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Croup Hospitalizations in Ontario: A 14-Year Time-Series Analysis

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ABSTRACT. Objective. Croup is the most common form of airway obstruction in children. Known to be primarily viral, the seasonality of croup has been examined largely through its association with the human parainfluenza viruses. This study examined the seasonal pattern of croup hospitalizations in relation to age and gender for the province of Ontario during a 14-year period.

Methods. A retrospective, population-based study design was used to examine seasonal and temporal patterns of croup hospitalizations from April 1, 1988, to March 31, 2002. All residents of Ontario who were aged 0 to 4 years and eligible for universal health coverage during the study period were included for analysis. Time-series analyses then were conducted on monthly aggregations of hospitalizations.

Results. This study found strong evidence of croup hospitalization seasonality, with a biennial midautumn peak and annual summer trough, evident throughout the 14-year study period (Fisher’s $k = 51.11$; Bartlett Kolmogorov Smirnov = 0.552). The pattern was observed in all children aged 0 to 4, although boys were hospitalized 2 times more often than girls of the same age. Rates of croup hospitalization were lower for children aged 1 to 4 years than for children aged 0 to <1. A marked decrease in croup hospitalizations was observed after the winter of 1993/1994 and continued to decrease in a step-wise manner for the remainder of the study period.

Conclusions. This study delineates a clear biennial pattern of seasonal croup hospitalizations, varying by age and gender, with a large decrease in hospitalizations after the winter of 1993/1994. It is expected that these findings will have important implications for the treatment and management of childhood croup. Pediatrics 2005;116:51–55; croup, hospital records, time, periodicity.

ABBREVIATION. HPIV, human parainfluenza virus.

Croup (laryngotracheobronchitis) is the most common form of airway obstruction in children between the ages of 6 months and 6 years, peaking between the ages of 1 and 2 years.1–4 Although the majority of croup-affected children can be treated in the home without physician input, croup nonetheless poses a significant burden on health care systems because of the frequent visits made to emergency departments and family doctors. It has been suggested that the annual incidence of croup in children who are younger than 6 years ranges from 1.5% to 6%, with outpatient admission rates of those affected ranging from 1.5% to 31%, depending on admission practices and severity of illness in the population.3,4

Characterized by hoarseness, a barking cough, and inspiratory stridor, croup is often thought to occur as a result of a recent viral infection, causing inflammation and edema of the larynx and trachea, resulting in subglottic narrowing.5,6 Human parainfluenza virus (HPIV) has been found to be the most frequent cause of croup, with HPIV type 1 responsible for most viral infections.3,4,7

A great deal of research has been conducted to examine the cause,4,8–10 treatment,2,5,6,11–13 and epidemiologic features3,4,7,10,14 of croup. The seasonality of croup has been well documented, although primarily only through its association with the temporality of HPIV.3,15,16 For example, croup hospitalizations in the United States have been found to exhibit major peaks in October of odd-numbered years, coinciding directly with peak activities of HPIV type 1.3 Numerous authors have similarly noted that croup occurs more frequently in winter months and demonstrates an increased prevalence in boys.4,17–19 Although several authors have examined the seasonality of croup hospitalizations, study periods generally have been relatively short and sample sizes small. To address these shortcomings, we conducted a population-based study of the province of Ontario, during a 14-year study period, to address the following objectives:

1. examine the seasonal patterns for croup hospitalizations by age and gender;
2. assess the strength of the seasonal patterns; and
3. determine the overall trends in croup hospitalizations during the 14-year study period.

METHODS

A retrospective, population-based study was conducted to determine the seasonal patterns of croup hospitalizations from April 1, 1988, to March 31, 2002. All Ontario residents who were
aged 0 to 4 years and eligible for universal health coverage during this period were included in the analysis. The Canadian Institute for Health Information Discharge Abstract database was used to obtain information regarding croup as the principal diagnosis. This database records discharges from all inpatient hospital stays in Ontario acute-care hospitals, documenting a scrambled patient identifier, date of admission, and discharge, up to 16 diagnoses as coded by the International Classification of Diseases, Ninth Revision, Clinical Modification, and up to 10 procedures.

In the past, researchers who have used similar databases have found that diagnoses are coded with a high degree of accuracy. In addition, very little information is missing from the Ontario database, supporting evidence from other provincial studies that <1% of the basic patient information is omitted in provincial databases.

All records with a principal diagnosis of croup (International Classification of Diseases, Ninth Revision, Clinical Modification code 464.4) for patients who were between the ages of 0 and 4 years were identified (n = 44,820). The total number of discharges by age and gender were assessed for each month. Using monthly population estimates derived through linear interpolation of annual census data, we calculated monthly hospitalization rates per 100,000 population, normalized for length of month. All transfers from within 1 acute-care hospital to another within this study group were excluded from the analysis. Time-series analysis then was conducted to assess seasonal variations and trends over time and to account for autocorrelation, typically problematic with time-related data.

Data analysis involved the use of several statistical techniques to assess the statistical significance of seasonal patterns and the consistency and magnitude of seasonal effects. Spectral analysis, useful for detecting periodicity in time series, was conducted to test data for seasonality. The data were detrended using moving averages before spectral analysis was conducted. Two statistical tests were used to test the periodicity of the spectral analysis series: first, Fisher’s χ² test, designed to test the null hypothesis that the series is Gaussian white noise against the alternative hypothesis that the series contains an added deterministic periodic component of unspecified frequency; and, second, the Bartlett Kolmogorov–Smirnov test, useful in accumulating departures from the white noise hypothesis over all frequencies. The correlation between observations at different time lags then was measured using the autocorrelation function. A strong correlation between the observations at 12 time lags indicates a strong seasonality of the period. Finally, R² autoregression coefficients (R² autoreg) were calculated. Autoregression uses the coefficient of determination of the autoregressive regression model fitted to the data and, as such, can be used for quantifying the strength of the seasonality correlated observations as occurs with time-series data. The R² autoreg is interpreted the same way as the coefficient of determination in classic regression: values from 0 to <0.4 represent nonexistent to weak seasonality, 0.4 to <0.7 represent moderate to strong seasonality, and 0.7 to 1 represent strong to perfect seasonality. All statistical analyses were performed by using SAS 8.2 (SAS Institute Inc, Cary, NC).

RESULTS

A total of 44,820 children between the ages of 0 and 4 years of age were admitted to Ontario hospitals with a diagnosis of croup from April 1, 1988, to March 31, 2002, 69.3% (31,057) of whom were boys. Peak croup hospitalizations are evident in October of odd-numbered years for both genders and age groups, with minor peaks occurring in February of alternate years (Fig 1). Seasonal troughs appear in July through August and, unlike the major seasonal peaks, are evident in all years in the study period. Spectral analysis indicates a consistent 12-month period seasonality (data not shown). The Fisher’s χ² and Bartlett Kolmogorov–Smirnov tests demonstrate a highly significant seasonal pattern (P < .01) of croup hospitalizations overall, as well as by age and gender (Table 1). The autocorrelation function for all data also shows significant seasonality, with autocorrelation function values ranging from 0.66 to 0.70 (data not shown).

The results also demonstrate striking differences in the rates of hospitalization by gender and age. The highest seasonal rate of croup hospitalizations occurred in October 1993, when 387 of 100,000 boys...
and 212 of 100 000 girls aged 0 to <1 year were admitted to Ontario hospitals with a diagnosis of croup. In the 1- to 4-year age group, during the same period, 340 of 100 000 boys and 172 of 100 000 girls were hospitalized. Correspondingly, the lowest rate of seasonal croup hospitalizations was observed in girls aged 1 to 4 years in May 2000 (0.9 of 100 000). Overall, the data demonstrate increased incidence in children aged 0 to 1 year (Fig 2), with boys exhibiting a relative risk of 2.08 over girls for croup hospitalizations (Fig 3).

The results of the $R^2_{\text{autoreg}}$ for the series are seen in Table 1 to be 0.842, with values within each age group and gender ranging from 0.778 to 0.844, indicating a very strong seasonality.

Finally, Figs 1, 2, and 3 demonstrate a downward trend in croup hospitalization rates after the winter of 1993/1994 to the end of the study period. For both age groups and genders combined, the rates decreased from 267 of 100 000 in 1993/1994 to 37 of 100 000 in 2001/2002, a drop of ~86%. Similar trends were seen in both age groups and genders.

### DISCUSSION

This study demonstrates the striking seasonality of croup hospitalizations in Ontario hospitals during a 14-year period. Croup hospitalizations exhibit large peaks in midautumn of odd-numbered years, with smaller peaks present during February of even-numbered years. Troughs follow a similar pattern, evident in July through August of all years. The results further revealed higher incidences of croup in boys, particularly between the ages of 0 and 1 year. Finally and perhaps most interesting, a sharp decrease in croup hospitalizations after the winter of 1993 is made evident.

Similar seasonal patterns to those identified herein have been reported in previous studies. Marx et al. described an analogous distinctive pattern of biennial epidemics of respiratory illness during the autumn months of odd-numbered years as a result of HPIV-1, whereas Monto noted that HPIV-2 may account for comparable increased croup hospitalizations in winter months when HPIV-1 is not present.

### TABLE 1

Results of $R^2_{\text{autoreg}}$ and Spectral Analysis Testing of the Seasonality of Croup Hospitalizations According to Age and Gender Between 1988 and 2002

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Boys</th>
<th></th>
<th>Girls</th>
<th></th>
<th>Both Genders</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$FK$</td>
<td>$BKS$</td>
<td>$R^2_{\text{autoreg}}$</td>
<td>$FK$</td>
<td>$BKS$</td>
<td>$R^2_{\text{autoreg}}$</td>
</tr>
<tr>
<td>0 to &lt;1</td>
<td>49.89</td>
<td>0.500</td>
<td>0.791</td>
<td>50.48</td>
<td>0.485</td>
<td>0.778</td>
</tr>
<tr>
<td>1 to 4</td>
<td>48.30</td>
<td>0.525</td>
<td>0.823</td>
<td>45.52</td>
<td>0.465</td>
<td>0.835</td>
</tr>
<tr>
<td>All</td>
<td>49.71</td>
<td>0.545</td>
<td>0.820</td>
<td>50.18</td>
<td>0.523</td>
<td>0.844</td>
</tr>
</tbody>
</table>

$FK$ indicates Fisher’s $\chi^2$; $BKS$, Bartlett Kolmogorov Smirnov. All test statistics were significant at the level of $P < .01$. 

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**Fig 2.** Croup hospitalization rates per 100 000 population in Ontario (1988–2002) for children aged 0 to <1 and 1 to 4 years, both genders combined.
prominent. With HPIV-1 and, secondarily, HPIV-2 known to be the most common pathogens associated with croup, it is clear that the seasonality of croup hospitalizations in this study reflects the seasonality of the HPIVs.

It is interesting that this study demonstrated higher rates of croup hospitalizations in children who were younger than 1 year. Many studies describe croup to be most prevalent in children during the second or third year of life, however, it is important to consider that children who are younger than 1 year and present with croup may be at greater risk for associated sequelae and, as such, may be more likely to be admitted to the hospital than an older child. In fact, Fitzgerald and Kilham listed “age <6 months” to be 1 of several predisposing factors for hospital admission after initial treatment for croup. In addition, the sample size and time frame during which this study was conducted provide strong evidence in favor of the validity of the results found herein.

The evidential decreasing trend in croup hospitalizations can likely be accounted for by the increasing use of corticosteroid treatment in patients who present to emergency departments with croup. Although there are no known Canadian data to verify the change in treatment practices, the change is evidenced in the literature. For example, The Canadian Pediatrics Society in 1992 recommended dexamethasone treatment in patients who are admitted to hospital with a diagnosis of croup. The later release of reports examining the efficacy of oral and nebulized glucocorticoids in the treatment of outpatient croup combined with the publication of a Cochrane Review outlining the benefit of glucocorticoids for croup, likely initiated change in clinical practice. The most recent literature similarly recommends the use of either oral or nebulized corticosteroids in most, if not all, cases of mild, moderate, and severe croup. Indeed, universal guidelines for the diagnosis and management of croup, including those released by the Alberta Medical Association, dictate the use of glucocorticoids in all children who receive a diagnosis of croup. It therefore is probable that the decrease in croup hospitalizations in the early 1990s in Ontario hospitals is a direct result of the introduction of widespread use of steroids in the treatment of croup.

Another possible explanation for the observed decrease in croup hospitalizations is a decrease in viral incidence or perhaps an increase in another lower respiratory diagnosis, such as bronchiolitis. This explanation, however, seems unlikely. An examination of Ontario viral isolation data and bronchiolitis hospitalization data showed no significant changes during the study period (data not shown).

The strengths of this study include a large sample size, a long study period, and the use of a comprehensive time-series analysis approach applied to age and gender. Furthermore, because Ontario has a publicly funded health care system that provides universal access, this study is truly population based. However, as this was a descriptive study detailing only hospitalizations, seasonal and annual variations in emergency department or physician visits could not be assessed and an analysis of therapeutic approaches to treatment or details of their outcomes could not be documented.

These findings may contribute to the further development of treatment protocols for croup, as well
as to the potential for vaccines toward the HPIVs. The decreasing trend in croup hospitalizations associated with changes in treatment of affected children provides evidence and impetus toward additional analysis of the health and societal benefits of steroid therapy for croup. This therefore potentiates the development of a study linking the decrease in croup hospitalizations that originated in the mid-1990s with an increase in dexamethasone use and a potential increase in emergency department observation duration before discharge.

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REFERENCES
