

The Relationship of Fall School Opening and Emergency Department Asthma Visits in a Large Metropolitan Area

Robert A. Silverman, MD; Kazuhiko Ito, PhD; Lori Stevenson, MPH; Harold M. Hastings, PhD

Background: Asthma morbidity is seasonal, with the fewest exacerbations occurring in summer and the most exacerbations in early fall.

Objective: To determine if the fall increase in pediatric asthma emergency department (ED) visits is related to the school year start.

Design: Time-series study of daily asthma ED visits taken from an administrative claims database for the years 1991 to 2002.

Setting: Eleven municipal hospitals in New York City, NY.

Patients: Emergency department visits with asthma as the primary diagnosis among children aged 2 to 4, 5 to 11, and 12 to 17 years and adults with asthma aged 22 to 45 years as comparative group.

Main Outcome Measure: Rate of asthma ED visits after the September school opening compared with before the opening, during a 60-day window of each year.

The delayed effect of school opening was examined by the lagged school-opening indicator for lag 0 through 9 days. The model adjusted for factors that may influence morbidity. There were 86 731 ED visits within the study period.

Results: Asthma ED visits for children aged 5 to 11 years were significantly associated with school opening day, with the highest lagged rate ratio being 1.46 (95% confidence interval [CI], 1.29-1.65). For children aged 2 to 4 years, the highest rate ratio was 1.19 (95% CI, 1.06-1.35), and for children aged 12 to 17 years, the highest lagged rate ratio was 1.13 (95% CI, 0.98-1.31). The rise in adult ED visits following school opening was less substantial, with the highest lagged rate ratio being 1.07 (95% CI, 1.00-1.14).

Conclusion: The start of the September school year was associated with increases in pediatric asthma ED visits, particularly among grade school children.

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Author Affiliations:

Department of Emergency Medicine, Long Island Jewish Medical Center, New Hyde Park, NY (Dr Silverman); Nelson Institute of Environmental Medicine, New York University School of Medicine, Tuxedo (Dr Ito); Department of Community Medicine, Mt Sinai School of Medicine, New York, NY (Ms Stevenson); Department of Physics and Astronomy, Hofstra University, Hempstead, NY (Dr Hastings).

SEASONAL ASTHMA WORSENING has been well described, with the greatest number of exacerbations occurring in autumn and the fewest in the midsummer.¹⁻¹⁰ There is a strong age-related seasonal variability, with grade school children being most vulnerable to seasonal changes.^{10,11} Since the annual peak number of asthma visits for children usually occurs in early fall, this leads to the question of whether the start of the new school year causes asthma worsening. A study from a pediatric hospital in Brighton, England, found the annual peak for asthma hospitalizations occurred after return to school from the summer holiday.⁵ Any relationship of asthma worsening to school opening could be important to help identify the triggers and to take pre-

ventive measures. This is particularly crucial in urban areas, where children are at increased risk for asthma.¹²

The goal of this study was to determine the relationship between pediatric asthma emergency department (ED) visits and the start of the public school year in a large metropolitan area. The study focused on the 30 days before and after the opening of school. Factors unrelated to the school start that could influence fall ED visits, such as day of week, temperature changes, temporal trends, and holidays, were taken into consideration.

METHODS

Data from ED visits to the 11 New York City Health and Hospitals Corporation medical centers with emergency receiving facilities were ob-

tained deidentified for the years 1991 to 2002. These hospitals are municipally run and serve a largely poor and minority population located within the 5 boroughs of New York City, NY. All are teaching hospitals affiliated with area medical schools and all 11 EDs serve both children and adults. Patients seen in the ED with asthma were identified through a centralized claims database using the *International Classification of Diseases, Ninth Revision, Clinical Modification*¹³ code 493 for a principal diagnosis of asthma. The study was reviewed by the Human Subjects Review Committee at Long Island Jewish Medical Center, New York.

Our main objective was to determine the relationship between asthma ED visits and fall school opening for grade school children. Other objectives were to (1) estimate the magnitude of any identified association and (2) determine the relationship between asthma ED visits and school opening among preschool children and adolescents. Since the data are daily counts over time, our basic strategy was a time-series analysis of counts to estimate any school opening effect while adjusting for other factors that might influence seasonal changes. The following age groups were selected a priori to approximate different school levels: 2 to 4 years (preschool), 5 to 11 years (grade school), and 12 to 17 years (middle and high school). Adults aged 22 to 45 years with acute asthma were included as a comparative group.

We took advantage of the year-to-year variation in school opening day, which ranged from September 4 to September 20 for the years 1991 to 2002. To focus on potential school-opening effects on the fall peaks in asthma ED visits, a 60-day window, August 12 to October 10, was chosen; it approximately centers in the vicinity of the school opening days and contains much of the fall peaks in this data set. Since these series were too highly overdispersed, negative binomial regression^{14,15} was used for all the models presented in this analysis. We used S-PLUS statistical software (1999; Mathsoft, Inc, Seattle, Wash) with a function for negative binomial regression written by Venables and Ripley.¹⁶ The regression model included an indicator variable that was equal to 1 on and after the school opening days and equal to 0 otherwise. This approach is similar to those in studies investigating the impact of introducing firearms laws on mortality¹⁷⁻¹⁹ and the impact of daylight saving time on traffic accidents.²⁰⁻²²

Assuming school opening influenced asthma ED visits, we did not expect a change in asthma ED visits exactly on the day of school opening but rather lagged in time. Based on the observed pattern for unadjusted ED visits, we lagged the school-opening indicator variable by 0 through 9 days (ie, shifted the series) and repeated the regression analysis. Because the school-opening indicator variable is a step function or a square-shaped wave, we did not expect it to fit the sawtooth-like pattern in asthma ED visits too well, although the sharp edge could estimate the beginning portion of the peak. It was also a convenient model because it allowed for the construction of indicator variables for other alternative temporal variables and comparison of the results without changing the functional forms or *df*.

The regression model adjusted for day-of-week indicator variables, year indicator variables, ozone, temperature, and alternative adjustment for other (unmeasured) temporal confounders. Based on a preliminary analysis, the average of 0- and 1-day lagged ozone was included as a linear continuous variable. Based also on preliminary analysis, temperature was modeled nonlinearly; we included a natural cubic spline smoothing term²³ of lag 0-day daily mean temperature with 3 *df* to model the immediate temperature effect, as well as a natural cubic spline smoothing term of the average of 2- and 3-day lagged temperature to model the lagged temperature effects. Also included were indicator variables for holidays in the study window.

Consideration was given to some unmeasured confounder that might create a general upward trend in asthma ED visits during this window. Including 59 dummy variables for each

of the 59 days in the 60-day window was not useful in this analysis because we planned to compare the school-opening day effects vs the day-of-year indicators, and the day-of-year indicators would be perfectly colinear with the 59 dummy variables. Therefore, a natural cubic spline of study days (ie, 1 through 60) with 5 *df* was used. We selected 5 *df* based on the model fit (see "Results" section) and the shape of the fitted curve.

Adjustment for unmeasured temporal confounders can be done by including a smoothing term of time (day) with certain *df* to capture adequate details of temporal fluctuations that are considered potentially confounding.^{24,25} However, such "adequate" extent of smoothing is not known a priori, and there is a risk of underfitting the asthma ED visits time series to leave residual confounding or overfitting it with many *df* to the point where no fluctuations are left to be explained by other variables. Therefore, in addition to our "base" temporal adjustment (5 *df*) for the school-opening indicator variable, we also considered natural cubic spline terms with *df* of 20, 15, 10, 3, and 2 as sensitivity analysis. Dummy variables for the 59 days of the 60-day window were also considered because it did not result in perfect colinearity for the school-opening indicator. In addition, for the school-opening indicators, we also considered (1) a quadratic spline model that had knots at intervals of 10 days (ie, linear day term plus 6 quadratic terms); (2) linear trend; (3) no trend term; and (4) no trend and no temperature terms, as sensitivity analyses.

Since both temperature and ozone had downward trends during the study window, they also can act as temporal adjustment terms (with negative coefficients). With all these terms, the regression model can be overfitted. The combinations of these environmental and temporal adjustment terms can have high colinearity with the school-opening indicator variable (lagged or unlagged), possibly making the interpretation of the rate ratio difficult. To help judge the extent of such a problem, for each model specification, we computed estimation of concurvity, the nonlinear analogue of colinearity,²⁶ by computing the correlation between the school-opening indicator variable and fitted school-opening indicator variable from the regression of the school-opening indicator variable on all the covariates.

To test if the school-opening indicator variable was a better predictor of the fall peaks in asthma ED visits than any given day of the year (eg, September 8) in the study window, indicator variables were prepared for each of the days between August 27 and September 25 in the same way as the school-opening indicator variable was created (label 1 on and after that day and label 0 before that day). Each of the alternative day indicators was entered into the negative binomial regression model with the covariates described earlier, and its rate ratio and 95% confidence intervals were computed. In addition, the model fit was examined using the Akaike information criteria.²⁷

RESULTS

There were 532 826 asthma ED visits among the 4 age groups during the years 1991 to 2002. The number of visits were as follows: age 2 to 4 years=91 496; age 5 to 11 years=133 141; age 12 to 17 years=55 143; and age 22 to 45 years=253 046. Forty-four percent of the population was African American and 46%, Latino. Medicaid and self-pay accounted for 84% of all visits; the other 16% included Medicare and other governmental or commercial third-party payers.

The annualized patterns appeared similar for the age groups, with large rises experienced in the fall, smaller increases in the spring, and substantial decreases in the summertime (**Figure 1**). Of the 4 age groups, grade

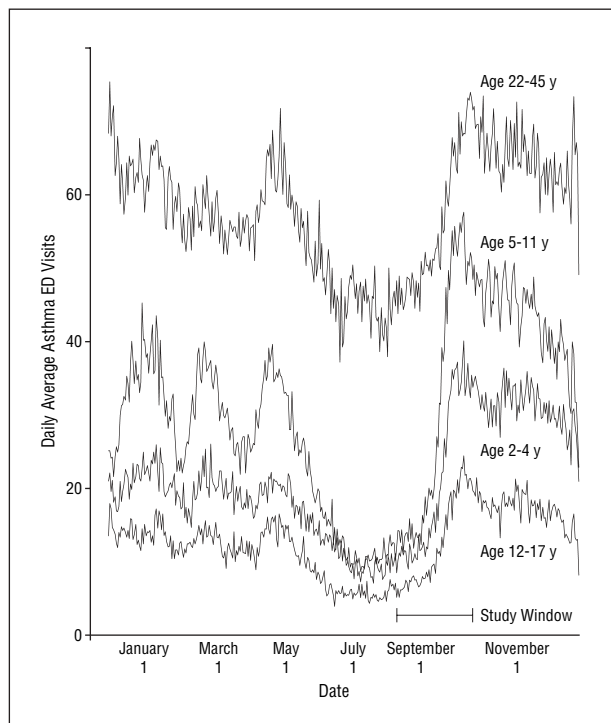


Figure 1. Daily asthma emergency department (ED) visits by age, averaged by day of year during 1991 to 2002. The 60-day study window (August 12 to October 10) is indicated.

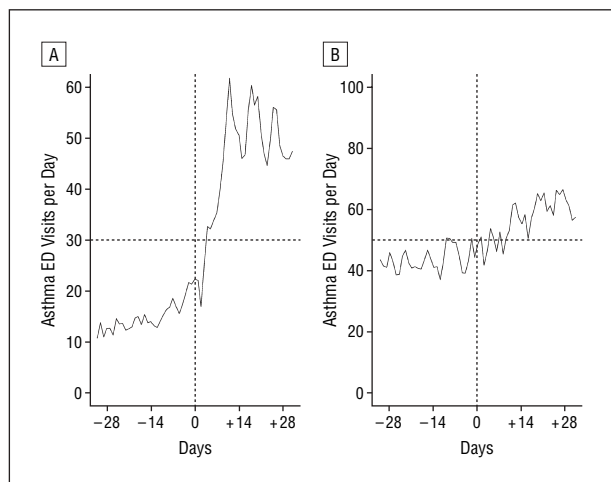


Figure 2. Daily asthma emergency department (ED) visits for children aged 5 to 11 years (A) and adults aged 22 to 45 years (B) (as comparative group) for the 30 days before and after school opening during 1991 to 2002 (unadjusted). 0 indicates school opening day. Horizontal dashed lines are the average daily counts for the 12 years.

school children had the more pronounced peaks (sharp rise) and troughs. The total asthma ED visits for the selected 60-day window of August 12 to October 10 during the 12 years were 86 731.

Figure 2 shows unadjusted asthma ED visits averaged for each of the 30 days before and after school started over the 12-year period for the age group 5 to 11 years and adults aged 22 to 45 years. Among children, the sharpest rise for ED visits appeared to occur within the first 10 days after school opening. A shallower upward trend

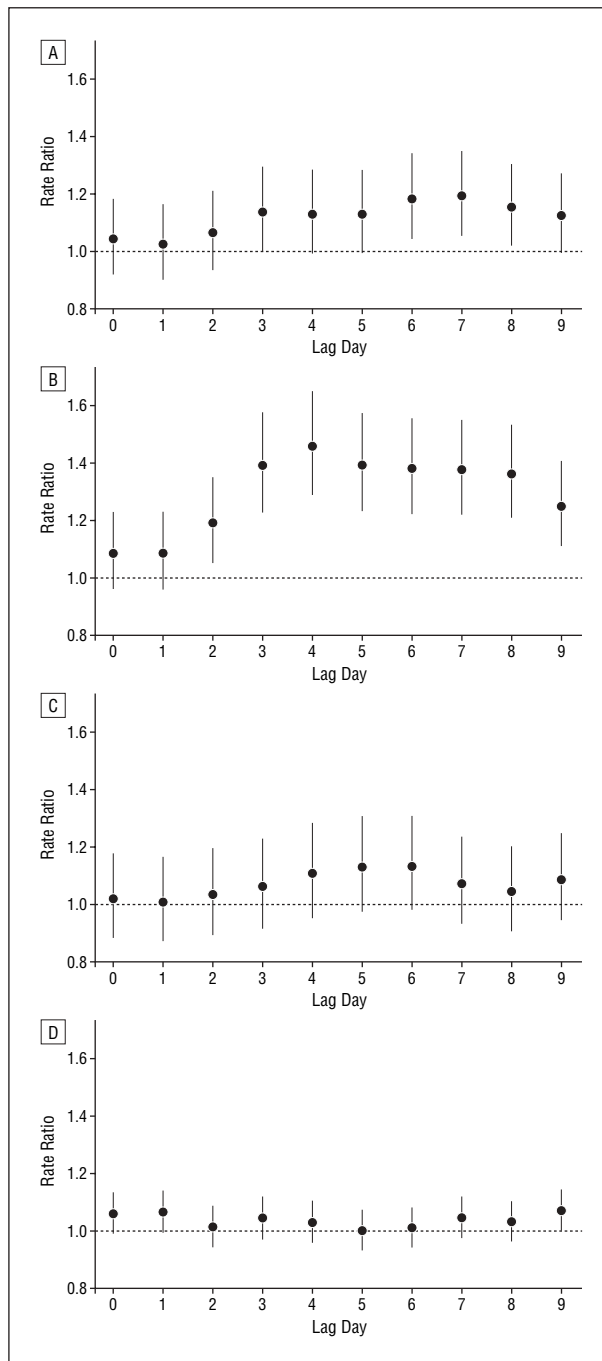


Figure 3. Rate ratios and 95% confidence intervals for the school-opening indicator variable with the delayed effect of school opening examined. The estimates are adjusted for temporal trends, day of week, study year, immediate and lagged temperature effects, ozone effects, and holidays. A, Children aged 2 to 4 years. B, Children aged 5 to 11 years. C, Children aged 12 to 17 years. D, Adults aged 22 to 45 years.

was seen even before the school start, but the rise appeared to be much sharper after school started.

The Akaike information criteria indicated that the date of school start plus a lag of up to 9 days was a better model for predicting ED visits than any of the day-of-year indicators between August 27 and September 25 (results not shown). The adjusted rate ratios for the school opening along with the 9-day lagged risk ratios are presented for grade school children in

Table. Sensitivity of Rate Ratio for School-Opening Indicator (at Lag 4 Days) to Alternative Temporal Trend Adjustment: Age 5 to 11 Years

Model	Alternative Temporal Adjustment Term	AIC ²⁷	Concurvity*	Rate Ratio (95% CI)
1	Natural cubic splines with <i>df</i> = 5 (base model)	4922.8	0.94	1.46 (1.29-1.65)
2	59 dummy variables for 59 of the 60 study days	4996.5	0.94	1.48 (1.30-1.68)
3	Natural cubic splines with <i>df</i> = 20	4938.5	0.94	1.47 (1.29-1.67)
4	Natural cubic splines with <i>df</i> = 15	4930.1	0.94	1.47 (1.29-1.67)
5	Natural cubic splines with <i>df</i> = 10	4922.5	0.94	1.47 (1.29-1.66)
6	Quadratic splines, <i>df</i> = 5	4926.9	0.94	1.48 (1.30-1.67)
7	Natural cubic splines with <i>df</i> = 3	4919.3	0.93	1.49 (1.33-1.67)
8	Natural cubic splines with <i>df</i> = 2	4970.2	0.87	1.94 (1.77-2.13)
9	Linear trend	4978.2	0.87	1.90 (1.74-2.09)
10	No trend term	4991.2	0.71	2.19 (2.05-2.33)
11	No trend term and no temperature terms	5132.1	0.51	2.75 (2.59-2.91)

Abbreviations: AIC, Akaike information criteria, an index of model fit with penalty for degrees of freedom (the smaller the AIC, the better the fit); CI, confidence interval.

*Concurvity: the extent of colinearity between the school-opening indicator and the rest of the covariates in the regression model.

Figure 3. The rate ratio for school opening was highest when lagged 4 days after school opening (1.46 [95% confidence interval (CI), 1.29-1.65]). The rate ratios, when lagged between 2 and 9 days, were all statistically significant after school opening at the level of $P < .05$.

For children aged 2 to 4 and 12 to 17 years, the lagged rate ratios were smaller (1.19 [95% CI, 1.06-1.35] and 1.13 [95% CI, 0.98-1.31], respectively, at their strongest lag) and occurred at longer lags (7 and 6 days, respectively) than that for children aged 5 to 11 years (Figure 3). For adults, there was little or no apparent relationship to ED visits lagged 9 days after school opened; the rate ratios ranged from 1.0 (95% CI, 0.93-1.07) at day 5 to 1.07 (95% CI, 1.00-1.14) at day 9.

To examine the sensitivity of the estimated rate ratio for school opening, we applied several alternative temporal adjustment models for the group aged 5 to 11 years (Table). Changing *df* for the natural cubic spline smoothing terms did not alter the estimated rate ratio for school opening (1.46-1.49) when the *df* were larger than 3. However, when the *df* were reduced to 2, the rate ratio increased to 1.94 and the model fit became worse. Using a linear trend resulted in a similar rate ratio. Not including a trend term and temperature terms increased the school-opening rate ratio further.

Not adjusting for the general upward trend in asthma ED visits during this period would bias the rate ratio estimate for school opening, leading to a greater apparent risk ratio from school opening. Adjusting for a possibly confounding temporal trend by fitting a smooth curve with *df* of 3 or larger results in a steep curve fit for the “confounding” trend (Figure 4) that may or may not be related to school opening. The high concurvity (colinearity between the school-opening indicator and the adjustment terms) as presented in the Table in these models also leaves the possibility that we erroneously ascribed some of the school-opening effects to the temporal trend in visits. Therefore, the rate ratio for school opening from our main result (1.46 [95% CI, 1.29-1.65]) may be a conservative estimate.

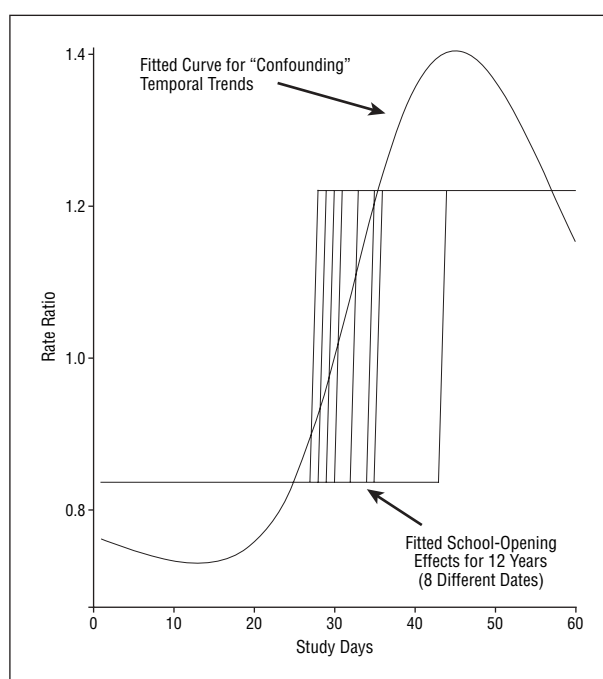


Figure 4. Comparison of fitted school-opening effects and temporal trends (for adjustment for unmeasured confounders) for the age group 5 to 11 years. The estimates are adjusted for temporal trends, day of week, study year, immediate and lagged temperature effects, ozone effects, and holidays.

COMMENT

We observed an increase in pediatric ED asthma visits following the start of the school year. For grade school children, school opening was associated with a 46% increase in ED asthma visits. While the association of school opening and ED asthma visits was greatest in children aged 5 to 11 years, increases were also noted in children aged 2 to 4 years and adolescents aged 12 to 17 years. The models took into account other seasonal factors known to worsen asthma, and the year-to-year variation in school opening dates further strengthened the findings.

The steep rise noted after school began was preceded by a more gradual increase in ED visits before school opened. Among previous studies, the increase in fall pediatric asthma hospitalizations also appeared before the return to school.^{5,28} These data suggest that factors unrelated to school account for the start of the autumn rise. The acceleration in ED visits after school opening may have resulted from new (and presumably school-related) exposures or school-related intensification of exposure to factors present before the start of school.

There are a number of potential explanations for the observed school-opening asthma morbidity. Viruses, and particularly rhinovirus, have been identified among school-aged children with worsening asthma symptoms. Common cold viruses were found in 80% to 85% of reported exacerbations of asthma in 9- to 11-year-old children, and rhinoviruses accounted for 2 of 3 of viruses detected.²⁹ Respiratory infections, and especially rhinovirus, have been linked to hospitalizations or ED visits among preschool children with asthma or wheezing.³⁰⁻³²

There is ample opportunity for children to contract the rhinovirus in early fall. The seasonal periodicity of rhinoviral illness^{33,34} is similar to the seasonal asthma patterns described in this study, with a sharp rise in rhinoviral upper respiratory tract infections beginning in August and peaking in September. Students in classrooms from day to day are at greater risk for infection, and symptom onset after viral entry to the nose or eyes is rapid.³⁵ Younger children may attend preschool or Head Start programs, potentially exposing them to similar triggers as the older children.³⁶ Further, a school-aged child can expose younger siblings to viruses,³⁷ with secondary attacks of rhinovirus in families typically occurring 1 to 5 days after exposure.

Emotional factors and stress can influence asthma, although the impact of school-related stress on acute asthma worsening in school-aged children has not been reported. Indoor irritants are important triggers of asthma, and the removal of home allergens decreases asthma symptoms in inner-city children.³⁸ Cat and dog dander, transported by clothing from pet owners, has been reported in Swedish and New Zealand schools,³⁹⁻⁴¹ and cockroach allergen at potentially significant concentrations has been found in school dust in some Chicago, Ill, inner-city schools.⁴² Less work has been done on linking school allergen exposure to asthma symptoms in children.

A temporal relationship between school opening and ED asthma visits does not establish causality. The relative contribution of viral respiratory infections or any other factor to seasonal asthma worsening needs to be prospectively established. This may involve evaluating asthma symptoms in children before and after the start of school and linking morbidity with triggers found in the school environment.

The September pattern in asthma morbidity may present an opportunity for intervention. Although most children aged 6 to 15 years with chronic asthma in the United States have moderate or severe persistent asthma, long-term asthma therapy is often inadequate,⁴³ and minorities are even less likely to be using controller medications.⁴³ The general benefits of controllers, such as inhaled steroids, in decreasing severe exacerbations

have been well documented.^{44,45} Still, studies evaluating the efficacy of controllers have not addressed specific seasonal triggers. This study highlights the need to prospectively determine whether starting or optimizing controller medication before the school start mitigates fall asthma worsening.

In summary, our study indicates a relationship between the start of school and asthma episodes requiring an ED visit among children. This information can possibly help schools, health care professionals, and children better prepare for the fall asthma season and lead to a better understanding of the causes of school-related asthma worsening.

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Correspondence: Robert A. Silverman, MD, Department of Emergency Medicine, Long Island Jewish Medical Center, New Hyde Park, NY 11040 (aresilv@aol.com).

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Announcement

Submissions. The Editors welcome contributions to Picture of the Month. Submissions should describe common problems presenting uncommonly, rather than total zebras. Cases should be of interest to practicing pediatricians, highlighting problems that they are likely to at least occasionally encounter in the office or hospital setting. High-quality clinical images (in either 35-mm slide or electronic format) along with parent or patient permission to use these images must accompany the submission. The entire discussion should comprise no more than 750 words. Articles and photographs accepted for publication will bear the contributor's name. There is no charge for reproduction and printing of color illustrations. For details regarding electronic submission, please see: <http://archpedi.ama-assn.org>.