Croup (laryngotracheobronchitis) is a common manifestation of lower respiratory tract infection in children. It is a syndrome associated with inflammation and obstruction of the larynx and trachea and is characterized clinically by inspiratory stridor, barking cough, and hoarseness. Most cases occur within the first 3 years of life, with the greatest incidence in the second year of life; at this age, 1%–5% of children may require outpatient evaluation for croup [1–4]. Croup accounts for 10%–35% of lower respiratory tract illness seen in pediatric practice [2, 3, 5]. The proportion of children hospitalized ranges from 1.3% to 5.6% of croup cases seen in pediatric practices [2–4] to 31% of croup cases seen in a pediatric emergency room [5].

Human parainfluenza virus 1 (HPIV-1) is the etiologic agent most commonly associated with croup and is estimated to cause ~18% of all cases of croup and ~38% of cases with known etiologic agents (table 1). Among the known agents of croup, HPIV-1 is unique in its association with epidemics of acute respiratory illness every other year. HPIV-1 has produced national epidemics in odd-numbered years since 1973 in the United States, and the virus is infrequently detected during the intervening periods [2, 16–19].

Despite the common occurrence of croup in young children, the morbidity and health care burden remains incompletely defined. To date, there are no estimates of croup hospitalizations based on a nationally representative sample. The objectives of this study were to describe the epidemiologic features and temporal trends of croup hospitalizations in the United States and to determine the proportion of croup hospitalizations attributable to HPIV-1 by using the unique temporal pattern of HPIV-1 activity.

Methods

Croup hospitalization data for 1979 through 1993 were obtained from the National Hospital Discharge Survey (NHDS) compiled by the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention (CDC) [20, 21]. The NHDS consists of a nationally representative probability sample of patient discharge records obtained from short-stay, nonfederal, general, and children’s hospitals in the United States. Croup hospitalizations were weighted according to NCHS procedures and rounded to the nearest thousand to obtain national estimates.

The International Classification of Diseases (9th revision, clinical modification [ICD-9-CM] code 464.4) was used to extract all hospitalizations with croup listed as one of as many as seven discharge diagnoses listed on the NHDS record [22]. Because croup is a childhood illness, we excluded records from persons ≥15 years of age (0.7%) and records with unstated ages (1.5%). The annual relative standard errors for hospitalization estimates ranged from 7% to 16% for each of the years from 1979 through 1991 and 25% for 1992 and 1993 [20, 21]. The variation in relative standard errors for the last 2 years of the study is mainly due to the loss of several children’s hospitals from the survey [21].

Overall hospitalization rates and those by 5-year age group were calculated using the census population for the respective years and are presented per 100,000 children [20, 21, 23]. Rates for infants and 1-year-old children were estimated using natality data [24]. Seasonal and temporal trends of HPIV4 activity during the study period were obtained from CDC’s National Respiratory and Enteric Virus Surveillance System and published reports [2, 16–19].

Results

There were 608,000 croup hospitalizations (mean, 41,000/year; range, 27,000–62,000) from 1979 through 1993 among
chiolitis (3.4%). Croup was recorded in 3.9% of hospitalizations. The seasonal trends in croup hospitalizations were age-dependent. For children <5 years of age, croup hospitalizations reflected the overall seasonal pattern, with major peaks in October and minor peaks around February (figure 2), and the annual hospitalization rate was 252.6/100,000 in odd-numbered years. For children ≥5 years old, the annual winter peak was similar in magnitude to the autumn peak and there was no apparent increase in the magnitude of the autumn peak during odd-numbered years.

When we compared the first 3 years of the 15-year study period with the final 3 years, we identified a 18.5% decline in croup hospitalizations during the study period and a 22.0% decline in hospitalizations from all causes for children <15 years old. The median duration of hospitalization was 2.0 days (mean, 2.8), and it decreased from 3.0 days (mean, 3.2) in the first 3 years of the study period to 2.0 days (mean, 2.4) in the last 3 years. The median duration of hospital stay decreased from 3.0 days (mean, 3.3) among infants <1 year of age to 2.0 days (mean, 2.2) among children 4 years of age and was 2.0 days (mean, 2.8) among children 5–14 years of age.

**Discussion**

During the 15-year study period, we observed major peaks in croup hospitalizations in October of odd-numbered years that are best explained by HPIV-1 infection. In the United States, HPIV-1 has produced biennial epidemics of acute respiratory illness in autumn of odd-numbered years since 1973, and this distinctive temporal pattern of HPIV-1 activity is coin-

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**Table 1. Etiologic agents isolated from patients with croup (laryngotracheobronchitis).**

<table>
<thead>
<tr>
<th>Agent</th>
<th>% specimens tested</th>
<th>% specimens of known etiology</th>
<th>Seasonality of peak activity in United States</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Range</td>
<td>Median</td>
</tr>
<tr>
<td>Parainfluenza virus 1</td>
<td>18</td>
<td>7–26</td>
<td>38</td>
</tr>
<tr>
<td>Parainfluenza virus 3</td>
<td>8</td>
<td>3–17</td>
<td>15</td>
</tr>
<tr>
<td>Respiratory syncytial virus</td>
<td>7</td>
<td>1–12</td>
<td>11</td>
</tr>
<tr>
<td>Parainfluenza virus 2</td>
<td>6</td>
<td>1–12</td>
<td>9</td>
</tr>
<tr>
<td>Influenza A</td>
<td>6</td>
<td>1–29</td>
<td>8</td>
</tr>
<tr>
<td>Rhinovirus</td>
<td>3</td>
<td>1–8</td>
<td>6</td>
</tr>
<tr>
<td>Adenovirus</td>
<td>2</td>
<td>1–4</td>
<td>4</td>
</tr>
<tr>
<td>Influenza B</td>
<td>2</td>
<td>1–3</td>
<td>3</td>
</tr>
<tr>
<td>Enteroviruses</td>
<td>1</td>
<td>1–4</td>
<td>3</td>
</tr>
<tr>
<td>Mycoplasma pneumoniae</td>
<td>1</td>
<td>0–2</td>
<td>2</td>
</tr>
</tbody>
</table>

* Data from selected studies using virus isolation and at least 2 consecutive years of observations [1, 2, 4, 6–12]; 29%–64% of cases had etiology determined (median, 54%).

† Based on CDC surveillance and published reports, except for rhinovirus and *M. pneumoniae* [13–15].
cident with the major peaks in croup hospitalizations that we observed. In addition, our estimate that 22.5% of all croup hospitalizations per biennium and 36.7% of hospitalizations during odd-numbered years can be attributed to HPIV-1 falls within the range expected from previous etiologic studies of croup (table 1). These studies have consistently shown HPIV-1 to be the most common etiologic agent identified in croup cases. HPIV-2 is likely to be the second most important contributor to the autumn peak each year [5, 18, 19].

The minor peaks of croup hospitalizations around February annually are most likely attributable to influenza virus and respiratory syncytial virus. While respiratory syncytial virus is

Figure 1. Hospitalizations for croup by month of hospital admission in children <15 years of age—United States, 1979–1993. Major autumn peak in hospitalizations is present in each odd-numbered year except 1993. Minor peak is present each year around February. Tick marks on horizontal axis delimit 3-month time intervals.

Figure 2. Seasonality of hospitalizations for croup by odd- and even-numbered years in children—United States, 1979–1993. Top: 0–4 years of age. Bottom: 5–14 years of age.
most important in children <5 years of age, influenza virus would be expected to be a more common cause of croup in children ≥5 years old [2, 15, 25].

In children ≥5 years old, there was no evidence of an HPIV-1–specific increase in croup hospitalizations because the odd- and even-numbered year peaks in autumn were of similar magnitude. Although other studies have demonstrated that HPIV-1 continues to be a cause of croup among older children that requires outpatient treatment [2], its relative importance as a cause of croup hospitalization decreases with age [1]. This decrease in rate of hospitalization with increasing age corresponds to an increase in the seroprevalence of antibodies to HPIV-1 [26, 27], suggesting that other etiologic agents assume greater importance as the cause of croup in older hospitalized children.

This study provides a population-based estimate of hospitalizations derived from a nationally representative probability sample. We found 49,000 croup hospitalizations in years when HPIV-1 is active and 31,000 in years when HPIV-1 is not active. During autumn epidemics in odd-numbered years, HPIV-1 may account for 18,000 (36.7%) croup hospitalizations. Our estimate for HPIV-1–associated hospitalizations is lower than the estimate by Henrickson et al. [5] of 28,000–33,000 croup hospitalizations nationally for autumn 1991. Their study provided estimates of HPIV-1– and HPIV-2–associated hospitalizations in the United States based on a study conducted in Milwaukee from mid-September 1991 to mid-December 1991. During the 3-month interval beginning mid-September, we estimate that there were 24,000 hospitalizations from all causes during odd-numbered years and 8000 during even-numbered years. Their higher estimates result in part from inclusion of HPIV-2 hospitalizations during a year in which high levels of HPIV-2 activity occurred in that community. Although HPIV-2 usually plays a minor role in croup hospitalizations compared with HPIV-1 [7, 9], HPIV-2 activity can vary from year to year in a community [2, 16–18], and in some instances may be a more important cause of croup hospitalization [5, 28, 29].

Our data suggest that croup is associated with significant health care costs. If we apply the number of croup hospitalizations in odd- and even-numbered years (49,000/year vs. 31,000/year), the mean hospital stay during the last 3 years of our study (2.4 days), and the mean costs of hospitalization ($619/day) from the Milwaukee study [5], then croup hospitalizations cost an estimated $73,000,000 during HPIV-1 epidemic years and $46,000,000 during nonepidemic years, for an estimated cost of $27,000,000 every other year for HPIV-1–associated hospitalizations. Our estimate for total croup hospitalization costs during the autumn of an odd-numbered year is $36,000,000, or 82% of the $44,000,000 for the cost of croup hospitalizations estimated in the Milwaukee study [5]. Our lower estimate probably reflects the impact of high HPIV-2 activity in Milwaukee in 1991.

The numbers of croup-associated outpatient visits may also be estimated, but with less certainty. On the basis of a hospitalization rate of 1.3% for patients seen in a pediatric practice [2] and 31% for patients seen in a pediatric emergency room [5], we estimate that there will be 3,077,000 provider contacts and 129,000 emergency room (ER) visits for croup each year. Using an average of 18,000 HPIV-1–associated croup hospitalizations every other year, we estimate that there are 1,385,000 clinic visits and 58,000 ER visits every other year attributable to HPIV-1. Extrapolation from our study provides an estimate of 77,000 croup-associated ER visits during the autumn of an odd-numbered year, which is 30% lower than a previous estimate of ER visits for croup [5].

Hospitalization for croup was more common among boys than girls. The magnitude of the difference, a 1.9-fold increase in boys compared with girls for children <5 years of age, is comparable to that reported by others [2, 3, 5, 30]. However, we also found that boys ≥5 years old had higher hospitalization rates than girls, and several previous studies have reported that incidence of croup becomes similar by gender with increasing age [2, 30]. The factors underlying these gender differences are not understood [31, 32].

Among infants <1 year of age, the numbers of hospitalizations for croup increased steadily between birth and the fifth month of life. This finding is consistent with maternally acquired antibodies protecting infants during the first months of life [26, 27, 33].

Our analysis shows a decline in croup hospitalizations and in hospitalizations from all causes for children <15 years of age. This decline may represent changing criteria for pediatric hospital admission aimed at decreasing health care costs [34]. The temporal change in hospitalizations makes it difficult to use these data to assess long-term trends in morbidity due to HPIV-1.

Several limitations need to be considered for NHDS-based estimates. First, sensitivity and specificity for identifying croup hospitalizations have not been independently validated. However, the clinical presentation of croup, with inspiratory stridor, barking cough, and hoarseness, is so striking that it may be less subject to misclassification bias than other clinically defined syndromes. Second, the sample includes only 0.5% of all hospitalizations and does not include federal institutions, such as Indian Health Service hospitals, which do provide pediatric care [20]. Third, changes in the NHDS sampling design in 1988 [20] may affect comparisons between earlier and later years. We would not expect these limitations to have a major impact on our results.

In summary, our data, based on a nationally representative probability sample of hospitalizations, provide estimates of disease burden that are similar to and complement previous estimates [5] based on extrapolations from community hospitalizations. Together, these data convincingly demonstrate the significant public health impact of HPIV-1 epidemics.

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