Evaluation of the Quality of an Injury Surveillance System

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The sensitivity, positive predictive value, and representativeness of the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) were assessed. Sensitivity was estimated at four centers in June through August 1992, by matching independently identified injuries with those in the CHIRPP database. The positive predictive value was determined by reviewing all "injuries" in the database (at Montreal Children's Hospital) that could not be matched. Representativeness was assessed by comparing missed with captured injuries (at Montreal Children's Hospital) on demographic, social, and clinical factors. Sensitivity ranged from 30% to 91%, and the positive predictive value was 99.9% (i.e., the frequency of false-positive capture was negligible). The representativeness study compared 277 missed injuries with 2,746 captured injuries. The groups were similar on age, sex, socioeconomic status, delay before presentation, month, and day of presentation. Injuries resulting in admissions, poisonings, and those presenting overnight were, however, more likely to be missed. The adjusted odds ratio of being missed by CHIRPP for admitted injuries (compared with those treated and released) was 13.07 (95% confidence interval 7.82–21.82); for poisonings (compared with all other injuries), it was 9.91 (95% confidence interval 5.39–18.20); and for injuries presenting overnight (compared with those presenting during the day or evening), it was 4.11 (95% confidence interval 3.11–5.44). These injuries were probably missed because of inadequate education of participants in the system. The authors conclude that CHIRPP data are of relatively high quality and may be used, with caution, for research and public health policy. Am J Epidemiol 1999;149:586–92.

child; evaluation studies; injuries; population surveillance

After the first year of life, injury is the leading cause of death and disability among children and adolescents (1). Fatal injuries, however, represent only the tip of the iceberg; a population-based survey showed that for every childhood injury death there were 45 hospital admissions and 1,300 emergency department visits (2). In addition to the health care burden associated with childhood injury are the economic costs and social consequences of suffering, family disruption, and lost productivity (3, 4).

Surveillance—defined as the systematic collection, analysis, interpretation, dissemination, and application of health data to a public health problem (5)—is seen as a necessary and important step in injury prevention and control (6–10). Such data may be used to quantify the magnitude of the injury problem, identify populations at risk, determine etiologic factors, guide program priorities, and evaluate injury control programs (11). Surveillance is expensive in terms of both personnel and cost; therefore, regular evaluation of the usefulness, cost, and quality of the data provided by any surveillance system is essential (12). Guidelines and explicit criteria for the evaluation of these systems have been developed (13, 14). Specifically, in the assessment of data quality, seven system attributes have been identified. Three of these—simplicity, flexibility, and acceptability—relate to the structure and ease of operation of the system and are qualitative in nature. The key quantitative attributes in the assessment of data quality include sensitivity, positive predictive value, representativeness, and timeliness of capture. Sensitivity is the proportion of all health events of interest that are captured by the surveillance system. Positive predictive value is the proportion of persons identified as "cases" who truly have the health event of interest (the aim of this attribute is to quantify "false-positive" capture). Under the assumption that surveillance system capture is rarely complete, the rep-
representativeness of surveillance data relates to the systematic errors (if any) in capture, that is, whether the captured health events represent a random or a biased sampling of the surveillance population of interest. Direct assessment of sensitivity, specificity, and representativeness usually involves comparing surveillance data with that collected from special studies that independently estimate the incidence and characteristics of the adverse health event being monitored. Last, timeliness represents the interval between occurrence of the health event and subsequent availability of surveillance information for disease control.

The Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) is an emergency department-based injury surveillance system administered by the Bureau of Chronic Disease Epidemiology within the federal government (15). Surveillance was inaugurated in 1990, with initial participation by all 10 children's hospitals across Canada. A standardized data collection form, completed by the parent and the attending physician, is used to gather demographic, injury sequence, and clinical information. Completed forms are sent to Ottawa for coding and entry into a national database. The goal of CHIRPP is to contribute to a reduction in pediatric injury incidence and severity in Canada through the collection of high-quality surveillance data (16). The aim of this research was to evaluate the quality of CHIRPP data through quantification of system sensitivity, positive predictive value, and representativeness. Specifically, the objective of the studies was to estimate the magnitude and direction of systematic errors (if any) in the capture of injury events by CHIRPP.

MATERIALS AND METHODS

Estimation of sensitivity and positive predictive value

For the purpose of these studies, the surveillance population of interest was acutely injured children attending children's hospitals. The objective of the sensitivity studies was to determine the frequency of capture by CHIRPP of eligible injuries. Sensitivity was estimated at four of the 10 participating centers: The Montreal Children's Hospital, L'hopital Sainte Justine, The Children's Hospital of Eastern Ontario, and The Children's Hospital of Western Ontario. These hospitals represented a sample of convenience (chosen because of accessibility), and the study was conducted over 3 months (June through August 1992).

At each hospital, injuries eligible for capture by CHIRPP were identified by reviewing both the emergency department registration logs (computerized files that contained demographic and clinical data) and the medical charts. These independently identified injuries were then matched with the CHIRPP database at each center. For three of the hospitals (Montreal Children's Hospital, L'hopital Sainte Justine, and The Children's Hospital of Western Ontario), this review occurred daily for the duration of the study. At The Children's Hospital of Eastern Ontario, because of the travel involved, simple random sampling (using a random numbers table) was used to select 30 days for review.

The numerator for CHIRPP sensitivity was the number of eligible injuries captured by the system, while the denominator was the total number of injured children attending the hospital. Sensitivity was estimated by center along with 95 percent confidence intervals.

The positive predictive value of CHIRPP data was estimated at Montreal Children's Hospital only. The frequency of false-positive capture was determined by reviewing (in detail) all "injuries" in the CHIRPP database that could not be matched with any of the injuries identified by the independent review.

Estimation of representativeness

The representativeness of CHIRPP data was determined at Montreal Children's Hospital. Factors associated with being missed by CHIRPP were identified by comparing eligible injuries missed by CHIRPP with those injuries captured by the system. Demographic, social, and clinical data were collected on both missed and captured groups of injuries by using the medical record as the primary data source. Demographic predictor variables included the child's age, sex, and socioeconomic status. Socioeconomic status was crudely estimated by linking the home address postal code (available from the medical record) with Statistics Canada census data. Each postal code was linked to its census tract of origin by using the Statistics Canada Postal Code Conversion File and the appropriate software (17). Census data were then used to estimate the percentage of families in that census tract with incomes below the Statistics Canada poverty level. Estimation of socioeconomic status was not possible if the postal code on the chart linked to a business, institution, or post office box rather than to a residential address.

Clinical data on the delay between injury occurrence and emergency department presentation, the nature of the injury, and patient disposition were also collected on both groups. Nature of injury was coded using the 26 categories on the CHIRPP data collection form. The patient disposition categories—treated and released or admitted to the hospital—were used as proxy estimates of increasing injury severity. Last, under the assumption that month, day, time of presentation, and daily emergency department patient volume might influence...
the operating characteristics of CHIRPP, data on these factors were also collected. The data were first assessed by examining the univariate relation between each of the predictor variables and being missed by CHIRPP (yes/no). For the categorical predictors, odds ratios and test-based 95 percent confidence intervals were also calculated (18). Multivariate logistic regression modeling was used to determine the relative importance of the predictor variables, with all factors given the opportunity of entering the model regardless of the univariate results. A stepwise method of model building was used, with entry and exit criteria of 0.10 and 0.15, respectively (19). Last, the Pearson chi-square statistic was used to estimate the goodness-of-fit of the main effects model (20).

Sample size calculation was based on the following criteria: alpha error of 0.05, power of 0.80, a prevalence of the predictor among captured injuries of 0.05, and the ability of the study to detect a twofold increased risk of being missed by CHIRPP. A pilot study showed that the ratio of captured:missed injuries was approximately 10:1. Therefore, on the basis of these criteria, 216 missed injuries and 2,157 captured injuries were required (21). Given a frequency of around 50 injuries each day presenting to the emergency department at Montreal Children's Hospital, missed and captured injuries were accrued over 2 consecutive months (July and August 1992).

RESULTS

The sensitivity of capture of childhood injuries by CHIRPP at each of the four centers is shown in table 1. Across the centers, sensitivity ranged from 30 to 91 percent, with the lowest frequency of capture at The Children's Hospital of Eastern Ontario. At Montreal Children's Hospital, 18,205 children presented to the emergency department over the summer months, 4,782 (26 percent) of whom attended because of an acute injury. Of the 13,423 noninjuries presenting to Montreal Children's Hospital, only three children were inappropriately entered into the CHIRPP database—a 9-year-old with an inflamed plantar wart, a 12-year-old with Osgood-Schlatter's disease, and a 3-year-old with abdominal pain secondary to a urinary tract infection. This extremely low frequency of false-positive capture resulted in a positive predictive value for CHIRPP data at Montreal Children's Hospital that was close to perfect (99.9 percent).

Over the 2-month period of the representativeness study, 3,023 children presented to the emergency department at Montreal Children's Hospital because of injury. Of these children, only 277 (9 percent) were missed by the surveillance system. These 277 missed injuries were compared with the 2,746 captured injuries.

The two groups of injuries were similar with respect to age, sex, socioeconomic status, and delay before presentation. The median age (interquartile range) of those with missed injuries was 7.6 years (ages 3–13 years) compared with 6.9 years (ages 3–12 years) for those with captured injuries (p = 0.23). Injured children were predominantly male, approximately 60 percent in both groups (p = 0.72). Census tract data showed a similar socioeconomic status level for missed and captured injuries, with the median percentage (interquartile range) of families with low income estimated at 24 percent (13–45 percent) for missed injuries and 23 percent (12–44 percent) for captured injuries (p = 0.61). Socioeconomic status could not be estimated for approximately 13 percent of subjects because the postal code was either missing from the medical chart or could not be linked to a residential address. The frequency of missing or unlinked postal codes was similar for both groups, however. The median delay (interquartile range) before emergency department attendance was similar for the two groups, at 2.0 hours (1–5 hours) for missed injuries and 1.8 hours (1–6 hours) for captured injuries (p = 0.97).

The frequency of injury capture by CHIRPP was similar by month (90 vs. 92 percent) and day of the week (range, 90–92 percent). Daily patient volume, defined as all presentations to the emergency department including injury, did not appear to influence

<table>
<thead>
<tr>
<th>Hospital</th>
<th>No. of Injuries</th>
<th>Sensitivity</th>
</tr>
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<tbody>
<tr>
<td>Montreal Children's Hospital</td>
<td>4,782</td>
<td>90</td>
</tr>
<tr>
<td>L'Hopital Sainte Justine</td>
<td>3,375</td>
<td>91</td>
</tr>
<tr>
<td>The Children's Hospital of Eastern Ontario</td>
<td>1,552</td>
<td>30</td>
</tr>
<tr>
<td>The Children's Hospital of Western Ontario</td>
<td>2,507</td>
<td>71</td>
</tr>
</tbody>
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TABLE 1. Sensitivity of capture of childhood injuries by the Canadian Hospitals Injury Reporting and Prevention Program at four centers, June through August 1992

95% confidence interval
Analysis by nature of injury showed that four types of injury were associated with an increased risk of being missed by CHIRPP (poisoning, asphyxiation, concussion, and hemorrhage), whereas lacerations/abrasions were associated with a decreased risk of being missed (table 2). Injured children admitted to the hospital were also more likely to be missed compared with injured children treated and released from the emergency department (54 vs. 8 percent, respectively, \( p < 0.01 \)).

An important issue was whether the nature of injury and admission to hospital were correlated. To determine whether these predictors represented independent risk factors, the frequency of being missed, along with the frequency of being admitted, were estimated by the nature of injury. A consistent pattern was hypothesized if the two predictors were dependent; that is, an increased (or decreased) frequency of being missed would be associated with an increased (or decreased) frequency of being admitted. As shown in table 2, this pattern occurred for all injuries except poisoning. In other words, three injury types associated with an elevated risk of being missed— asphyxiation, concussion, and hemorrhage—were all associated with an increased risk of being admitted. Conversely, the decreased risk of being missed for laceration/abrasion injuries was associated with a decreased risk of admission for such injuries. Poisoning injuries, however, although associated with a significantly increased risk of being missed, were not associated with an increased (or decreased) risk of being admitted. For poisoning injuries, therefore, it was assumed that the risk of being missed was independent of admission to hospital.

In summary, of 3,023 injured children presenting to the emergency department at Montreal Children's Hospital, 277 (9 percent) were missed by CHIRPP. Univariate analyses showed that injuries resulting in admissions, poisonings, and presenting overnight were significantly associated with being missed. In total, 71 injured children (2.4 percent) were admitted to the hospital, and of these, 38 (54 percent) were missed. Of the 50 children (1.7 percent) presenting because of poisoning, 23 (46 percent) were missed by the system. Last, of the 473 children (15.7 percent) presenting overnight, 108 (23 percent) were missed by CHIRPP. (Time of presentation was not correlated with either admission to hospital or poisoning).

Stepwise logistic regression analysis (with being missed by CHIRPP as the outcome variable) resulted in a main effects model that contained the same three predictors—admission, poisoning, and time of presentation. The adjusted odds ratio of being missed by CHIRPP for admitted injuries (compared with those treated and released) was 13.07 (95 percent confidence interval 7.82–21.82), the adjusted odds ratio of being missed for poisonings (compared with all other injuries) was 9.91 (95 percent confidence interval 5.39–18.20), and the adjusted odds ratio of being missed for injuries presenting overnight (compared with those presenting during the day or evening) was 4.11 (95 percent confidence interval 3.11–5.44). There were no significant interactions between the predictor variables, and the Pearson chi-square statistic for goodness-of-fit indicated a good overall fit for the final model (\( p = 0.49 \)).

**DISCUSSION**

The quality of CHIRPP data was determined through assessment of system sensitivity, positive predictive value, and representativeness. The sensitivity studies showed variation in injury capture, ranging from 30 to 91 percent at four CHIRPP centers. The frequency of false-positive capture at Montreal Children's Hospital was extremely low (less than 0.05 percent). The representativeness study showed systematic errors in capture at Montreal Children's Hospital, i.e., admitted injuries, poisonings, and those presenting overnight were more likely to be missed by the system.

**Strengths and limitations of the sensitivity studies**

CHIRPP sensitivity was estimated over 3 months at four centers that differed by size, geographic location,
and population served. Convenience sampling, however, was used to select the four centers, chosen because of accessibility. An important issue, therefore, was whether the selected centers were different from other CHIRPP centers in ways that might influence capture. In general, all 10 CHIRPP centers in existence at the time of the study were considered relatively homogeneous, since all were urban, teaching, tertiary care pediatric hospitals affiliated with a local medical school. In addition, the process of injury surveillance was similar across centers.

Strengths and limitations of the representativeness study

Sample distortion bias was considered unlikely, given that all injured children presenting to the emergency department over the 2-month period were included in the analyses. In other words, the entire inception cohort of 3,023 injured children was accounted for, with analyses on the 277 missed and 2,746 captured injuries. Information bias was minimized by using a standardized data collection form and the same data source (the medical chart) for both groups of injuries. In addition, chart review was blind, i.e., data were abstracted with the reviewer unaware of the (captured or missed) status of the injured child. Stepwise logistic regression analysis was used to reduce or eliminate the effects of confounding variables.

Because the studies were conducted over the summer months, the influence of season on sensitivity and representativeness could not be determined. Seasonal variation in childhood injury occurrence is well documented, e.g., the frequency of motor vehicle injury is highest during the summer months (22, 23). The representativeness study, however, showed that emergency department volume and nature of injury (other than for poisoning) were not associated with being missed by CHIRPP. In addition, because of the large sample size, all injury categories were represented in the analyses. The likelihood of a marked seasonal effect on CHIRPP sensitivity and representativeness is, therefore, probably low.

Census tract data were used to estimate socioeconomic status. Although causal inference is strengthened by using data from individuals rather than populations, previous studies have demonstrated that census data provide a good approximation of individual-level socioeconomic status (24, 25).

Interpretation of results

Although not formally studied, the variability in sensitivity by center appeared to be correlated with local leadership. For example, the two centers with high sensitivity (Montreal Children's Hospital and L'Hôpital Sainte Justine) had identifiable CHIRPP proponents who actively encouraged data collection in the emergency department and who were available for problem solving. At The Children's Hospital of Eastern Ontario, no such person was present. In addition, feedback of injury data to the emergency department staff appeared to be more common at the other centers than at The Children's Hospital of Eastern Ontario.

The positive predictive value of CHIRPP data at Montreal Children's Hospital was shown to be almost perfect, given the high sensitivity of injury capture and the negligible frequency of false-positive capture. It should be noted that for all three noninjuries in the database, the self-report parent component of the CHIRPP form gave a history of prior trauma, i.e., of falls for two of the children and stepping on a sharp object for the child with the plantar wart.

The representativeness study demonstrated systematic errors in CHIRPP capture, i.e., poisonings, injuries admitted to the hospital, and injuries presenting overnight were more likely to be missed. These injuries were probably missed because of inadequate education of participants involved in the system. For example, although poisoning is included as a specific injury type on the CHIRPP form, many registration clerks failed to regard poisonings as injuries. Therefore, forms were often not distributed to these families. Admitted children were more likely to be missed because many bypassed the registration desk and went directly to triage for immediate resuscitation and treatment. These patients were then registered by an emergency department clerk rather than by the registration clerk. Almost invariably, a data form was not provided to these families, either because the clerk involved was not aware of CHIRPP or was uncomfortable about troubling distraught parents. Not all admitted children presented as an acute emergency; therefore, many were captured during routine registration.

There are two reasons why injuries presenting overnight were more likely to be missed. First, the CHIRPP coordinator was routinely present in the emergency department during the day. This may have improved capture because someone was available to answer queries or because of the "Hawthorne Effect," i.e., capture may have been improved because the clerks were aware that they were being scrutinized (26). Second, in-service training of clerks about CHIRPP was always conducted during the day, thus, making attendance by night shift workers more difficult. In other words, the overnight clerks who were responsible for patient registration and distribution of
forms may have been less aware of (or less committed to) the injury surveillance system.

An important issue is whether the results of the representativeness study are generalizable, given that the study was conducted at a single center (Montreal Children's Hospital). As described earlier, CHIRPP centers were considered relatively homogeneous (urban, tertiary care pediatric hospitals), and the surveillance process was similar across centers. In addition, the representativeness study suggested that inadequate education of participants and failure to consider all entry points into the system were associated with errors in capture. In other words, the systematic errors in capture were related to the operation of the surveillance system itself rather than to features of the patient population or to the structure of the emergency department at Montreal Children's Hospital that may have been unique.

Relatively few studies have formally evaluated the quality of data provided by injury surveillance systems. In addition, the majority of such studies have restricted their evaluations to assessment of system sensitivity, or (less frequently), representativeness. For example, Gallagher et al. (2) conducted a population-based survey of childhood injuries in Massachusetts that used (in part) emergency department data. Independent review of these data gave a sensitivity of capture by the survey of around 85 percent. Likewise, using similar methods, the sensitivity of capture by an (all-age, all-injury) emergency department-based surveillance system in Stockholm was estimated at 87 percent (27). Last, McClure and Burnside (28) evaluated the sensitivity and representativeness of an emergency department-based surveillance system in Australia. Sensitivity was only 30 percent; there were no marked differences, however, between captured and missed cases on age, sex, socioeconomic status, or nature of injury. Nevertheless, injuries to children admitted to the hospital were twice as likely to be missed by the system (compared with those who were treated and released).

Summary

Surveillance data may be used to identify priorities, determine etiologic factors, allocate resources, and evaluate interventions. The value of injury surveillance was demonstrated in Sweden, where a commitment to surveillance (and education and legislation) resulted in a lowering of the childhood injury mortality rate in that country to the lowest in the world (29). A review of public health surveillance in the United States, however, noted that the usefulness of many data sources for injury remains to be assessed (5). We determined the quality of data provided by a national injury surveil-

lance system (CHIRPP) through assessment of system sensitivity, positive predictive value, and representativeness. The frequency of false-positive capture at Montreal Children’s Hospital was negligible, and CHIRPP sensitivity ranged from 30 to 91 percent at four centers. In addition, poisonings, injuries resulting in admissions, and injuries presenting overnight were systematically missed by the system.

From the public health perspective, low system sensitivity leads to an underestimation of the injury problem. Systematic errors in capture, however, may lead to an inefficient use of resources, e.g., interventions may be targeted away from high-risk populations. CHIRPP sensitivity was high (>75 percent) in three of four centers, with estimates similar to those obtained in other studies evaluating emergency department-based surveillance systems. The sampling frame for this study was acutely injured children presenting to the emergency departments of children’s hospitals. Based on this surveillance population of interest, the level of underestimation of the injury problem by CHIRPP is low. The systematic errors in capture are also amenable to solution, e.g., through education of participants and improved distribution of data collection forms. Of note, the finding that admitted patients were more likely to be missed was replicated in another study that evaluated an emergency department-based injury surveillance system. Emergency department-based surveillance is primarily intended to capture injuries presenting to the emergency department. Other data sources, e.g., hospital discharge data, are available to “capture” those injuries resulting in admission.

In conclusion, CHIRPP data are of relatively high quality and may be used, with caution, for research and public health policy. For example, CHIRPP data may be used to estimate (within 10–20 percent) the frequency of emergency department attendance because of injury at children’s hospitals across Canada. Further, these data may be used to identify emerging problems and to generate hypotheses. At present, CHIRPP data underestimate the admission rate and also demonstrate some systematic errors in capture. Therefore, the data should be used cautiously in studies of etiology. The systematic errors identified, however, are amenable to solution through the ongoing education of participants involved in the system to maintain awareness and to highlight the importance of CHIRPP.

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