Intracranial Complications of Sinusitis in Children and Adolescents and Their Outcomes

John A. Germiller, MD, PhD; Daniel L. Monin, MD; Anthony M. Sparano, MD; Lawrence W. C. Tom, MD

Objective: To gain insight into patterns of presentation, imaging, microbiological aspects, therapy, disease course, and outcome of intracranial complications of sinusitis (ICS), which are challenging conditions with the potential to cause significant morbidity and mortality. We reviewed our experience with ICS in children and adolescents.

Design: Consecutive case series with a mean follow-up of 12 months.

Setting: Tertiary pediatric referral center.

Patients: Consecutive sample of 25 children and adolescents treated for 35 intracranial complications (mean age, 13.2 years [range, 4-18 years]).

Interventions: Medical and surgical management.

Main Outcome Measures: Survival and temporary and permanent neurologic sequelae.

Results: Most patients were adolescents (n=19; 76%) and male (n=19; 76%). Epidural abscess was most common (13 complications), followed by subdural empyema (n=9), meningitis (n=6), encephalitis (n=2), intracerebral abscess (n=2), and dural sinus thrombophlebitis (n=2). Abscesses were primarily located in the frontal or frontoparietal regions. Magnetic resonance imaging was extensively used and was superior to contrast computed tomography in diagnosis. All patients received intravenous antibiotics, 21 underwent endoscopic sinus surgery, and 13 underwent neurosurgical drainage. Only 1 death occurred from sepsis secondary to meningitis (mortality, 4%). Overall, neurologic outcome was excellent. Although 10 patients (40%) had neurologic deficits, most resolved within 2 months. Only 2 patients had permanent neurologic sequelae. Among ICS, epidural abscesses appeared to be a distinct clinical entity. Epidural abscesses typically presented without specific neurologic symptoms or signs, were more often associated with orbital complications, and had outcomes considerably better than the other ICS.

Conclusion: Intracranial complications of sinusitis are challenging, but prognosis can be favorable in children and adolescents by using aggressive medical and surgical management.

Arch Otolaryngol Head Neck Surg. 2006;132:969-976
though rates under 10% have been reported in several studies. From the institutional databases of inpatient admissions and outpatient visits, procedures, and admissions. The study was approved by the institutional review board of The Children’s Hospital of Philadelphia, Philadelphia, Pa.

### METHODS

A consecutive sample of 25 children with ICS was identified, who were treated between January 1, 1999, and April 30, 2004. From the institutional databases of inpatient admissions and otolaryngology consultations, patients whose admission or discharge diagnoses included central nervous system infection (which includes intracranial abscesses, meningitis, encephalitis, and dural sinus thrombophlebitis), were crossed with procedure codes for sinus surgery (endoscopic or external) or for diagnoses of either acute or chronic sinusitis. Screening of inpatient records to confirm intracranial complications yielded 25 subjects. Data were then collected from complete inpatient records, as well as postdischarge outpatient visits, procedures, and admissions.

### RESULTS

Twenty-five consecutive children with ICS were identified during the study period. Nineteen (76%) were male, and most (n = 19; 76%) were 12 years or older (15 [60%] were male adolescents). The mean age was 13.2 years (range, 4.6-18.1 years). Thirteen patients (52%) were transferred from outside hospitals. The average length of stay was 10 days (range, 4-24 days). There was 1 death in our series, and of the 24 survivors, only 1 was lost to follow-up. All of the remaining patients had at least 2 months of follow-up data (range, 2-50 months; mean, 11.9 months).

### COMPLICATIONS

There were 35 intracranial complications in the 25 patients (Table 1). Intracranial collections predominated. Epidural abscess was the most common, and 12 of the 13 epidural abscesses were frontal. Nine subdural empyemas occurred, all located anteriorly, and there were 2 intracerebral abscesses. Nine patients (36%) had 2 or more concurrent intracranial complications. These included 5 patients having 2 distinct abscesses, 3 patients with meningitis who also had encephalitis and/or dural sinus thrombosis, and 1 patient who had middle cerebral artery ischemia complicating a frontoparietal subdural empyema (Table 1). Eleven patients (44%) also had 1 or more simultaneous extracranial complications. Most were orbital infections. Of the 10 patients who had extracranial complications, 7 (70%) had epidural abscesses as their intracranial complication.

### PRESENTATION

Presenting symptoms and history were available in 24 cases. All patients were previously healthy, with no conditions causing immunodeficiency. The mean duration of symptoms was 12 days (range, 1-75 days). Nonspecific symptoms predominated, with most complaining of fever (n = 18; 75%), headache (n = 16; 67%). Over half had a facial mass or swelling at presentation (n = 13; 54%). Notably, only 4 patients had any history of sinusitis, and none had prior sinus surgery. Presenting examination findings were available in 22 patients. Fever was measured in the majority (n = 12; 55%), and facial mass or edema was common (n = 12; 45%). Ocular findings were common (abnormal visual examination [n = 12; 18%] and ophthalmoplegia and/or proptosis [n = 12; 14%]) and occurred mainly in patients having associated peri-orbital

---

**Table 1. Intracranial and Simultaneous Extracranial Complications**

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. (%)</th>
<th>Complications, No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intracranial Complications</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epidural abscess</td>
<td>13 (52)</td>
<td></td>
</tr>
<tr>
<td>Frontal</td>
<td>12 (48)</td>
<td></td>
</tr>
<tr>
<td>Middle fossa</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td>Subdural empyema</td>
<td>9 (36)</td>
<td></td>
</tr>
<tr>
<td>Frontal</td>
<td>5 (20)</td>
<td></td>
</tr>
<tr>
<td>Frontoparietal, frontotemporal, or</td>
<td>4 (16)</td>
<td></td>
</tr>
<tr>
<td>frontotemporoparietal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meningitis (without abscess)</td>
<td>6 (24)</td>
<td></td>
</tr>
<tr>
<td>Encephalitis (without abscess)</td>
<td>2 (8)</td>
<td></td>
</tr>
<tr>
<td>Intracerebral abscess</td>
<td>2 (8)</td>
<td></td>
</tr>
<tr>
<td>Dural sinus thrombophlebitis</td>
<td>2 (8)</td>
<td></td>
</tr>
<tr>
<td>Cavernous sinus</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td>Cavernous/superior sagittal sinus</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td>Middle cerebral artery ischemia</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td>Total intracranial complications</td>
<td>35 (100)</td>
<td>25 (100)</td>
</tr>
</tbody>
</table>

| Simultaneous Extracranial Complications | No. (%) | | Complications, No. (%) |
|-----------------------------------------|---------| |                        |
| Orbital/periorbital cellulitis           | 5 (20)  | |                        |
| Orbital/periorbital abscess             | 4 (16)  | |                        |
| Forehead abscess                        | 2 (8)   | |                        |
| Total simultaneous extracranial         | 11 (40) | |                        |
| complications                           |         | |                        |

*Percentages may not add to total sums owing to rounding.
cellulitis or abscesses. Of the 24 patients with available history, most (n = 14; 58%) lacked any central neurologic symptoms at presentation, and of the 22 patients with available physical examination findings, most (n = 13; 59%) had a normal neurologic examination result. The most common neurologic symptom was mental status change (n = 7; 29%). In the 9 patients with an abnormal neurologic examination result, hemiparesis was the most common finding (n = 5; 23%).

Because neurologic deficits at presentation have prognostic significance, patients were divided into 2 groups based on neurologic findings (Table 2). The presence of neurologic signs and symptoms correlated strongly with both the type of ICS and presence of extracranial complications. In the group lacking any central neurologic symptoms or signs, nearly all the patients had epidural abscesses. Their presentations were dominated by signs and symptoms referable to the eye and forehead. This was consistent with the high prevalence of concomitant extracranial, particularly orbital, complications in this group. By contrast, in the group presenting with neurologic findings, every patient was diagnosed with at least 1 of the more serious complications (meningitis, encephalitis, cerebroabscs, subdural empyema, and dural sinus thrombosis). Simultaneous extracranial complications were far less common in this group.

IMAGING

All 25 patients underwent CT (15 with contrast), and 19 also underwent MRI (Table 3). Magnetic resonance imaging was more sensitive than contrast CT, being diagnostic for 93% of complications. Magnetic resonance imaging was very sensitive for meningeal enhancement, either alone in cases of meningitis or adjacent to the focal collections. Meningeal enhancement was demonstrated in 17 of the 19 studies. By comparison, CT detected only 12 of 19 complications (sensitivity, 63%). Of the 7 patients for which CT was nondiagnostic, there were 2 cases of meningitis with normal study results and 5 intracranial collections in which the CT result, while not diagnostic, was abnormal enough to prompt further studies (all were later found on MRI). Sinus disease was equally well demonstrated on both CT and MRI, with 100% concordance found between the two in identifying involved sinuses. Nineteen patients (76%) had bilateral involvement of more than 1 sinus, and 12 (48%) had bilateral pansinusitis. Frontal sinusitis was present in 19 of the

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Intracranial Complication</th>
<th>Presentation*</th>
<th>Simultaneous Extracranial Complication</th>
<th>Outcome Group†</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>EA</td>
<td>Ocular symptoms, eye swelling, fever, HA, and N/V</td>
<td>Orbital cellulitis</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>EA</td>
<td>Fever, HA, and cough</td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>EA</td>
<td>Frontal pain, forehead swelling, eye swelling, photophobia, fever, and N/V</td>
<td>Orbital cellulitis and forehead edema</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>EA</td>
<td>Forehead and eye swelling</td>
<td>Orbital cellulitis</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>EA</td>
<td>Forehead swelling, ocular symptoms, and N/V</td>
<td>Subgaleal forehead abscess</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>EA</td>
<td>Photophobia, ocular symptoms, fever, and HA</td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>EA</td>
<td>Forehead swelling and pain, fever, HA, and N/V</td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td>23</td>
<td>EA</td>
<td>Ocular symptoms and proptosis</td>
<td>Orbital/periorbital abscess</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>EA</td>
<td>Ocular symptoms, proptosis, frontal pain, and HA</td>
<td>Orbital/periorbital abscess</td>
<td>2</td>
</tr>
<tr>
<td>21</td>
<td>EA and SE</td>
<td>Eye swelling and pain, and rhinorrhea</td>
<td>Orbital/periorbital abscess</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>EA and SE</td>
<td>Fever, HA, and photophobia</td>
<td>None</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>SE</td>
<td>Proptosis, fever, and N/V</td>
<td>Orbital cellulitis</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>Menin</td>
<td>Eye swelling, rhinorrhea, and fever</td>
<td>Orbital cellulitis</td>
<td>1</td>
</tr>
</tbody>
</table>

*Ocular symptoms include eye pain, swelling, vision changes, diplopia, and photophobia.
†Neurologic outcomes (see Table 6).

Table 2. Neurologic Presentation of Patients

Abbreviations: DST, dural sinus thrombophlebitis; EA, epidural abscess; Enceph, encephalitis; HA, headache; IA, intracerebral abscess; MCA, middle cerebral artery; Menin, meningitis; MS, mental status; N/V, nausea/vomiting; SE, subdural empyema.

©2006 American Medical Association. All rights reserved.
20 patients who had significant anatomic development of the frontal sinus.

MICROBIOLOGICAL EVALUATION

Cultures of the abscesses, sinus cavities, and/or peripheral blood were performed in all patients (Table 4). Positive cultures were obtained in all but 1 patient, for a total of 49 isolates. Multiple organisms grew in cultures from 13 patients (54%). *Streptococcus* species predominated (n=26; 53%), and the *Streptococcus milleri* group was most common. *Staphylococcus* species, particularly coagulase-negative species, were also common. By metabolism, most organisms were either facultative anaerobes (n=23; 47%) or aerobes (n=18; 37%). Only 7 isolates (14%) were strict anaerobes, the most common of which was *Peptostreptococcus*. No *Bacteroides* species were identified. We did not observe any relationships between organism type and the type of ICS or neurologic outcome.

MEDICAL/SURGICAL MANAGEMENT

All patients received intravenous antibiotics. All but 1 patient received combination therapy, with the most common combination (16 patients [67%]) being vancomycin hydrochloride, a third-generation cephalosporin, and metronidazole. At discharge, all patients were maintained on intravenous antibiotics until completing 2 to 6 weeks of intravenous therapy. Anticoagulation was used in both patients with dural sinus thrombophlebitis.

Twenty-one patients underwent endoscopic sinus surgery (ESS) (Table 5). Of the 3 patients who did not, 2 had diffuse meningitis or disseminated encephalomyelitis that responded to medical therapy and 1 had bilateral frontal trephination alone. Revision sinus surgery was performed in 10 patients, mostly as planned procedures after discharge. Thirteen patients, all with intracranial abscesses, underwent neurosurgical drainage procedures. Pus was found in all cases. Cranialization of the frontal sinus was needed in only 1 patient. Neurosurgical procedures were not performed in 5 smaller intracranial abscesses.

OUTCOME

Neurologic outcome was favorable, with only 1 death (mortality, 4%) and 2 patients with permanent neurologic deficits (long-term morbidity, 8%). To help identify factors associated with better outcome, patients were assigned to 3 outcome groups based on neurologic morbidity (Table 6). Group 1 comprised 14 patients who never had neurologic deficits at any time during admission, at discharge, or in follow-up; group 2, 8 patients with neurologic deficits that ultimately resolved; and group 3, 3 patients who had permanent neurologic sequelae or who died.

Most patients in the best outcome group had epidural abscesses, with 8 being isolated epidural abscesses. The 2 patients with intracerebral abscesses also fell into this group. At presentation, only 4 patients in group 1...
had any neurologic findings, and these were mild (mental status changes, nystagmus, and neck stiffness); the remainder had nonspecific symptoms or orbital or facial swelling. Symptoms had been present for an average of 13 days, and patients were hospitalized an average of 9.7 days. In contrast, group 2 patients experienced short-term sequelae, the most common of which were seizures and hemiparesis. These deficits had resolved by the time of discharge in half of these patients. Of the remaining 4 patients with deficits at discharge, 3 had hemiparesis that resolved within 2 months of follow-up, and 1 patient had speech deficits that resolved within 1 month. Six patients received prophylactic phenytoin for several days to 4 months. Most patients in this group (6 of 8) had subdural empyemas. At presentation, the majority (5 of 8) had central neurologic symptoms, all of which were serious, including 4 presenting with hemiparesis. Disease also had a more fulminant onset than for group 1 patients, with a mean duration of symptoms of only 4.3 days. The mean length of stay was similar (9 days).

Two patients had permanent neurologic deficits and 1 died (Table 6, group 3). Patient 1 had a frontotemporal subdural empyema complicated by rapidly rising intracranial pressure. He underwent emergent hemicraniectomy and ESS and survived but has permanent hemiparesis, expressive aphasia, seizure disorder, and a ventriculoperitoneal shunt. Patient 11 has permanent sensorineural hearing loss resulting from meningitis but no other long-term sequelae. The 1 death (patient 10) involved a 12-year-old boy with group C streptococcal meningitis, cavernous and superior sagittal sinus thrombosis, and a peri-orbital abscess, who developed seizures, obtundation, overwhelming sepsis, and respiratory distress syndrome at an outside facility and was transferred to our institution in pulmonary failure. His status worsened over his 15-day admission, and he died from septicemia.

### COMMENT

Intracranial infections are uncommon but potentially devastating complications of sinusitis. Diagnosis and management of ICS are challenging and require close collaboration among specialists in otolaryngology, neurosurgery, infectious disease, neurology, and rehabilitative medicine. Fortunately, the incidence of ICS has declined considerably in recent decades with improvements in the diagnosis and management of sinusitis.

This review, to our knowledge, is the largest pediatric series to date, suggests that outcomes can be favorable in children with prompt diagnosis and aggressive treatment.

In our series, ICS were caused exclusively by acute sinusitis, with no patient having a significant history of sinus disease nor any significant comorbidities. Furthermore, symptoms that would suggest sinusitis (eg, purulent rhinorrhea) were uncommon. Both observations are in agreement with other pediatric series. By contrast, in adults with ICS, chronic sinusitis is much more prevalent. Thus, when evaluating a child with intracranial infection, the clinician should consider sinusitis as a cause, even in the absence of sinus history.

The majority of ICS were intracranial collections (abscesses and empyemas), in agreement with most prior series. However, published series differ widely on the relative frequency of different types of collection. For many decades, subdural empyema or intracerebral abscess were accepted as being the most common. Recently, however, epidural abscesses have become the predominant type of ICS in several series. Likewise, in our series, epidural abscess was the most common complication, occurring in 52% of our patients. Location of intracranial infections strongly influences their clinical presentation and disease course. Epidural abscesses form between skull and dura and expand slowly because of the tight adherence of dura to bone. Their clinical presentation is typically insidious (up to several weeks), with a prolonged period of nonspecific symptoms until either the infection penetrates the dura or the abscess becomes large enough to cause elevated intracranial pressure. By contrast, the subdural empyema spreads rapidly and freely within a preformed space, typically resulting in a more fulminant, acute presentation than with epidural abscess, with earlier development of neurologic deficits. Intracerebral abscesses are equally likely to present with or without focal signs. For all ICS, a paucity of local presenting symptoms and signs (“silent” intracranial involvement) is common, especially in children. Indeed, in our series, more than half of the patients lacked any focal neurologic findings. A high index of suspicion for ICS must be maintained when sinusitis fails to respond to therapy or progresses locally, even in the absence of neurologic symptoms.
A notable observation from our series was that extracranial complications, especially orbital infections, not only commonly coexisted with ICS but also dominated the presentation of the majority of children whose intracranial infections were otherwise silent. These complications likely prompted these patients to seek medical care sooner, thus leading to an earlier diagnosis of the ICS than might have otherwise occurred. Earlier diagnosis, in turn, may have contributed to the improved outcome we found in this subset of patients. Significant rates of

**Table 6. Outcomes of Intracranial Complications of Sinusitis in Patients**

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Intracranial Complication</th>
<th>Predominant Presentation</th>
<th>Simultaneous Extracranial Complication</th>
<th>Sinus Surgery</th>
<th>Neurosurgery</th>
<th>Short-term Sequelae</th>
<th>Permanent Sequelae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1: Never Had Neurologic Deficits or Events</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/F/12</td>
<td>EA</td>
<td>Ocular</td>
<td>Orbital cellulitis</td>
<td>Bilateral FESS</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>12/M/14</td>
<td>EA</td>
<td>Nonspecific</td>
<td>None</td>
<td>Bilateral Trephine</td>
<td>Burr</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>13/M/14</td>
<td>EA</td>
<td>Ocular and forehead</td>
<td>Orbital cellulitis and forehead edema</td>
<td>Unilateral FESS</td>
<td>Burr</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>14/M/13</td>
<td>EA</td>
<td>Ocular and forehead</td>
<td>Orbital cellulitis and subacute forehead abscess</td>
<td>Bilateral FESS</td>
<td>Unilateral FESS</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>16/M/15</td>
<td>EA</td>
<td>Ocular and forehead</td>
<td>Orbital cellulitis and subacute forehead abscess</td>
<td>Bilateral FESS</td>
<td>Unilateral FESS</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>17/M/15</td>
<td>EA</td>
<td>Ocular</td>
<td>None</td>
<td>Unilateral FESS</td>
<td>Burr</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>18/F/4</td>
<td>EA</td>
<td>Forehead</td>
<td>Orbital/periorbital abscess</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>23/F/12</td>
<td>EA</td>
<td>Ocular</td>
<td>Orbital/periorbital abscess</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>2/M/10</td>
<td>EA and IA</td>
<td>Neurological (nystagmus)</td>
<td>None</td>
<td>Unilateral FESS</td>
<td>Burr</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>21/M/14</td>
<td>EA and SE</td>
<td>Ocular</td>
<td>Orbital/periorbital abscess</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>5/M/15</td>
<td>SE and IA</td>
<td>Neurological</td>
<td>None</td>
<td>Bilateral FESS</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>6/M/6</td>
<td>Menin</td>
<td>Neurological</td>
<td>None</td>
<td>Bilateral FESS</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>20/M/4</td>
<td>Menin, Enceph, and DST</td>
<td>Ocular</td>
<td>Orbital cellulitis</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>25/M/16</td>
<td>Menin, Enceph, and DST</td>
<td>Neurological</td>
<td>None</td>
<td>Bilateral FESS</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Group 2: Short-term Neurologic Sequelae Only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/M/16</td>
<td>EA</td>
<td>Ocular and forehead</td>
<td>Orbital/periorbital abscess</td>
<td>Bilateral FESS</td>
<td>Craniotomy</td>
<td>Seizure and cognitive deficit</td>
<td>None</td>
</tr>
<tr>
<td>9/F/17</td>
<td>EA and SE</td>
<td>Neurological (hemiparesis)</td>
<td>None</td>
<td>Unilateral FESS</td>
<td>Craniotomy</td>
<td>Seizure and hemiparesis</td>
<td>None</td>
</tr>
<tr>
<td>19/M/18</td>
<td>EA and SE</td>
<td>Nonspecific</td>
<td>None</td>
<td>Bilateral FESS</td>
<td>Craniotomy and frontal craniotomy</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>4/F/13</td>
<td>SE</td>
<td>Neurological</td>
<td>None</td>
<td>Bilateral FESS</td>
<td>Craniotomy</td>
<td>Hemiparesis, tongue deviation, and cognitive deficit</td>
<td>None</td>
</tr>
<tr>
<td>15/M/10</td>
<td>SE</td>
<td>Ocular</td>
<td>Orbital cellulitis</td>
<td>Bilateral FESS</td>
<td>None</td>
<td>Seizure</td>
<td>None</td>
</tr>
<tr>
<td>22/M/17</td>
<td>SE</td>
<td>Neurological (MS changes and seizures)</td>
<td>None</td>
<td>Bilateral FESS</td>
<td>None</td>
<td>Seizure and cognitive and speech deficits, and pronator drift</td>
<td>None</td>
</tr>
<tr>
<td>8/F/8</td>
<td>SE and MCA ischemia</td>
<td>Neurological</td>
<td>None</td>
<td>Bilateral FESS</td>
<td>None</td>
<td>Seizure and hemiparesis</td>
<td>None</td>
</tr>
<tr>
<td>24/M/16</td>
<td>Menin and Enceph</td>
<td>Neurological</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Hemiparesis, ataxia, and oculomotor palsy</td>
<td>None</td>
</tr>
<tr>
<td>Group 3: Death or Permanent Neurologic Sequelae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/M/13</td>
<td>SE</td>
<td>Neurological (MS changes, hemiparesis, facial twitching, and abnormal Babinski reflex)</td>
<td>None</td>
<td>Bilateral FESS</td>
<td>Hemicraniectomy and craniotomy</td>
<td>Elevated ICP (near herniation) requiring hemicraniectomy and VP shunt, seizure, hemiparesis, cognitive deficit, and expressive aphasia</td>
<td>Hemiparesis, cognitive deficits, expressive aphasia, long-term anticonvulsants, and VP shunt</td>
</tr>
<tr>
<td>11/M/13</td>
<td>Menin</td>
<td>Neurological (MS changes)</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Cognitive deficit, hearing loss, facial weakness, dysmetria</td>
<td>SNHL (profound [left] and moderate-severe [right]) Injury to the brainstem, bilateral facial weakness, third cranial nerve deficit and severe hearing loss</td>
</tr>
<tr>
<td>10/M/12</td>
<td>Menin and DST</td>
<td>Neurological (MS changes) and ocular</td>
<td>Orbital abscess</td>
<td>Bilateral FESS</td>
<td>None</td>
<td>Seizures, obtundation, seizures, ARDS, pulmonary hemorrhage, and ventilator dependence</td>
<td>SNHL (profound [left] and moderate-severe [right]) Injury to the brainstem, bilateral facial weakness, third cranial nerve deficit and severe hearing loss</td>
</tr>
</tbody>
</table>

Abbreviations: ARDS, adult respiratory distress syndrome; Burr, burr hole drainage; DST, dural sinus thrombophlebitis; EA, epidural abscess; Enceph, encephalitis; FESS, functional endoscopic sinus surgery; IA, intracerebral abscess; ICP, intracranial pressure; Menin, meningitis; MCA, middle cerebral artery; MS, mental status; SE, subdural empyema; SNHL, sensorineural hearing loss; VP, ventriculoperitoneal.
concurrent orbital complications with ICS have also been observed by others.\textsuperscript{3,5,10,16} Our data support this relationship, and, furthermore, suggest a predilection for epidural abscess as the coincident ICS. Likewise, Singh et al\textsuperscript{11} found extracranial complications in 59% of patients with meningitis, 37% of patients with subdural empyemas, 26% of patients with intracerebral abscesses, and over 80% of patients with epidural abscesses. When evaluating children presenting with orbital or forehead swelling and sinusitis, the clinician should consider the possibility of a concurrent intracranial infection, even in the absence of neurologic findings.

By contrast, disease characteristics were distinctly different in the group of children who had prominent central neurologic findings at presentation (Table 2). First, there were almost no epidural abscesses in this group, and the 2 that did exist both occurred alongside deeper abscesses. This finding further supports the concept that epidural abscess is distinct from the other ICS in its mode of presentation. Second, there were almost no extracranial complications in this group. A likely explanation is that the more rapidly developing neurologic symptoms in these patients prompted earlier presentations, before orbital or frontal complications developed. Finally, this group as a whole had worse outcomes than did the previous group of patients who were neurologically silent at presentation. Others\textsuperscript{3,5} have also observed a significant correlation between severity of neurologic presentation and incidence of neurologic sequelae or death.

Magnetic resonance imaging was used extensively in our evaluation of ICS. It was superior to contrast CT in detection of intracranial collections, and its ability to detect meningeal inflammation was useful in confirming meningitis. Magnetic resonance imaging also played an important role in confirming the diagnosis of ICS in 5 patients with abnormal but inconclusive CT scans. The added sensitivity of MRI may have allowed earlier diagnosis of ICS and/or detection of smaller abscesses, which together may have contributed to the excellent outcomes in this series. Other smaller series also found MRI to be more accurate than CT in diagnosing ICS.\textsuperscript{3,16,17} It allows excellent soft tissue discrimination, allows multiplanar reconstruction to help evaluate complex fluid collections and to plan surgery, and is uniquely suited to define dural sinus abnormalities, particularly when applied as magnetic resonance angiography and venography. In our series, it was also as accurate as CT in diagnosing sinusitis. However, MRI is poor at defining bony anatomy, which is critical in guiding ESS. Thus, our current practice is to use both modalities: MRI with gadolinium enhancement and noncontrast sinus CT if surgery is indicated.

Medical management of ICS requires aggressive, culture-directed intravenous antibiotics with cerebrospinal fluid penetration. Early consultation with infectious disease specialists is critical. Surgical management requires coordination between otolaryngology and neurosurgery services. Based on our experience, following the diagnosis of ICS, surgical drainage of diseased sinuses should be performed as soon as possible, with craniotomy performed under the same anesthetic if deemed necessary by the neurosurgical service. Cranialization of the frontal sinus may be necessary if inspection of the posterior table reveals marked osteitis with perforation or necrosis.\textsuperscript{3} However, this was rarely required in the present series.

Intracranial complications of sinusitis can result in significant morbidity and mortality. Mortality can occur by elevated intracranial pressure, transtentorial herniation, propagation of thrombosis, infarction, and overwhelming sepsis. Mortality has been declining over several decades, and our rate of 4% compares favorably with other recent series.\textsuperscript{7,10} Despite improved mortality, however, even recent series report significant rates (13%-35%) of long-term neurologic deficits, such as hemiparesis, cognitive deficits, cranial nerve palsy, aphasia, epilepsy, hydrocephalus, visual deficits, and hearing loss. By comparison, our patients had a lower rate of long-term morbidity (8%). Although more than one third of patients had early neurologic deficits during their admission, most had resolved either before discharge or within 1 to 2 months. Hospitalizations were also shorter, averaging 10 days compared with the 15 to 30 days commonly reported elsewhere.\textsuperscript{3,8-10}

Several factors likely contributed to these excellent outcomes. First, our series included only children, and morbidity and mortality have been shown to rise with increasing age.\textsuperscript{1,11} Another factor is the high rate of orbital and other extracranial complications in our patients. These may have prompted earlier presentations, hence earlier diagnosis and better outcome. Third, extensive use of MRI may have contributed to earlier diagnosis, particularly of smaller abscesses. Finally, a proportionately larger share of our complications were epidural abscesses. Epidural abscesses have a favorable prognosis regardless of the origin of infection because they progress more slowly than subdural empyemas.\textsuperscript{11} Furthermore, our series shows that epidural abscesses often occur alongside concurrent orbital and forehead complications, increasing the likelihood of earlier diagnosis. Although other series have not singled out epidural abscess, a tendency toward better outcomes for patients with epidural abscess can be inferred from their data.\textsuperscript{3,5,14} Together, existing data suggest that epidural abscess is a distinct clinical entity among ICS, with a distinct manner of presentation and a more favorable prognosis.

We believe that aggressive use of ESS in nearly all patients also contributed to the favorable outcomes we observed. In general, our decision to perform ESS was not influenced by whether neurosurgical drainage was indicated. In our series, 11 patients were not drained by neurosurgery. Of these, 6 had meningitis and/or encephalitis, and 4 of these 6 still underwent ESS and had good outcomes overall (3 of the 4 were in outcome group 1 [no deficits]). The remaining 5 patients who did not undergo neurosurgery had small, thin collections (3 epidural abscesses and 2 subdural empyemas), with no mass effect. All 5 still underwent ESS, and all had good outcomes with no permanent deficits (outcome groups 1 or 2).

A reasonable related question is whether ESS is always necessary in the setting of ICS, particularly when the patient is not already being taken to the operating room for neurosurgical treatment. This question is difficult to answer with our data because only 3 patients did
not undergo ESS, and 1 of them (patient 12) actually was drained (but externally by trephination) because of isolated frontal sinus disease. This leaves 2 patients (patients 11 and 24) whose sinuses were not drained. Both had meningitis or encephalitis, and in both, sinus surgery was withheld because of a combination of 2 factors: early uncertainty about the contribution of sinusitis and early rapid improvement on treatment with antibiotics. Patient 11 had only partial opacification of the sinuses in the setting of a ventilator and endotracheal tube. Thus, at the time it was unclear whether the sinuses were the cause of his meningitis. He was also showing rapid improvement of his mental status on treatment with antibiotics, and so the family declined sinus surgery. He had permanent sensorineural hearing loss, but his other neurologic deficits ultimately resolved soon after discharge. In patient 24, sinus CT demonstrated pansinusitis but the CT was not performed until hospital day 4. By that time, the patient’s neurologic deficits were showing steady daily improvements; thus, surgery was deferred, and his short-term deficits resolved. Although both patients improved with nonsurgical management, the numbers are far too small for us to recommend this strategy routinely for patients with ICS. Moreover, we cannot speculate whether these 2 patients would have improved faster had ESS been performed. One could speculate, for example, that in patient 11, early ESS might have accelerated his recovery enough to prevent his presumed labyrinthitis and hearing loss. Thus, unless future studies show conclusively that outcomes are equivalent with nonsurgical management, we will continue to recommend ESS as part of the routine management for most patients with ICS. Endoscopic sinus surgery has generally low morbidity, and we believe it has potential to considerably accelerate the clinical improvement in patients with ICS.

In conclusion, ICS in children are challenging to diagnose and treat and have considerable potential to cause long-term morbidity and mortality. A high index of suspicion is needed in pediatric patients because they frequently lack sinus history and often present with vague, nonlocalizing signs and symptoms. Orbital complications should further elevate suspicion because they frequently coexist with ICS. Early imaging is critical to establish diagnosis, and if available, MRI should be used owing to its superior sensitivity for ICS. Prognosis is favorable in children with expedient diagnosis and aggressive medical and surgical management, particularly in the case of epidural abscesses.

Submitted for Publication: December 30, 2005; final revision received March 18, 2006; accepted April 4, 2006. Correspondence: John A. Germiller, MD, PhD, Division of Pediatric Otolaryngology, The Children’s Hospital of Philadelphia, Wood Center, First Floor, 34th St & Civic Center Blvd, Philadelphia, PA 19104 (germiller@email.chop.edu).

Author Contributions: Dr Germiller had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Germiller and Tom. Acquisition of data: Germiller, Monin, Sparano, and Tom. Analysis and interpretation of data: Germiller, Monin, and Tom. Drafting of the manuscript: Germiller, Monin, and Tom. Critical revision of the manuscript for important intellectual content: Germiller, Monin, and Tom. Administrative, technical, and material support: Monin. Study supervision: Germiller and Tom.

Financial Disclosure: None reported.

Previous Presentation: This study was presented in part at the 20th Annual Meeting of the American Society of Pediatric Otolaryngology; May 28, 2005; Las Vegas, Nev.

REFERENCES