Trends in Orbital Complications of Pediatric Rhinosinusitis in the United States

Gregory Capra, MD; Bryan Liming, MD; Mark E. Boseley, MD; Matthew T. Brigger, MD, MPH

**IMPORTANCE** Several studies have documented the prevalence and treatment of orbital complications secondary to pediatric rhinosinusitis, but to our knowledge, none have investigated the national health care burden of this disease since the introduction of the heptavalent pneumococcal vaccine (PCV-7).

**OBJECTIVE** To identify the current public health burden of orbital complications of pediatric rhinosinusitis, and to determine if the introduction of the PCV-7 has resulted in a change in national practice patterns.

**DESIGN, SETTING, AND PARTICIPANTS** Population-based study using the 2000 and 2009 Kids’ Inpatient Databases to gather data on a sample of all pediatric discharges in the United States during the years 2000 and 2009. Children diagnosed as having orbital complications of sinusitis were identified by corresponding International Classification of Diseases, Ninth Revision (ICD-9) codes. Database analyses generated national estimates of summary statistics and comparison of trends over the 9-year period.

**INTERVENTIONS** Database analysis.

**MAIN OUTCOMES AND MEASURES** National health care trends according to year. End points assessed included prevalence, age, sex, length of hospital stay, and treatment of disease.

**RESULTS** The estimated prevalence of orbital complications of sinusitis requiring hospitalization in the United States has slightly decreased from 5338 (95% CI, 4956-5720) admissions in 2000 to 4511 (95% CI, 4165-4858) in 2009. However, the mean age has increased from 4.77 (95% CI, 4.56-4.97) years to 6.07 (95% CI, 5.87-6.26) years. The proportion of children undergoing surgical treatment increased from 0.108 (95% CI, 0.093-0.123) to 0.195 (95% CI, 0.176-0.213). Total charges increased from $4 140 000 (95% CI, $3 440 000-$4 830 000) to $10 000 000 (95% CI, $8 480 000-$11 600 000) with a mean charge per admission increasing from $8390 (95% CI, $7096-$9685) in 2000 to $22 656 (95% CI, $19 997-$25 314) in 2009. The mean length of stay remained stable at 3.67 (95% CI, 3.37-3.97) to 4.05 (95% CI, 3.81-4.29) hospital days.

**CONCLUSIONS AND RELEVANCE** The public health impact of orbital complications of pediatric rhinosinusitis continues to be substantial. Since the institution of the PCV-7 vaccine, national trends demonstrate a slightly decreased prevalence of hospital admissions. However, there is a shifting trend toward an older age at admission and a higher proportion of children undergoing surgical treatment.
Orbital complications are known sequelae of pediatric rhinosinusitis. In fact, published clinical practice guidelines for the diagnosis and treatment of pediatric acute bacterial sinusitis recognize that intraorbital complications are the most common complication of acute bacterial sinusitis. The ethmoid sinus is the nidus of orbital spread in most cases, with the frontal and maxillary sinuses the source less frequently. One study found that 100% of patients with subperiosteal abscesses (SPAs) demonstrated concurrent sinusitis in at least 1 sinus, while 63% had multiple sinus involvement. Theories suggesting why a sinus infection causes a subsequent postseptal orbital complication generally revolve around the ease by which infection and inflammation can traverse the lamina papyracea. This thin bony septum between the orbit and the paranasal sinus is naturally porous, is susceptible to congenital dehiscences, has large vascular foramina, and has the potential for open suture lines. All of these properties have been implicated as possible routes of infectious transmission between the paranasal sinuses and orbit.

In contrast, preseptal disease is commonly a complication of trauma or dacryocystitis. As described by Chandler et al, periorbital and orbital infections are categorized based on location of infection. The categories represent a progression of severity from mild preseptal cellulitis to potentially deadly cavernous sinus thrombosis. Given the potential morbidity and even mortality, treatment strategies include aggressive intravenous antibiotics, topical nasal decongestants, and potentially surgical drainage. While there has been controversy over the evolving roles of surgery vs medical treatment, it is clear that orbital complications of rhinosinusitis remain a clinically significant problem.

Traditionally, Streptococcus pneumoniae, Haemophilus influenzae, and Moraxella catarrhalis have been the most commonly implicated pathogens in acute bacterial rhinosinusitis. The introduction of the H influenzae type b (HiB) vaccine in 1985 altered the landscape of many pediatric infectious diseases.

Although HiB has not been completely eradicated, studies have shown a shift in microbiological trends of acute pediatric infections related to epiglottitis, meningitis, rhinosinusitis, periorbital infections, and otitis media.

The heptavalent pneumococcal conjugate vaccine (PCV-7) was introduced in 2000 for children younger than 24 months. Many authors have studied the effects of the vaccine on common pediatric diseases. McKinley et al discovered that few orbital infections were S pneumoniae in origin in the post-PCV-7 population. Similarly, Peña et al concluded that fewer S pneumoniae infections occurred, while an increase in Staphylococcus aureus prevalence was seen in these types of infections. With changing microbiologic characteristics of orbital complications secondary to pediatric rhinosinusitis over the first decade of the PCV-7 introduction, it could be expected that the national health care impact of this disease may similarly be affected. The purpose of this study was to examine these national trends with regards to the prevalence, treatment, and overall charges of orbital complications of pediatric rhinosinusitis for the years 2000 and 2009, corresponding to the introduction and widespread administration of the PCV-7 vaccine.

Methods

This study was approved by the institutional review board of the Naval Medical Center San Diego. The data are from the Kids' Inpatient Database (KID), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality (AHRQ). The 2000 and 2009 KIDs were used to gather data on a sample of all pediatric discharges younger than 18 years in the United States during 2000 and 2009. These data are a representative sample of discharges occurring in the United States during those years. The sampling strategy is single stage and is designed to select 10% of uncomplicated in-hospital births as well as 80% of complicated births and other pediatric admissions from each frame hospital. Discharge weights were according to AHRQ protocol using poststratification of 6 characteristics of each hospital (ownership or control, bed size, teaching status, rural or urban location, and US region, free-standing children’s hospital) in order to calculate national estimate data. The 2000 KID includes 2784 hospitals from 27 states, and the 2009 KID includes 4121 hospitals from 44 states.

Given the known natural association of orbital cellulitis with sinusitis, all children requiring admission with a diagnosis of orbital cellulitis were identified by the International Classification of Diseases, Ninth Revision (ICD-9) code 37601. Children who had a trauma or injury code were excluded from the analysis. The population generated by this search was then stratified according to applicable HCUP Procedure Clinical Classification Software codes for nasal or orbital surgical procedures. Other information, such as sex, mean total charges, and mean length of hospital stay was also obtained. Analysis using each database’s weighted sampling schema generated national estimates of summary statistics.

Results

The national public health burden of pediatric orbital complications in 2000 and 2009 is estimated in the Table. Based on the weighted estimates, the prevalence of orbital complications for the years 2000 and 2009 were 5338 (95% CI, 4956-5720) and 4511 (95% CI, 4165-4858), respectively, for individuals 18 years or younger. The US census population data estimates of this age group for the years 2000 and 2009 were 72.3 million and 74.5 million, respectively. This gives an approximate estimate of incidence for these 2 populations of nearly 7.38 children per 100 000 in 2000 and 6.05 per 100 000 in 2009. Mean ages between the 2 groups demonstrated an increase from 4.77 (95% CI, 4.56-4.97) years to 6.07 (95% CI, 5.87-6.26) years over this time span. The median age showed a similar trend. Sex distribution remained stable, with a slight male predominance at 57.6% (CI, 55.4%-59.7%) in 2000 and 59.9% (CI, 58.1%-61.8%) in 2009.

Children hospitalized in the year 2000 incurred hospital charges greater than $4 million and accounted for 19 592 (95% CI, 17 488-21 696) inpatient days. These charges more than doubled in 2009 to $10 million, although the total inpatient days of 18 293 (95% CI, 16 378-20 209) were not significantly
different. Mean charges were substantially more in 2009, with estimates of $22,656 (95% CI, $19,997-$25,314) per hospitalization compared with $8,390 (95% CI, $7,096-$9,685) in the year 2000. Despite the differences in total and mean charges per hospital stay, the length of stay of 3.67 (95% CI, 3.37-3.97) days prior to PCV-7 was similar to the post–PCV-7 era at 4.05 (95% CI, 3.81-4.29) days.

The data showed an increasing trend toward surgery, whereby the estimated total number of those surgically treated increased from 579 (95% CI, 493-665) in 2000 to 879 (95% CI, 760-998) in 2009. This represents an increase from 10.8% (95% CI, 9.3%-12.3%) of patients to 19.5% (95% CI, 17.6%-21.3%) between these years. The surgical age was consistent between the 2 groups, with an average age of 8.43 (95% CI, 7.72-9.14) years in 2000 and 9.02 (95% CI, 8.63-9.41) years in 2009. In contrast, a slight increase in age for medically treated patients was seen. An increase from 8.43 (95% CI, 4.08-4.51) years to 5.33 (95% CI, 5.13-5.52) years was observed for the age of medically treated patients for these years. Across the years, medically treated patients were younger than the surgical age of patients. As would be expected, the total charges for surgical patients between these 2 groups were significantly different.

In 2000, mean charges for surgically treated patients were $17,403 (95% CI, $13,552-$21,403) in 2000 and 2009, respectively.

### Discussion

The effect of vaccines has been substantial in combatting childhood infectious diseases. This is no more evident than with the introduction of the Hib vaccine.16 However, the overall effect from a national perspective may be difficult to extrapolate from single-institution studies. Although a vaccine may reduce the prevalence of a specific causative pathogen, disease trends themselves can go unchanged, and vaccines could hasten the emergence of new pathogens. Furthermore, it is important in this era of increased awareness of health care economics to identify how health care dollars are spent. This knowledge will better shed light on allocation of resources and the burden with which a disease places on the health system. Large-scale population level databases fill our knowledge gap and are essential in providing accurate epidemiologic data that can be applied toward better understanding national trends. However, they are not without their own limitations. When coupled with institutional studies, the information we can glean from large databases may shed light on a disease and aid in developing new prevention strategies.

Our goal was to compare pre–PCV-7 era and post–PCV-7 era hospitalizations related to orbital complications of pediatric rhinosinusitis in order to detect trends related to the vaccination for S pneumococcus in the pediatric population. To our knowledge, no prior study has evaluated this relationship on a national level. Using the same rationale described by Peña et al16 regarding the concept of herd immunity, we chose to compare KID data from 2000 and 2009. Between these years, we found a slight decrease in prevalence of severe rhinosinusitis resulting in hospital admission for orbital complications from 2000 to 2009. It is difficult to impart a definite cause and effect relationship between the decrease in S pneumonieae infections and the decrease in severe pediatric orbital complications of rhinosinusitis. It may also depend on specific bacterial isolates combined with other factors.1 In fact, the study by Peña et al16 supports this theory. When comparing these 2 eras, they found a 13% rise in cases after the introduction of the vaccine. Cultures from their patients prior to the vaccine’s introduction predominately demonstrated the presence of S pneumonieae, but this pathogen was absent in all aspires for their post–PCV-7 group. Instead, a dramatic rise in S aureus was seen in these patients, with a trend toward a growing percentage of cultures demonstrating methicillin-resistant S aureus (MRSA). These data are supported by another study,13 which showed S pneumonieae to predominate prior to 2000. However, in the late 2000s, infections caused by S pneumonieae have occurred less frequently giving way to more

### Table. National Estimates for Admissions for Orbital Complications of Sinusitis

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>2000</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, total No.</td>
<td>5338 (4956-5720)</td>
<td>4511 (4165-4583)</td>
</tr>
<tr>
<td>Male sex, %</td>
<td>57.6 (55.4-59.7)</td>
<td>59.9 (58.1-61.8)</td>
</tr>
<tr>
<td>Age, mean, y</td>
<td>4.77 (4.56-4.97)</td>
<td>6.07 (5.87-6.26)</td>
</tr>
<tr>
<td>Median</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Charges, $</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>414,000 (3,440,000-4,830,000)</td>
<td>10,000,000 (8,480,000-11,600,000)</td>
</tr>
<tr>
<td>Mean</td>
<td>8390 (7,096-9,685)</td>
<td>22,656 (19,997-25,314)</td>
</tr>
<tr>
<td>Median</td>
<td>4586</td>
<td>11,089</td>
</tr>
<tr>
<td>Total hospital days</td>
<td>19,592 (17,488-21,696)</td>
<td>18,293 (16,378-20,209)</td>
</tr>
<tr>
<td>Length of stay, d</td>
<td>3.67 (3.37-3.97)</td>
<td>4.05 (3.81-4.29)</td>
</tr>
<tr>
<td>Median</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Surgically treated, total No.</td>
<td>579 (493-665)</td>
<td>879 (760-998)</td>
</tr>
<tr>
<td>Total, %</td>
<td>10.8 (9.3-12.3)</td>
<td>19.5 (17.6-21.3)</td>
</tr>
<tr>
<td>Age, mean, y</td>
<td>8.43 (7.72-9.14)</td>
<td>9.02 (8.63-9.41)</td>
</tr>
<tr>
<td>Length of stay, mean, d</td>
<td>6.69 (5.83-7.56)</td>
<td>6.89 (6.14-7.63)</td>
</tr>
<tr>
<td>Charges, mean, $</td>
<td>25,348 (17,294-33,401)</td>
<td>53,251 (43,881-62,620)</td>
</tr>
</tbody>
</table>

*The data are from the Kids’ Inpatient Database, Healthcare Cost and Utilization Project. Agency for Healthcare Research and Quality.*
staphylococcal infections, including MRSA.\textsuperscript{2,8,9,11,20-22} Although these data suggest that PCV-7 has had a dramatic affect in the reduction of invasive \textit{S pneumoniae} infections, other factors may be at work, such as emerging antibiotic resistance, \textit{S pneumoniae} strains not covered by PCV-7, or other uneluci-
dated host factors.\textsuperscript{16,21} In 2010 the PCV-13 vaccine was made available, which may ultimately further shift bacterial iso-
lates. As these data become more widely available, future in-
vestigations are warranted.

Historically, males have been more likely than females to present with orbital complications of rhinosinusitis.\textsuperscript{9,11,21,22} This was the case in our data, which showed a male predominance in the pre–PCV-7 and post–PCV-7 eras that has not signifi-
cantly changed. In these 2 groups, males represented 57.6\% and
59.9\% of the populations for 2000 and 2009. This is consist-
ent with the findings of another database study for 2006,\textsuperscript{24} which found that males comprised 59.5\% of patients, and with the report by Peña et al,\textsuperscript{16} who found that males were more likely to be affected regardless of the vaccine.

Historically, orbital complications of sinusitis tend to oc-
cur in children younger than 10 years.\textsuperscript{9,11,21} In studies prior to
PCV-7 immunizations, Garcia and Harris\textsuperscript{10} found an average age at complications of 7.2 years. In the post–PCV-7 era, Sed-
agh  et al\textsuperscript{25} found patients had an average age of 8.6 years, although they found that age was not associated with in-
creased complication rates based on multivariate analysis. For the years 2000 and 2009, our study demonstrated an in-
crease in the mean age at presentation from 4.77 to 6.07 years, suggesting a trend of increased age of presentation as more children were vaccinated. Likewise, Peña et al\textsuperscript{16} found that older children were more commonly affected by orbital complica-
tions in the post–PCV-7 era. The exact reason for this dispar-
ity in age between the years 2000 and 2009 is unclear but once again may have to do with the interaction of bacterial isolate and host factors. One could argue that despite the wide-
spread dissemination of PCV-7 in 2000, not all children were ini-
itially vaccinated. Peña et al\textsuperscript{16} suggested that true herd immu-
nity did not occur until 2003, and thus it is possible that the older age of presentation in the post–PCV-7 group may re-
fect children who failed to benefit from herd immunity. An-
other argument may lie in the type of microbiologic infec-
tions in older children. A 2012 study\textsuperscript{26} of chronic rhinosinusitis
aspirates in children found that \textit{Staphylococcus} species ac-
counted for most cases, of which older children were more likely to experience polymicrobial infections. This is in con-
trast to younger children, who seem to be single nasophary-
geal pathogen carriers.\textsuperscript{26} The companion studies by Gordts et al\textsuperscript{23,27} support this theory in their findings prior to 2000. They found that middle meatus aspirates in 50 children were most likely to be represented by the common upper respiratory tract pathogens \textit{H influenzae}, \textit{M catarrhalis}, and \textit{S pneumoniae}, which represented 50\% of cultures. In contrast, only 2\% of adults had \textit{S pneumoniae} cultures. Adult pathogens were in-
stead highly represented by coagulation-negative \textit{Staphylo-
coccus} species, \textit{Corynebacterium} species, and \textit{S aureus}.\textsuperscript{27}

Both historically and in these databases, age also seems to affect the surgical rate of patients with orbital complica-
tions. In one study,\textsuperscript{28} age was predictive of the need for sur-
gery, with nonsurgical patients averaging 6.1 years while sur-
gical patients averaged 10.1 years. Peña et al\textsuperscript{16} also found that older children were taken back to the operating room earlier than younger children, but the exact reason for this was un-
clear. However, this same study found no significant differ-
ence in surgery rates (17\% and 22\%) for the pre–PCV-7 and post-
PCV-7 eras. Garcia and Harris\textsuperscript{10} showed that children younger
than 9 years were successfully treated medically, while older children had an increased likelihood of requiring surgical drain-
age. Our national data support these findings. In both 2000 and
2009, the mean age of surgically treated patients was signifi-
cantly higher than those who were medically treated (Table). In both years the medically treated mean age averaged about
age 5 years, while the surgical patient was close to the age of 9 years. Although polymicrobial or more virulent infections may account for the age discrepancy, another explanation may lie in the development of the paranasal sinuses. Dewan et al\textsuperscript{16} found that children with frontal sinusitis or nonmedial SPAs were more likely to be older and require surgical treatment compared with their younger counterparts. This may be ex-
plained by the lack of paranasal sinus development in the younger population.

Since the publication of the article by Garcia and Harris\textsuperscript{10} in 2000, it has been thought that a shift away from surgical treatment of orbital complications toward primarily medical treat-
ment of this disease has occurred.\textsuperscript{3,4,6,8} These authors\textsuperscript{10} showed prospectively that 93\% of children younger than 9 years with small, medial SPAs, no frontal sinusitis, and no visual im-
pairment could be safely treated medically. Since its publica-
tion, authors\textsuperscript{2,8,9,22,29} have sought to better define other char-
acteristics of patients who can be safely treated medically. These studies have regularly focused on the radiographic size and location of SPAs. In contrast to the perception that pa-
tients are treated more conservatively today than in years past, our data suggest that surgical rates have actually increased with time. We found that despite stricter criteria for medical treat-
ment, surgical rates nearly doubled from 10.8\% in 2000 to 19.5\% in 2009. This is compared with the study by Mahalingam-
Dhingra et al,\textsuperscript{25} which showed that surgical rates of 12.4\% for
2006, which are closer to our pre–PCV-7 data surgical rates. Our data also are not in agreement with those of Peña et al,\textsuperscript{16} who found no significant difference in surgical rates between their study groups. The reason for this discrepancy remains un-
clear. Again, this may reflect the age of patients, presumed mi-
crobiological nature of infection, regional variation in KID data sources, or the sample size.

Regardless of the increase in surgical rates between 2000 and
2009, it seems that the length of hospital stays has not changed over the decade. A direct comparison of children who were surgically treated also showed that they did not have longer stays, and neither did those medically treated. However, within each year group, length of stay was significantly differ-
ent between the medical and surgical patient groups. These data are in agreement with those of one study\textsuperscript{4} that found surgically treated patients averaged 7.1 days of hospital admission compared with 3.4 days for their medically treated counter-
parts. Factors that may affect length of hospital stays are nu-
merous and are not accounted for in this study. A natural con-
Conclusions

The public health impact of pediatric patients with orbital complications secondary to rhinosinusitis continues to be substantial. In the post–PCV-7 era, many of the characteristics of disease remain stable, including a male predominance, a significantly older surgical population, and the average length of stay. In contrast, the prevalence has slightly decreased, the average age of patients has increased from 4.77 to 6.07 years, and surgical rates have nearly doubled from 2000 to 2009. Finally, health care charges have shown a dramatic increase in just 9 years, which places an added burden on an already stressed health care system.


