Sinogenic Intracranial Empyema in Children

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ABSTRACT. Background. Sinogenic intracranial empyema (SIE) is an uncommon complication of sinusitis that can lead to devastating neurologic sequelae. Early recognition of the clinical findings is critical so that proper management can be instituted.

Objective. To describe the symptoms, signs, and laboratory and imaging findings from one of the largest pediatric SIE case series reported.

Methods. Descriptive study of a retrospective cohort of all children admitted to Primary Children’s Medical Center with SIE between June 2000 and February 2004. Children were identified by a computerized search of Primary Children’s Medical Center medical records using the terms “sinusitis” and “brain/subdural/epidural empyema.” Erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) values of children with SIE were compared with a group of children with uncomplicated sinusitis cared for in the same health care system as outpatients. The medical records of the uncomplicated sinusitis group were not reviewed for any clinical or radiographic data other than CRP and ESR values.

Results. Twelve children with SIE were identified. The median age of children with SIE was 11.5 years. Symptoms were usually present 10 days (median) before diagnosis and included headache (10), fever (11), nausea/vomiting (7), mental-status changes (5), and seizures (3). Physical findings included abnormal neurologic examination (9), Pott’s puffy tumor (4), and orbital cellulitis (3). Using the Intermountain Health Care system’s computerized database, 142 children with uncomplicated sinusitis treated as outpatients were identified. Children with SIE had markedly higher CRP levels (median: 10.05 mg/dL) and ESRs (median: 87 mm/hour) than those with uncomplicated sinusitis (median CRP: 0.7 mg/dL; median ESR: 6 mm/hour). Four children had hyperglycemia. Four children had a lumbar puncture at presentation, and the findings were normal for all of them. Craniofacial imaging included computed tomography (CT) and magnetic resonance imaging (MRI). SIE was not detected in 4 patients who had nonenhanced CT. Axial imaging alone was unable to demonstrate SIE in 1 child with sphenoid and ethmoid sinusitis, and coronal images were needed to demonstrate its presence and extent. The initial facial/orbital imaging studies in 2 patients with physical signs of complicated sinusitis (orbital cellulitis and Pott’s puffy tumor) were not adequate to detect SIE. Using contrast-enhanced head CT or MRI, SIE was diagnosed in all 12 children.

Conclusions. Children with sinusitis and any neurologic finding, signs of complicated sinusitis such as Pott’s puffy tumor or orbital cellulitis, or persistent headache, fever, or nausea and vomiting after antibiotic therapy should have additional evaluation for SIE. Children with hyperglycemia or diabetes may be at increased risk for SIE. The ESR and CRP levels are markedly elevated in children with SIE and may be useful screening tools. MRI with gadolinium is the preferred method to diagnose SIE. If MRI is unavailable, a contrast-enhanced head CT with axial and coronal planes should be obtained. Nonenhanced CT alone lacks sensitivity, and a normal study may be falsely reassuring. Pediatrics 2005; 116:e461–e467. URL: www.pediatrics.org/cgi/doi/10.1542/peds.2004-2501; pediatric sinusitis, brain abscess, sinogenic intracranial empyema, intracranial infection, computed tomography.

ABBREVIATIONS: SIE, sinogenic intracranial empyema; PCMC, Primary Children’s Medical Center; ICD-9, International Classification of Diseases, Ninth Revision; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; IHC, Intermountain Health Care; WBC, white blood cell; CSF, cerebrospinal fluid; CT, computed tomography; CECT, contrast-enhanced computed tomography; NECT, nonenhanced computed tomography.

Acute bacterial sinusitis in children can be complicated by Pott’s puffy tumor, orbital or peri-orbital cellulitis, and epidural, subdural, or brain abscesses.1,2 The intracranial complications of sinusitis can result in devastating neurologic sequelae and may be life threatening.

Several case series have been published describing pediatric sinogenic intracranial empyema (SIE).3–11 However, the majority have been in specialty journals that may not be accessed routinely by primary care or emergency physicians.3–11 Our experience with SIE patients suggests that nearly all present initially to their primary care provider or an emergency department. Therefore, it is important that generalist pediatric care providers are aware of the clinical, laboratory, and radiographic findings associated with SIE so that prompt diagnosis and treatment can be provided.

We recently cared for a group of patients that were diagnosed with SIE at Primary Children’s Medical Center (PCMC) in Salt Lake City, Utah. Our objective was to describe their symptoms, signs, and laboratory findings and offer suggestions for screening that may lead to earlier diagnosis in patients with SIE.

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METHODS
Approval to conduct this research was obtained by the University of Utah Health Sciences Center Institutional Review Board.

Identification of Patients With SIE and Comparison Group
In this study, SIE includes subdural, epidural, and parenchymal brain abscesses or empyema. Patients with SIE who were treated at PCMC between June 2000 and February 2004 were identified by query of the hospital’s computerized medical-record database. PCMC is a 252-bed urban children’s hospital that serves as a community hospital for children from the Salt Lake City metropolitan area and as a tertiary referral center for the rest of Utah and the 6 other states that comprise the Intermountain West, including Idaho, Montana, Wyoming, and portions of Nevada, Arizona, and western Colorado. Approximately 1 million children live in the region served by PCMC.

The search identified all medical records with the International Classification of Diseases, Ninth Revision (ICD-9) codes for acute bacterial sinusitis (461.0, 461.1, 461.2, 461.3, 461.8, and 461.9) and brain abscess/empyema (324.0), epidural abscess/empyema (324.9), or subdural abscess/empyema (324.9). Patients had to have a diagnosis of sinusitis as well as any type of intracranial empyema based on the discharge diagnosis codes to be included in the study. The identified records were cross-referenced with the billing records of the University of Utah Pediatric Infectious Diseases Division for case confirmation. This 4-member division is the exclusive provider of infectious disease consultation at PCMC. The same ICD-9 codes entered into the PCMC computerized medical-records database were entered into the division’s billing database. All but 1 of the patients identified by PCMC’s medical-records database matched those of the division.

We wanted to evaluate inflammatory markers, specifically erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP), in children with SIE. However, a review of the literature did not reveal expected values for children with uncomplicated sinusitis. Therefore, we chose to evaluate the CRP and ESR values of children of similar age with uncomplicated sinusitis treated as outpatients. Children 6 to 15 years old who were treated for sinusitis without complications in the outpatient setting functioned as our comparison group for ESR and CRP values only. The medical records of these 142 patients were not reviewed for any clinical or radiographic data. Children with immunologic compromising illnesses such as cystic fibrosis or cancer were excluded. The children with an ICD-9 diagnosis of acute bacterial sinusitis (461.0, 461.1, 461.2, 461.3, 461.8, or 461.9) who also had CRP and ESR testing performed were identified by using the computerized records of the Intermountain Health Care (IHC) Enterprise Data Warehouse. IHC is an integrated health care system located in Salt Lake City, Utah, and is the largest insurer of children and provider of pediatric services in the Intermountain West. IHC operates 20 hospitals and an extensive network of outpatient facilities throughout Utah and Idaho, including PCMC. Children treated within the IHC health care system may carry Medicaid, IHC, private, or no insurance.

Review of Medical Records
The medical records of children with SIE were reviewed retrospectively for age, gender, ethnicity, underlying conditions before diagnosis, duration of symptoms before admission, presenting symptoms, neurologic findings, and clinical outcomes. We recorded laboratory data including CRP level, ESR, white blood cell (WBC) count, and, when present, blood glucose levels at the time of admission, glycosylated hemoglobin, and cerebrospinal fluid (CSF) profiles.

Review of Radiographic Records
The computed tomography (CT) scans and magnetic resonance imaging (MRI) findings were reviewed blindly by a board-certified pediatric neuroradiologist (G.H.) to obtain an unbiased opinion. The neuroradiologist’s retrospective interpretation was compared with the original computerized radiology report obtained at the time of presentation. The results of his readings are reported in the figure legends.

Statistical Analysis
CRP and ESR means, medians, and 25% and 75% quartiles for the SIE and the uncomplicated sinusitis groups were obtained. We compared the CRP and ESR values of children with SIE to the CRP and ESR values of children with uncomplicated sinusitis by using the Mann-Whitney test. In children with SIE, we compared the findings from brain contrast-enhanced CT (CECT) and MRI with enhancement to other modalities including nonenhanced CT (NECT) of the orbits or maxillofacial region. Fisher’s exact test was used to compare the diagnostic yield of the different radiographic studies. A $P$ value of $\leq.05$ was considered significant in both analyses.

RESULTS

Patients
We identified 12 patients with SIE and 142 with uncomplicated sinusitis. Demographic and clinical data for the SIE patients are shown in Tables 1 and 2.

Clinical Findings
The following results reflect only the SIE group. The median and 25% to 75% quartiles for the duration of symptoms were 10 and 4.75 to 36.25 days, respectively. Three patients had a history of nasal congestion or rhinorrhea. Other symptoms included fever (11), headache (10), nausea/vomiting (7), first-time seizures (3), and mental-status changes (5) (Table 2). The median temperature was 38.3°C on the day of admission. Physical findings included abnormal neurologic examination (9), Pott’s puffy tumor (4), and orbital cellulitis (3). Three patients had a normal neurologic examination on admission.

Laboratory Data
All children with SIE showed evidence suggestive of a bacterial infection when a combination of routinely available laboratory tests including WBC count, CRP level, and ESR were administered. The median WBC count was 16.8 μL (25–75% quartiles were 13.9–19 μL) with a range of 10.4 to 20.1 μL. The differential for 10 patients showed elevated neutrophils. For the SIE group, the CRP level (range: 0.7–84 mg/dL) and ESR (range: 17–123 mm/hour) mean, median, and 25% to 75% quartiles were 18.1, 10.05, and 3.53 to 22.93 mg/dL and 82, 87, and 63.25 to 105.5 mm/hour, respectively. For the uncomplicated-sinusitis group, the CRP level (range: 0.1–15.8 mg/dL) and ESR (range: 0–59 mm/hour) mean, median, and 25% to 75% quartiles were 3.0, 0.7, and 0.7 to 5 mg/dL and 10.3, 6.0, and 3.0 to 12.0 mm/hour, respectively. The difference between the SIE and the uncomplicated-sinusitis groups was significant for CRP level and ESR ($P \leq .001$ for both). Patients 1, 3, 4, and 11 had lumbar punctures during the first presentation, and all had a normal CSF WBC count.

TABLE 1.  Collective Demographic and Clinical Data

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Median Age, y (range)</th>
<th>25–75 Quartiles</th>
<th>Male Gender, %</th>
<th>Race/Ethnicity, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11.5 (6–21)</td>
<td>7.75–14</td>
<td>6 (50)</td>
<td>White 9 (75)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hispanic 2 (17)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Native American 1 (8)</td>
</tr>
<tr>
<td>Case</td>
<td>Age, y/Gender/Ethnicity</td>
<td>Temperature, °C</td>
<td>Symptoms (Duration, d)</td>
<td>Neurologic Findings</td>
</tr>
<tr>
<td>------</td>
<td>------------------------</td>
<td>----------------</td>
<td>------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>1</td>
<td>6 y/M/W</td>
<td>38.3</td>
<td>Headache, N/V, fever, photophobia, neck pain (14)</td>
<td>Foot drop, leg weakness and numbness</td>
</tr>
<tr>
<td>2</td>
<td>14/M/H</td>
<td>40.3</td>
<td>Headache, N/V, fever, eye pain, decreased EOM, seizure (42)</td>
<td>Diplopia, MS changes</td>
</tr>
<tr>
<td>3</td>
<td>10/F/H</td>
<td>39/39.8</td>
<td>Headache, N/V, fever, malaise, seizure with status, (42)</td>
<td>MS changes, obtunded</td>
</tr>
<tr>
<td>4</td>
<td>14/F/W</td>
<td>37.4</td>
<td>Headache, malaise, dizziness, hyper-ventilation, stiff neck (10)</td>
<td>Arm numbness, twitching, facial numbness</td>
</tr>
<tr>
<td>5</td>
<td>14/M/W</td>
<td>37.0</td>
<td>Headache, N/V, fever, confusion, odd behavior (7)</td>
<td>Dragging foot gait, slurred speech, obtunded</td>
</tr>
<tr>
<td>6</td>
<td>7/F/W</td>
<td>37.4</td>
<td>Headache, N/V, fever (180)</td>
<td>Clonus, hyperreflexia, asymmetric plantar reflexes</td>
</tr>
<tr>
<td>7</td>
<td>6/M/NA</td>
<td>39.2</td>
<td>Fever, mouth pain, limping, shoulder pain with decreased ROM (10)</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>12/M/W</td>
<td>38.8</td>
<td>Headache, fever, nasal congestion, eye swelling with proptosis (2)</td>
<td>None</td>
</tr>
<tr>
<td>9</td>
<td>15/F/W</td>
<td>37.3</td>
<td>Headache, N/V, fever, nasal drainage, sustained grip, unilateral leg/arm weakness and tingling, seizure with status (10)</td>
<td>Arm drift, foot drag, hyperreflexia, MS changes</td>
</tr>
<tr>
<td>10</td>
<td>11/F/W</td>
<td>37.8</td>
<td>Headache, fever, hairline tenderness, right-sided weakness, dysarthria (19)</td>
<td>Decreased movement and sensation, MS changes</td>
</tr>
<tr>
<td>11</td>
<td>21/M/W</td>
<td>38.6</td>
<td>Fever, lethargy, rhinorrhea, periorbital swelling (2)</td>
<td>Lethargy</td>
</tr>
<tr>
<td>12</td>
<td>10/F/W</td>
<td>37.5</td>
<td>Headache, N/V, fever (4)</td>
<td>None</td>
</tr>
</tbody>
</table>

M indicates male; F, female; W, white; H, Hispanic; NA, Native American; N/V, nausea/vomiting; EOM, extraocular movements; FHT2DM, family history of type 2 diabetes mellitus; VP, ventriculoperitoneal; MS, mental status; ROM, range of motion; PPT, Pott's puffy tumor; UE, upper extremity; NG, no growth; N/A, not applicable; S, sinus surgery; C, craniotomy; I and D, incision and drainage.
Four patients had glucose values that were >120 mg/dL at the time of admission. Three of these children had a family history of type 2 diabetes mellitus. In addition to their positive family history for type 2 diabetes mellitus, 2 of these children were Latino and obese and had acanthosis nigricans. One of these patients (3) did develop diabetes that required treatment with oral hypoglycemics as an outpatient while she was no longer acutely ill. Her blood glucose levels normalized, and she no longer required medical therapy after she lost 40 pounds. She was also our patient with the worst outcome. Hemoglobin A1C was drawn on 4 children, and these levels ranged from 4.6% to 6.5%.

The microbiologic data available for children with SIE are shown in Table 2. All but 1 case of SIE had pathogenic bacteria recovered from sinuses, intracranial spaces, or both. Infections were polymicrobial in 6 patients. The flora represented included Gram-positive organisms in 10 patients, Gram-negative organisms in 3 patients, and fungus in 1. Mixed aerobic and anaerobic infections were documented in 3 patients. Although treatment of SIE was not the focus of this investigation, all patients received treatment with broad-spectrum antibiotics to cover Gram-positive organisms, Gram-negative organisms, and anaerobes as recommended based on previous studies.

**Radiographic Data**

CT and/or MRI were performed on all children with SIE (Table 3). All patients had radiographic evidence of sinus disease. The frontal and ethmoid sinuses were the most affected in this series. Nine patients had frontal sinus involvement, 9 with ethmoid, 7 with sphenoid, and 6 with maxillary sinus opacification (Table 3).

Seven patients had frontal disease and no rhinorrhea, whereas 2 of the patients with frontal involvement did have rhinorrhea. Six patients with maxillary disease had no rhinorrhea and 1 patient with maxillary sinusitis did. There was 1 patient with exclusively sphenoid and ethmoid disease and no rhinorrhea. The 3 patients with rhinorrhea had a combination of maxillary (1), frontal (2), ethmoid (3), and sphenoid (1) sinusitis.

Images from NECT and CECT obtained at the same time from 1 of our patients are shown in Fig 1. The NECT was read as normal, whereas the CECT demonstrated an interhemispheric epidural abscess that required neurological drainage by showing increased attenuation of the brain parenchyma and decreased attenuation of SIE, allowing the abscess to be easily appreciated.

The diagnosis of SIE was delayed in 1 patient with sphenoid and ethmoid sinusitis who had axial NECT imaging alone (Fig 2A). The initial scan was read as normal. The patient returned 3 days later complain-

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**TABLE 3. Radiographic Data**

<table>
<thead>
<tr>
<th>Case</th>
<th>Initial Radiographic Study</th>
<th>Diagnosis Made?</th>
<th>Time to Diagnosis After Initial Study, d</th>
<th>Diagnostic Study</th>
<th>Sinuses Involved</th>
<th>Intracranial Infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Axial brain CT with and without contrast</td>
<td>Yes</td>
<td>N/A</td>
<td>CECT of brain</td>
<td>Frontal, maxillary, sphenoid</td>
<td>Right frontal and interhemispheric subdural abscess</td>
</tr>
<tr>
<td>2</td>
<td>CT of orbits with contrast</td>
<td>No</td>
<td>4</td>
<td>MRI of brain</td>
<td>Frontal, maxillary, ethmoid, sphenoid</td>
<td>Left frontal epidural abscess with interhemispheric extension</td>
</tr>
<tr>
<td>3</td>
<td>Axial brain CT without contrast</td>
<td>No</td>
<td>36</td>
<td>CECT of brain</td>
<td>Frontal, maxillary, ethmoid, sphenoid</td>
<td>2 left frontal lobe brain abscesses</td>
</tr>
<tr>
<td>4</td>
<td>Axial brain CT without contrast</td>
<td>No</td>
<td>3</td>
<td>MRI and CECT, coronal image</td>
<td>Frontal, maxillary, ethmoid, sphenoid</td>
<td>Left middle cranial fossa epidural abscess</td>
</tr>
<tr>
<td>5</td>
<td>Maxillofacial CT</td>
<td>Yes (midline shift)</td>
<td>N/A</td>
<td>CECT of brain</td>
<td>Frontal, maxillary, ethmoid, sphenoid</td>
<td>Left middle cranial fossa epidural abscess</td>
</tr>
<tr>
<td>6</td>
<td>MRI of brain</td>
<td>Yes</td>
<td>N/A</td>
<td>MRI of brain</td>
<td>Frontal</td>
<td>Right frontal brain abscess</td>
</tr>
<tr>
<td>7</td>
<td>MRI of brain</td>
<td>Yes</td>
<td>N/A</td>
<td>MRI of brain</td>
<td>Maxillary, ethmoid</td>
<td>Right middle cranial fossa abscess</td>
</tr>
<tr>
<td>8</td>
<td>Maxillofacial CT without contrast</td>
<td>Yes (intracranial gas)</td>
<td>N/A</td>
<td>CECT of brain</td>
<td>Maxillary, ethmoid</td>
<td>Left-sided interhemispheric abscess</td>
</tr>
<tr>
<td>9</td>
<td>Axial brain CT without contrast</td>
<td>Yes (mild-mass effect)</td>
<td>N/A</td>
<td>CECT of brain</td>
<td>Frontal, ethmoid</td>
<td>Right frontal epidural abscess</td>
</tr>
<tr>
<td>10</td>
<td>Axial brain CT with contrast</td>
<td>Yes</td>
<td>N/A</td>
<td>CECT of brain</td>
<td>Frontal</td>
<td>Left frontal subdural abscess</td>
</tr>
<tr>
<td>11</td>
<td>Axial brain CT with and without contrast</td>
<td>Yes</td>
<td>N/A</td>
<td>CECT of brain</td>
<td>Frontal, ethmoid, sphenoid</td>
<td>Right frontal epidural abscess</td>
</tr>
<tr>
<td>12</td>
<td>Maxillofacial CT without contrast</td>
<td>No</td>
<td>2</td>
<td>CECT of brain</td>
<td>Frontal, maxillary, ethmoid, sphenoid</td>
<td>Left frontal epidural abscess</td>
</tr>
</tbody>
</table>

N/A indicates not applicable.
ing of severe headache and transient facial numbness; at this time an MRI was performed that demonstrated an SIE. A coronal cranial CECT also showed SIE extending into the middle cranial fossa. The subdural collection was not seen easily on axial CECT images alone. Coronal images were needed to demonstrate SIE and define the extent of disease (Fig 2).

Finally, 2 patients with physical evidence of complicated sinusitis, including orbital abscess or Pott’s puffy tumor, did not have a brain CT performed on presentation. One of these patients was diagnosed with orbital cellulitis based on a CT scan of the orbits. Four days after admission, the patient developed mental-status changes, and an MRI of the brain and an orbital CT with a more extensive field of view revealed a small epidural fluid collection and subperiosteal abscess requiring neurosurgical drainage.

Overall, SIE was not visualized in 4 patients who had axial NECT and 2 patients with orbital or sinus CT only, 4 of whom had a delay in diagnosis of SIE. NECT and/or sinus CT that did not include the entire brain in the field of view was able to diagnose

Fig 1. Anterior parafalcine subdural empyema. A, NECT shows a subtle right anterior parafalcine region of increased fluid attenuation (arrow). B, CECT shows perimeter enhancement of the right parafalcine subdural empyema (arrows).

Fig 2. Left subtemporal epidural empyema. A, NECT of the brain shows moderate streak artifact within the middle cranial fossa. B, Axial CECT of the brain shows subtle left middle cranial fossa dural thickening and enhancement (arrow). C, Coronal CECT examination of the brain shows a small left subtemporal epidural empyema (arrow).
SIE only in patients with late findings such as midline shift or intracranial gas (Table 3). In contrast, brain CECT or MRI was able to demonstrate SIE in all 12 children \( (P \leq .006 \text{ when compared with other modalities}) \).

**Clinical Outcomes**

Nine children had neurologic compromise of varying degrees related to SIE (Table 2) at the time of admission. Patient 3 developed increased intracranial pressure and cerebral herniation in the outpatient setting. She required temporary gastric tube feedings and, 12 months after the event, is cognitively delayed and has severe expressive aphasia. Six patients had a normal or baseline neurologic examination at the time of discharge, whereas the remaining 6 patients sustained a wide spectrum of neurologic deficits (Table 2). There were no deaths in this series.

**DISCUSSION**

SIE is a rare complication of bacterial sinusitis and may be difficult to diagnose. We present a pediatric case series with radiographically and microbiologically confirmed SIE. The clinical triad of fever, headache, and altered mental status is often reported in adults\(^3\) was seen in only half of the pediatric patients in our series. The case series that we present highlights the variable clinical presentation as well as important laboratory and radiographic findings in children with SIE.

Many of the children presented with nonspecific complaints such as fever, headache, and nausea or vomiting. The temperatures documented in the outpatient setting for children with SIE were relatively low, and 1 child was afebrile by history. Similar to findings reported by others, only one quarter of the children in our series had symptoms of nasal congestion, rhinorrhea, or cough that might be expected to accompany acute sinusitis.\(^3\)–\(^9\) All of our patients had radiographic evidence of sinusitis. Previous studies have suggested that patients who don’t drain their sinuses well may be at higher risk for developing SIE because the infection is more likely to extend intracranially along the valveless diploic veins.\(^5\) For this reason, physicians must have a high index of suspicion of SIE even in the absence of nasal drain-

age. Most reports of pediatric SIE have suggested that this entity predominantly affects adolescent males.\(^3\)–\(^6,8,10\) Our results were strikingly different; the median age was <12 years, and females were equally likely to be affected.

Three children presented with new-onset seizures. These children would not be expected to have benign febrile seizures, because they were >5 years old. Physicians should consider the possibility of SIE in children with a new-onset seizure, especially in those who might also have a history of persistent headache, nausea, vomiting, or fever, even if signs and symptoms suggestive of acute sinusitis are not present.

The physical examination may also be suggestive of SIE. Half of the patients in this series presented with known complications of sinusitis including tooth abscess, Pott’s puffy tumor, and orbital cellulitis. The ophthalmology and otolaryngology literature cites orbital and periorbital infections as the most common complication of sinusitis.\(^11\)–\(^14\) Herrmann and Forsen\(^15\) recently described a case series in which 4 of 43 pediatric patients >7 years old admitted for orbital sinogenic complications were also diagnosed with intracranial infections. Reynolds et al\(^16\) also reported a case series of 10 immunocompetent pediatric patients with periorbital or orbital cellulitis and concurrent SIE. Four of their patients also had Pott’s puffy tumor. The association between Pott’s puffy tumor and SIE has been well described in the literature.\(^17,18\) Although rare, odontogenic sinusitis has also been associated with SIE\(^19\) as in the case of our patient with tooth abscesses. Our findings along with those of others emphasize the critical need to perform appropriate imaging of the brain and its coverings in addition to the orbits and maxillofacial region in patients who present with signs of known sinogenic complications.\(^3,4,7,15,16\)

In addition to physical findings, laboratory data may be helpful in determining which children might benefit from imaging of the brain. Our data are the first to compare inflammatory markers in children with uncomplicated sinusitis to children with SIE, although others have reported elevated ESR and/or WBC count in their SIE patients.\(^6,16\) Although this study does not determine a value in which CRP and ESR can distinguish SIE from uncomplicated sinusitis, it does show that CRP level and ESR can be useful screening tools in this situation. Most patients with uncomplicated sinusitis in our study did not have CRP and ESR values in the range of SIE patients.

Hyperglycemia was encountered in 33% of our patients during the acute illness, and 1 patient had evidence of type 2 diabetes that responded to oral hypoglycemics and weight loss after the acute illness. We cannot ascertain whether the hyperglyce-

mia in these children was causative or a result of the SIE. The 4 children who had hemoglobin A1C testing were in the non diabetic range. Others have noted an apparent association between SIE and hyperglycemia. Johnson et al\(^6\) reported that 1 of their patients was hyperglycemic, with a blood sugar level of 210 mg/dL on admission. The apparent association between hyperglycemia and SIE warrants additional study, especially because of the rising incidence of childhood obesity and type 2 diabetes in the United States. At present, we would suggest that screening for diabetes or insulin resistance should be considered in all children with SIE.

The frontal and ethmoid sinuses were the most affected in the children in this case series, and more than half of the patients had sphenoid sinus involvement. Previous studies have shown that the frontal and ethmoid sinuses are most commonly infected in patients with SIE,\(^4,5,7,9,11\) and Saxton et al\(^3\) suggested that when these 2 sinuses are involved, it must be considered clinically significant in the context of suspecting intracranial infection. Our study emphasizes the importance of sphenoid sinusitis in patients with
SIE. There did not seem to be a relationship between the presence of nasal drainage and the sinuses affected, although the 3 children with rhinorrhea did have either maxillary or frontal sinusitis.

After a physician decides which child to image for SIE, the correct study must be obtained. Our study suggests that contrast-enhanced MRI and CECT are the most useful studies for evaluating SIE. When CECT is performed, it is imperative that axial and coronal planes are obtained and that the images extend through the frontal sinuses, the convexity of the frontal bone, and through the sella and parasellar regions to avoid missing SIE adjacent to the sphenoid or ethmoid sinuses within the anterior and middle cranial fossae and small abscesses that may not be apparent without contrast because of the similarity of texture of brain parenchyma and the abscess itself. The high cuts will avoid missing the epidural abscesses or interhemispheric abscesses that may not be visualized with a maxillofacial or orbital CT scan alone. This type of CT scan has been recommended in other series and in the clinical practice guideline for the management of sinusitis by the American Academy of Pediatrics.

MRI with gadolinium remains the gold standard for diagnosing any sinogenic intracranial complication. However, not all institutions have access to MRI technology, and an MRI often cannot be obtained on an emergent basis. If a CT scanner is available, a CECT of the brain and sinuses with axial and coronal planes should be obtained in all patients suspected of having SIE.

Our study has several limitations. First, the study is limited by its retrospective design. We cannot draw any conclusions regarding the risk of SIE in children with sinusitis. Second, because some children with SIE may have been miscoded or misdiagnosed or the discharge diagnosis of some children with SIE may not have included the diagnosis of sinusitis, there is the possibility of incomplete ascertainment. Third, the number of cases is relatively small. However, it represents one of the largest published case series of children with SIE.

Despite its limitations, our report highlights the important laboratory and radiographic findings in children with SIE. Knowledge of these findings will enable clinicians to improve their ability to promptly identify and treat children with SIE.

CONCLUSIONS

Children with sinusitis and any focal neurologic abnormality, seizures, orbital cellulitis, Pott’s puffy tumor, or persistent headache, fever, nausea, or vomiting despite antibiotic therapy warrant additional evaluation for SIE with MRI or CECT. MRI is the preferred method to diagnose SIE, but if unavailable, CECT of the brain, face, and orbits with axial and coronal planes should be obtained. NECT alone should be avoided, because the technique lacks sensitivity, and a normal study may be falsely reassuring and thus lead to a delay in diagnosis.

WBC count, ESR, and CRP level are markedly elevated in children with SIE and may be useful in deciding which children should be imaged.

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