infants (79.9 per 1000 PY; 95% CI: 73.4–86.4) was slightly higher than that estimated among females (72.1 per 1000 PY; 95% CI: 65.7–78.5).

Common natures of these injuries are described in Table 1. There was variation between age groups in terms of the most frequent causes, although head (242/990; 24.4%) and superficial (232/990; 23.4%) injuries predominated. Compared with the younger age groups, open wounds (81/399; 20.3%), burns (36/399; 9.0%), and poisoning (14/399; 3.5%) were most common among 9-month-old to 11-month-old children.

Falls accounted for the majority (605/990; 61.1%) of infant injuries reported (Table 2). Where identified, the most common mechanisms of falls were from furniture, falls from car seats, falls down stairs with or without an infant walker, and those caused by being dropped by an older person. Falls by being dropped occurred most frequently among infants 0 months old to 2 months old (25/121; 20.7%), whereas falls from furniture frequently occurred among infants 3 months old to 11 months old (214/869; 24.6%). Other leading causes of injury in the youngest infants were motor vehicle crashes and being struck by a falling object. Among the slightly older age groups, other leading circumstances included ingestions and contact with hot objects or substances. Common hot objects/substances that led to burns included hot liquids (25/56; 44.6%) and hot objects (22/56; 39.3%).

The injuries were further divided into those with "major" (admission, transfer, or medical treatment and follow-up required) and "minor" (left without being seen, advice only, follow-up only if required)

TABLE 1. Infant Injuries by Nature of Injury and Age, 1994–2000

Nature of Injury	Age Group								Total	
	0–2 Months		3–5 Months		6–8 Months		9–11 Months			
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Head injury	27	22.3	50	30.1	85	28.0	80	20.1	242	24.4
Superficial	24	19.8	42	25.3	80	26.3	86	21.6	232	23.4
Open wound	7	5.8	13	7.8	30	9.9	81	20.3	131	13.2
Fracture/dislocation	17	14.0	21	12.7	33	10.9	36	9.0	107	10.8
Burn	4	3.3	2	1.2	15	4.9	36	9.0	57	5.8
Poisoning	4	3.3	0	.0	4	1.3	14	3.5	22	2.2
Other/unspecified	38	31.4	38	22.9	57	18.8	66	16.5	199	20.1
Total	121	100.0	166	100.0	304	100.0	399	100.0	990	100.0

TABLE 2. Infant Injuries by Circumstance and Age, 1994-2000

Circumstance	Age group								Total	
	0-2 Months		3-5 Months		6-8 Months		9-11 Months			
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
All falls	64	52.9	122	73.5	194	63.8	225	56.4	605	61.1
Falls from furniture	15	12.4	56	33.7	87	28.6	71	17.8	229	23.1
General falls	3	2.5	5	3.0	22	7.2	76	19.0	106	10.7
Falls by being dropped	25	20.7	21	12.7	23	7.6	23	5.8	92	9.3
Falls in car seats	16	13.2	36	21.7	17	5.6	4	1.0	73	7.4
Falls on stairs	5	4.1	2	1.2	20	6.6	36	9.0	63	6.4
Falls in a walker	0	.0	2	1.2	25	8.2	15	3.8	42	4.2
Ingested substance	5	4.1	2	1.2	16	5.3	42	10.5	65	6.6
Hot object or substance	4	3.3	2	1.2	15	4.9	35	8.8	56	5.7
Falling object	9	7.4	8	4.8	13	4.3	17	4.3	47	4.7
Motor vehicle accident	9	7.4	10	6.0	11	3.6	9	2.3	39	3.9
Sharp object	3	2.5	1	.6	9	3.0	13	3.3	26	2.6
Pulled arm	3	2.5	8	4.8	10	3.3	4	1.0	25	2.5
Pinched in door	0	.0	0	.0	6	2.0	14	3.5	20	2.0
Animal involved	4	3.3	0	.0	3	1.0	12	3.0	19	1.9
Other/unspecified	20	16.5	13	7.8	27	8.9	28	7.0	88	8.9
Total	121	100.0	166	100.0	304	100.0	399	100.0	990	100.0

injuries (Table 3). Forty-two infants (4.2%) were hospitalized and there were no identified fatalities. Admissions were mainly for the medical care of fractures (23/42; 54.8%), head injuries (8/42; 19/0%), and burns (4/42; 9.5%).

Table 4 describes the natures of injuries cross-tabulated against the circumstances leading to injury. Falls most commonly resulted in head injuries (219/605; 36.2%) and superficial injuries (159/605; 26.3%), although fractures/dislocations (74/605; 12.2%) were also common medical sequelae. There were 24 skull fractures reported of which 23/24 (95.8%) were caused by falls.

DISCUSSION

Although childhood injuries occur frequently and their epidemiology has been described,^{1,7-8} studies that focus on the very young are uncommon. Infant injuries are unique in that someone older is always providing direct care to the child and hence is a responsible authority associated with the injury event. Focused analyses can lead to the development and targeting of interventions toward these persons.

Historically, Gusstafsson¹⁹ developed a causative model for the occurrence of childhood injuries that involved consideration of the environment, a genetic predisposition to "accidents" (which has been dis-

puted), supervision issues, and education of the child. This model is useful in that it considers the complex etiology that surrounds these injuries. Many infant injuries occur, in retrospect, because a responsible authority has failed to anticipate the presence of an immediate hazard or they have experienced even a short lapse in attention. This anticipation is also influenced by underlying etiologies, for example, time and other parental stresses that impact on the supervision provided. All of these behavioral risk factors are very difficult to modify in practice.

What is simple about the occurrence of infant injuries is that they all involve an unplanned contact between a physical or other force and an unprotected child. Most often they occur in the home.⁶⁻⁷ Given that it is more difficult to modify circumstances and adult behaviors, prevention efforts should be focused on environmental modification. In general, the results suggest that most infant injuries could be prevented by placing limits on infant mobility through the use of passive safety devices, and similarly limiting contact between physical hazards and children via other forms of environmental vigilance.

Illustrative Vignettes

A number of more specific patterns and associated prevention concepts arose during our analysis. Some

TABLE 3. Infant Injuries by Disposition/treatment and Age, 1994-2000

Disposition	Age Group								Total	
	0-2 Months		3-5 Months		6-8 Months		9-11 Months			
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Left without being seen	1	.8	2	1.2	2	.7	5	1.3	10	1.0
Advice	40	33.1	56	33.7	72	23.7	63	15.8	231	23.3
Follow-up if necessary*	47	38.8	79	47.6	187	61.5	219	54.9	532	53.7
Follow-up required†	16	13.2	17	10.2	29	9.5	91	22.8	153	15.5
Observation in emergency department	5	4.1	0	.0	2	0.7	3	.8	10	1.0
Admission to this hospital	12	9.9	6	3.6	8	2.6	16	4.0	42	4.2
Transferred to another hospital	0	.0	6	3.6	4	1.3	2	.5	12	1.2
Total	121	100.0	166	100.0	304	100.0	399	100.0	990	100.0

* Further care/treatment is advised, as needed.

† Further care/treatment is medically required.

TABLE 4. Infant Injuries by Circumstance and Nature of Injury, 1994-2000

Circumstance	Nature of Injury (n, column %)														Total n
	Head Injury		Superficial		Open Wound		Fracture/ Dislocation		Burn		Poisoning		Other/ Unspecified		
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	
All falls	219	90.5	159	68.5	71	54.2	74	69.2	0	.0	0	.0	82	41.2	605
Falls from furniture	95	39.3	55	23.7	21	16.0	25	23.4	0	.0	0	.0	33	16.6	229
General falls	17	7.0	33	14.2	39	29.8	11	10.3	0	.0	0	.0	6	3.0	106
Falls by being dropped	31	12.8	26	11.2	0	.0	19	17.8	0	.0	0	.0	16	8.0	92
Falls in car seats	29	12.0	17	7.3	6	4.6	11	10.3	0	.0	0	.0	10	5.0	73
Falls on stairs	26	10.7	13	5.6	4	3.1	6	5.6	0	.0	0	.0	14	7.0	63
Falls in a walker	21	8.7	15	6.5	1	.8	2	1.9	0	.0	0	.0	3	1.5	42
Ingested substance	0	.0	2	.9	5	3.8	0	.0	1	1.8	21	95.5	36	18.1	65
Hot object or substance	0	.0	0	.0	0	.0	0	.0	56	98.2	0	.0	0	.0	56
Falling object	9	3.7	15	6.5	10	7.6	2	1.9	0	.0	0	.0	11	5.5	47
Motor vehicle accident	3	1.2	6	2.6	1	.8	1	.9	0	.0	0	.0	28	14.1	39
Sharp object	0	.0	3	1.3	23	17.6	0	.0	0	.0	0	.0	0	.0	26
Pulled arm	0	.0	3	1.3	0	.0	18	16.8	0	.0	0	.0	4	2.0	25
Pinched in door	0	.0	12	5.2	4	3.1	1	.9	0	.0	0	.0	3	1.5	20
Animal involved	0	.0	1	.4	2	1.5	1	.9	0	.0	0	.0	15	7.5	19
Other/unspecified	11	4.5	31	13.4	15	11.5	10	9.3	0	.0	1	4.5	20	10.1	88
Total	242	100.0	232	100.0	131	100.0	107	100.0	57	100.0	22	100.0	199	100.0	990

of these issues can be illustrated through the use of short vignettes.

Pattern 1—Falls. A young parent is changing a 7-month-old infant's diaper at a change table. It has been a long day, and she is tired and preoccupied with a number of family matters. She turns away from the child to deposit the diaper in the garbage container. The infant reaches, rolls, and falls 1 meter onto the floor, banging her head during the process. She rushes her to emergency where the child is observed for several hours and released with instructions to return if his symptoms worsen.

Consistent with other studies,^{6,9-11} the majority of infant injuries observed in Kingston were due to falls. Major external causes included falls from furniture (tables, desks, change tables, other infant equipment), from poorly placed or unbalanced car seats, from stairs including walkers falling down stairs, and by being dropped by another person. The above incident is typical because: 1) the parent did not anticipate the infant rolling off so quickly; 2) there was a short lapse in attention; 3) there was no change table strap or other passive barrier in place to prevent the fall; and 4) the infant was treated for a minor head injury in emergency and released.

Pattern 2—Physical Vulnerability. A 9-month-old boy toddles about the house. He appears to be gaining confidence every day as his walking and climbing improves. One evening his parents are getting ready to go out. The babysitter arrives. During this time, the infant manages to pull himself up on a kitchen stool. The stool topples over, striking the child on his forehead.

Injuries caused by falling objects and motor vehicle crashes were also important injury mechanisms, particularly among the very young. Although these represent divergent types of injury, what is common between them is that they illustrate the principle of vulnerability. There is nothing that the child can do to protect him/herself; the onus is on the responsible adult to minimize risks within the child's environment. This above incident is typical because: 1) the parents did not anticipate that the infant's growing

abilities would put him at risk; and 2) the child is vulnerable to even minor physical forces caused by (in this case) a falling object.

Pattern 3—Burns and Ingestions. A 10-month-old infant was crawling around the kitchen as her father was preparing breakfast. Unobserved, the infant makes her way to a pot of hot coffee sitting near the edge of the table. Curious, she reaches for the coffee pot, spills the contents on her arm, and suffers a minor burn over the trunk.

Burns and ingestion injuries were also common. Many of these occurred when a child had hot liquid spilled over them, they were allowed to come into contact with a hot physical object, or they reached for and ingested something that was in their area. Older infants seemed to be particularly at risk due to their higher level of mobility. This above vignette is typical because: 1) the parent has a short lapse in attention while taking care of a highly mobile and curious child; and 2) previously inaccessible hot objects are now within the reach of the child.

Pattern 4—Equipment Hazards. A caregiver sets an infant secured in a car seat on the freezer top as she enters the house and frees her hands of grocery bags and car keys. The infant manages somehow to tip the car seat off the freezer, falling a few feet to the floor.

Poorly designed equipment and/or its inappropriate placement may put children at risk for falls and other forms of trauma. These types of injury poignantly illustrate the role that parents and caregivers have for the safety of children, and the importance of judgment and vigilance during supervision.^{7,9} Despite warnings and educational efforts, a well-known type of injury in this category continues to be infant-walker injuries caused by falls down stairs.²⁰ However, the results suggest that there are analogous patterns of injury that are less well known, such as injuries that occur due to careless placement of restraining equipment. There is an ongoing need for innovation in the design of car and other infant carriers/seats so that they are functional and stable. From the perspective of stability, poorly designed

equipment places the infant at undue risk. The above incident is typical because: 1) the infant is strapped into a car seat that appears to be safe and immobile; 2) there is a brief lapse in attention; and 3) (like infant walker injuries) the equipment itself is subject to a fall or other injury hazard.

Head Injury

Head injury is a common form of trauma among children <4 years old,^{10,21-24} and this was reflected in our case series. Over 90% of the head injuries observed were treated with advice and observation, or discharged with a recommendation for follow-up care if required. In some clinical settings, asymptomatic intracranial injuries are common^{13,23} and routine radiologic evaluation^{13,23} and/or computerized tomography^{13-14,24} have been recommended. The obvious worry is the delayed development of subdural hematomas and other intracranial injuries even among patients who are awake and alert. There is a need for the development of highly sensitive clinical decision rules for these situations.

Strengths and Limitations

Our population-based infant case series represents 1 of the largest of its kind for a geographically distinct population. Our ability to focus exclusively on children of a very narrow age range is helpful.

The data are limited to emergency department encounters, which may or may not be representative of injury patterns presenting to other primary care settings. Emergency department visits represent only a fraction of the infant injuries that require and/or receive medical attention. In Kingston and area, it is not possible to determine the number of infants treated in physicians' offices and outpatient clinics, or infants that did not seek medical care. A study of youth comparing all medically attended injuries from a national survey and emergency department visits for the Kingston CHIRPP site found virtually identical external causes of injury in both data sources.²⁵ Although this analysis has not been performed for infants, if this trend holds it can be inferred that injury patterns occurring among patients presenting to an emergency department for medical care are representative of those in other primary care settings.

Other limitations include the fact that descriptions of injury circumstances are based on self-reports collected as part of an established injury surveillance system. The Kingston CHIRPP site registers injuries experienced by patients (of all ages) who present to 2 general hospital emergency departments for medical care. This system was not developed exclusively for the study of infant injuries, and its main purpose is to monitor and describe patterns of injury within our community. Furthermore, although standard approaches to the triage and initial management of these injuries are in place in the emergency departments, individual physicians vary in their approach to the assessment, diagnosis, and treatment of some injuries. Therefore, caution is warranted in the interpretation of some diagnostic figures (eg, those that require radiologic evidence), as these may have been

based on variable amounts of diagnostic information ordered and available to these physicians.

The injury rates presented in this study are from 1 of the only injury surveillance systems in Canada that is purported to be population-based. Limitations of these injury rates warrant recognition. First, injuries treated in other primary care settings are not included. This limitation is ameliorated somewhat by the fact that it is standard practice for most family physicians to refer acute injury events for emergency department care, and the hospitals are the only sources for basic radiology services in our community. Second, revisits for treatment of the same injury were included here (3 cases) and the injuries are not all incident in the purest sense. Third, some patients from outside the hospital catchment area were also included (13% of cases) and this is further confounded by the designation of Kingston General as a regional trauma hospital that will accept nonresident trauma cases. Although not tested empirically, it was assumed that the number of nonresident infants treated in Kingston was roughly equivalent to the number of resident infants seeking care outside of the catchment area. We believe this to be a population-based injury surveillance system despite these recognized limitations, and on balance the rates provide one means for describing the magnitude of the problem in our population.

Finally, it was not possible to reliably identify cases of abuse or neglect directly from these data. It is often difficult to distinguish intentional from unintentional injuries in the emergency department based on self-reports from caregivers, and in cases where intention is unclear this will be documented with caution by attending medical staff. Abuse may be suspected but only confirmed cases (while in attendance of the emergency department) are entered as such in CHIRPP. In Canada, cases of infant abuse are not typically confirmed without an investigation that extends beyond the emergency department encounter.

CONCLUSION

Injury control science acknowledges the importance of various approaches to injury prevention, and in the past these have been summarized as the "3 E's": Education, Engineering/Environmental modification, and Enforced regulation of legislated safety standards.¹ Although these are important and applicable, some additional principles that are analogous to the "3 E's" emerged from our infant case series. In spirit of past injury control thinking, we have decided to call these the "3 A's" for infant injury control: Anticipate, Act, and be Accountable. All of these injuries documented in this case series were preventable if the possibility of injury had been anticipated by an accountable caregiver, and this person had acted to prevent the injury. Parents and others who care for infants are entirely responsible for prevention. The patterns of injury reported in this study are recurrent and should form the basis for evidence-based injury control efforts.

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