

TITLE: Complications of Rhinosinusitis: Synopsis of Critical Sequelae

SOURCE: Grand Rounds Presentation,

The University of Texas Medical Branch (utmb Health), Department of Otolaryngology

DATE: April 22, 2011

RESIDENT PHYSICIAN: Viet Pham, M.D.

FACULTY PHYSICIAN: Patricia Maeso, M.D.

SERIES EDITOR: Francis B. Quinn, Jr., M.D.

ARCHIVIST: Melinda Stoner Quinn, MSICS

"This material was prepared by resident physicians in partial fulfillment of educational requirements established for the Postgraduate Training Program of the UTMB Department of Otolaryngology/Head and Neck Surgery and was not intended for clinical use in its present form. It was prepared for the purpose of stimulating group discussion in a conference setting. No warranties, either express or implied, are made with respect to its accuracy, completeness, or timeliness. The material does not necessarily reflect the current or past opinions of members of the UTMB faculty and should not be used for purposes of diagnosis or treatment without consulting appropriate literature sources and informed professional opinion."

RHINOSINUSITIS

Rhinosinusitis describes the presence of inflammation of the nasal mucosa and paranasal sinus lining. The fundamental pathophysiology behind this process revolves around obstruction of the sinus ostia, often attributed to an anatomical blockage or from impaired ciliary transport. Symptoms regarded as “major” diagnostic criteria include facial pain or pressure, nasal obstruction, hyposmia or anosmia, and purulent nasal discharge—especially if noted emanating around from the middle meatus. “Minor” symptoms include headache, halitosis, fatigue, dental pain, cough, or otalgia or aural pressure. A diagnosis of rhinosinusitis is supported with the presence of either two major symptoms or one major one and two minor ones.

While many patients who present with such symptoms often implore for antibiotics, the majority of cases arise from a viral etiology such as rhinovirus, coronavirus, influenza A and B, parainfluenza, respiratory syncytial virus, adenovirus, and enterovirus. A superimposed bacterial infection is usually present in only up to 2% of cases. Suspicion of a concurrent bacterial process should be considered if symptoms have been present for at least 7-10 days or if there is a symptomatic worsening after 5-7 days. For the pediatric and adult populations, the most common bacterial agents responsible for rhinosinusitis are *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Moraxella catarrhalis*.

The term acute rhinosinusitis (ARS) denotes that symptoms have been present for no more than four consecutive weeks. Recurrent ARS refers to when four distinct episodes of ARS have transpired, each lasting at least 7-10 days. When symptoms of rhinosinusitis have been present for at least three consecutive months, it is considered to be chronic rhinosinusitis (CRS) while a duration between 4-12 weeks is understandably labeled as subacute rhinosinusitis.

Chronic inflammation of the paranasal sinuses is the key characteristic of CRS, but there is no clear consensus as to what leads to this persistent process. Although there are those who believe that CRS is related to a chronic infectious presentation like its acute counterpart, others have advocated alternative factors such as allergic, immunological, anatomic, and genetic ones that may play a more significant role. One major problem with ascertaining a clear pathogenesis of CRS is that symptoms, findings, and radiographs, when taken independently, have not been found to provide a sufficient basis for a diagnosis (Stankiewicz 2002). Some of the more commonly identified microbial agents associated with CRS include anaerobes, *Staphylococcus aureus*, and *Haemophilus influenzae*.

COMPLICATIONS OF RHINOSINUSITIS

The incidence of rhinosinusitis-related complications has fortunately decreased since the introduction of antibiotics, but they result in devastating consequences if they are not promptly recognized and treated. They are often categorized based on orbital, intracranial, or osseous involvement. In general, computed tomography (CT) is considered ideal for radiographical evaluation of the orbit while magnetic resonance imaging (MRI) is better utilized for the intracranium.

ORBITAL COMPLICATIONS

Its close proximity to the paranasal sinuses makes the orbit the most commonly involved structure in rhinosinusitis-related complications, encompassing between 60-75% of such events. This is usually attributed to the ethmoid sinuses although the frontal and maxillary sinuses may occasionally contribute to these conditions. The orbit is often the first to experience sequelae of rhinosinusitis in light that the bony lamina papyracea and the fibrous periorbita and orbital septum are the only major anatomic barriers protecting the orbit from direct extension of the inflammatory and infectious changes occurring in the neighboring sinuses. Furthermore, the valveless superior and inferior ophthalmic veins facilitate a relatively unimpeded route for infectious thrombophlebitis to travel past the periorbita and affect the orbital contents.

Children tend to experience orbital complications more than the adult population, but they do not always exhibit typical clinical findings suggestive of acute infection such as complaints of pain or a general deterioration, and leukocytosis is found only in approximately half of cases. Among the pediatric population itself, there is an age-dependent dichotomy in complication susceptibility. Individuals younger than seven years of age are usually afflicted solely with orbital manifestations while older children often experience both orbital and intracranial complications. This difference is thought to be related to the age-related sinus development of the frontal sinus. *Streptococcus* and *Staphylococcus* species are the more commonly responsible microbial agents involved in pediatric orbital complications, while *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Moraxella catarrhalis* usually affect adult patients.

Although it has been altered and modified over the years since its inception in 1970, Chandler devised a classification scheme that categorizes the various forms of rhinosinusitis-related orbital complications and seemingly triages them in increasing severity: preseptal cellulitis, orbital cellulitis, subperiosteal abscess, orbital abscess, and cavernous sinus thrombosis. Despite five distinct processes described with this classification scheme, it is important to appreciate that they are not mutually exclusive and may occur concurrently.

Preseptal Cellulitis

Eyelid edema and erythema is quite noticeable with preseptal cellulitis, but a small eyelid abscess may occasionally be encountered. A key characteristic is the integrity of both extraocular muscle movement and inherent vision. CT images will only reveal diffuse thickening of the eyelids and conjunctiva, all of which should occur superficial to the orbital septum. As such, medical therapy is typically sufficient to adequately treat cases of preseptal cellulitis with the initiation of intravenous antibiotics, application of warm compresses, and elevating the head of the bed. Additionally, facilitating sinus drainage with nasal saline irrigations, decongestants, and mucolytics may provide some benefit.

Orbital Cellulitis

Progression of the inflammatory changes deep to the orbital septum constitutes orbital cellulitis. While eyelid edema and erythema will also be present, the eye may demonstrate proptosis and chemosis. Some patients may complain of pain or diplopia due to impaired extraocular muscle movement, but the vision itself remains unaffected. Low-attenuation adjacent to the lamina papyracea is often noticed on CT, but a discrete abscess should not be encountered. As with preseptal cellulitis, medical management with antibiotics and nasal drainage is often successful. Clinical reassessment and surgical drainage should be considered if visual acuity is at 20/60 or worse or if there is no improvement or even symptomatic progression within 48 hours.

Subperiosteal Abscess

As the two major structural barriers between the orbit and the paranasal sinuses, the coalescence of purulent material between the lamina papyracea and the periorbita is one of the first signs of compromise to this protective role against rhinosinusitis. This subperiosteal collection typically displaces orbital contents inferiorly-laterally with subsequent exophthalmos. While some may exhibit normal extraocular muscle movement early on, patients will present with proptosis, chemosis, and ophthalmoplegia leading to complaints of orbital pain, diplopia, and reduced visual acuity. Some abscesses may extrude through the eyelid. CT imaging is diagnostically accurate in 86-91%, revealing a rim-enhancing hypodensity adjacent to the lamina papyracea with mass-effect, although a more superior location should raise awareness of an origin from the frontal sinus.

Acquiring the assistance from the ophthalmologist and pursuing prompt surgical intervention is clearly warranted since drastic visual sequelae may result if this condition is not addressed, especially in the face of progressively worsening vision or extraocular muscle movement or if there is a lack of improvement after 48 hours. There is a small contingent that advocates medical therapy alone may be sufficient in 50-67%, but this notion is usually reserved for children less than four years of age with small abscesses. Ultimately, a combined surgical and medical treatment plan should achieve complete resolution in 95-100% of cases.

The chosen surgical approach varies by surgeon but is often set with the goal of removing the lamina papyracea and opening the ethmoid cells to remove the abscess and facilitate sinus drainage. Most prefer an external incision, such as the Lynch incision, along the medial-superior aspect of the orbital rim to provide access to the subperiosteal plane. An endoscopic approach may be ideal for more medially located collections, allowing the removal of the lamina papyracea while sparing the patient an external facial incision. Some have advocated a transcaruncular approach implementing a transconjunctival incision and extending it around the lacrimal caruncle. It is felt that a subperiosteal dissection may be facilitated in this fashion as with a traditional external approach but without a noticeable external incision.

Orbital Abscess

An abscess formation within the orbital tissues themselves will present with a similar clinical picture as a subperiosteal abscess. Ophthalmoplegia and reduced visual acuity is also present, but the degree of exophthalmos and chemosis is felt to be more severe compared to that experienced with subperiosteal abscesses. A similar rim-enhancing hypodensity is noted on CT, but it is not relegated solely to near the lamina papyracea. In conjunction with draining the responsible paranasal sinuses, incising the periorbita and draining the intraconal abscess with the assistance with ophthalmology is paramount to avoid the significant risk of irreversible blindness.

CAVERNOUS SINUS THROMBOSIS

Just as serious with its clinical implications, cavernous sinus thrombosis often manifests with similar signs as an orbital abscess as the inflammatory and infectious process traverses posteriorly from the orbit toward the intracranium. Orbital pain, proptosis, chemosis, ophthalmoplegia, and impaired vision are also present, but the key distinguishing feature is that there is also contralateral involvement. Poor venous enhancement may be noted on CT, but the presence of heterogeneity and increased size of the cavernous sinus on MRI is considered a more confirmatory radiographical finding.

Cavernous sinus thrombosis is often associated with meningismus and sepsis, and not surprisingly carries a mortality rate up to 30%. High-dose intravenous antibiotics that can cross the blood-brain barrier and surgical drainage of the paranasal sinuses are clearly warranted, but the use of anticoagulation to prevent thrombus propagation has been highly controversial. While there have been a number of case reports that mention its use, two of the more

commonly cited studies were retrospective ones investigating the potential risks and benefits to anticoagulation. Southwick concluded that there was a reduction in mortality with such therapy but did not recommend it for similar applications with thrombotic involvement of other dural sinuses (1986). Levine was not able to ascertain a significant difference in mortality rates but did insinuate that a reduction may be attainable if begun early (1988). In an extensive literature review, Bhatia suggested that maintaining a prothombin time ratio between 1.5-2.5 and an international normalized ratio between 2-3 for three months would provide therapeutic alleviation. This was countered with some caution as Bhatia commented on cases of fatal hemorrhagic cerebral infarction and a subarachnoid hemorrhage that required reversal with protamine (2002).

INTRACRANIAL COMPLICATIONS

Rhinosinusitis-related intracranial complications tend to occur in the setting of CRS, possibly attributed to hidden infectious foci within the mucosal scarring and polypoid changes inherent with CRS that diminishes antibiotic penetration. Other etiologies include direct extension of infectious and inflammatory agents via erosion of the sinus bony walls or traversing through past traumatic fracture lines or naturally occurring neurovascular foramina such as for the optic and olfactory nerves. It is also possible for infectious thrombophlebitis to affect the diploic emissary skull veins that may result in subdural infections without contaminating the intermediary structures. For example, a subdural empyema may exist without evidence of an extradural infection or osteomyelitis.

Male teenagers tend to experience intracranial complications more often than younger children, and this is thought to be related to the development of the frontal and sphenoid sinuses. Fever, headache, nausea, and vomiting are commonly observed symptoms, signs compatible with the increased intracranial pressure that can occur with the pathological process. Other affected individuals often demonstrate an altered level of consciousness, seizures, hemiparesis, visual disturbances, and meningismus. Keeping in mind that they are not mutually exclusive, the five main types of rhinosinusitis-related intracranial complications are meningitis, epidural abscess, subdural abscess, intracerebral abscess, and dural venous sinus thrombosis.

Meningitis

Inflammation of the meninges is the most common intracranial complication of rhinosinusitis, but it should be noted that rhinosinusitis itself is an unusual cause of meningitis. The involved sinuses are typically the ethmoid and sphenoid sinuses and are usually caused by *Streptococcus pneumoniae*, *Staphylococcus aureus*, and *Hemophilus influenzae*. Symptoms tend to include fever, headache, meningismus, and an overall septic-like presentation similar to other cases of meningitis. Medical management alone is often sufficient, but facilitating sinus drainage should be considered if no improvement is appreciated after 48 hours. Prompt treatment is important in light of the high incidence of neurologic sequelae such as sensorineural hearing loss and seizures.

Epidural Abscess

A collection of purulent material between the skull and the dura often hails from frontal sinusitis and is regarded as the second-most common intracranial complication. As with meningitis, affected individuals will present with signs reflective of increased intracranial pressure including fever, headache, nausea, vomiting, and papilledema, but others may also exhibit hemiparesis and seizures. A crescent-shaped hypodensity is appreciated on CT with similar radiographical findings on MRI.

Resolution of this process is best achieved with concurrent medical and surgical modalities, and consequently, quick neurosurgical involvement is vital. Broad-spectrum antibiotic coverage with good cerebral penetration is often initiated with a combination of a third-generation cephalosporin, vancomycin, and metronidazole for 4-8 weeks. Prophylactic seizure therapy is not typically necessary, and a lumbar puncture is contraindicated to prevent cerebral herniation. The abscess and the affected sinuses can be surgically drained through an external approach using either a frontal sinus trephination or cranialization, although some have advocated stereotactically-guided drainage of the intracranial component and allowing any external drainage to be limited to the sinuses alone.

Subdural Abscess

While it can originate from the frontal sinus, a purulent collection just deep to the dura mater may also arise from the ethmoid sinuses. The presenting signs are similar to epidural abscesses and may even accompany 10% of epidural abscesses, but patients may present with lethargy or comatose states in more severe cases. Although it is only the third-most common rhinosinusitis-related intracranial complication, this condition is notable for rapid clinical deterioration resulting in mortality in up to 35% and residual neurological sequelae in 35-55% of those who survive.

A similar long-term regimen of broad-spectrum antibiotics with good blood-brain penetration is clearly warranted as with epidural abscesses. Lumbar punctures are also contraindicated, and there is a general consensus to initiate prophylactic anticonvulsants and decreasing intracranial pressure with hyperventilation or mannitol. Some have mentioned the potential benefit to steroids citing its beneficial anti-inflammatory properties, but others have countered that they may impair the abscess encapsulation process, increase necrosis, reduce antibiotic penetration into the abscess, and alter the appearance on CT scans.

Surgical drainage of the abscess and the involved paranasal sinuses should be pursued. The intracranial approach depends on the preference of the neurosurgeon, but a craniotomy is often favored over burr hole placement due to its improved exposure. There have been some reports of successful medical management for abscesses less than 1.5cm in size, but it is often reserved for patients less than four years of age.

Intracerebral Abscess

An uncommon complication, purulent coalescence within the brain parenchyma itself can have devastating results with mortality rates up to 30% and neurological sequelae in 60%. The frontal and frontoparietal lobes are usually afflicted and may be attributed to rhinosinusitis of the frontal, sphenoid, and ethmoid sinuses (in descending order of frequency). In addition to the common clinical signs of increased intracranial pressure, individuals tend to demonstrate altered mentation, focal neurological deficits, and seizures. Patients have been known to exhibit mood swings and behavioral changes if the frontal lobe is involved, and a progressively worsening headache with meningismus should raise concern for a possible abscess rupture.

A combined medical and surgical endeavor similar with subdural abscesses is the treatment modality of choice. Antibiotics, anticonvulsants, hyperventilation, mannitol, and steroids carry the same considerations. While there have been reports of successful resolution of intracerebral abscesses less than 2.5cm with medical management alone, most cases are dealt with stereotactically-guided aspiration in conjunction with external or endoscopic surgical drainage of the involved sinuses.

The majority of microorganisms responsible for epidural, subdural, and intracerebral abscesses are anaerobes, accounting for 60-100% of cases, while *Staphylococcus* and *Streptococcus* species, and gram-negative bacilli have been noted.

Venous Sinus Thrombosis

Similar to the cavernous sinus thrombosis encountered with orbital-pertaining complications, any of the dural venous sinuses may be affected by rhinosinusitis. The sagittal sinus is the most commonly involved, often attributed to retrograde thrombophlebitis from frontal rhinosinusitis. Patients are extremely ill with a significantly elevated mortality rate and will almost always have an associated intracranial abscess formation. MRI can help confirm the suspicion with the presence of a decreased cavernous carotid artery flow void.

Medical and surgical therapy is similar to other suppurative intracranial complications, but there remains a significant amount of controversy regarding systemic anticoagulation. Supporters believe that alleviating the increased intracranial pressure outweighs the risk for bleeding. Heparin is often started on an inpatient basis before conversion to warfarin in the outpatient setting, and thrombus resolution is usually achieved after six weeks of therapy.

BONY COMPLICATIONS

First described by Sir Percivall Pott in 1768, "Pott's Puffy Tumor" denotes the simultaneous presence of a subperiosteal purulent collection and osteomyelitis due to frontal rhinosinusitis, resulting in a "puffy" appearance on radiographical images. This is not a common occurrence, and the exact prevalence is unknown with one report of 20-25 cases mentioned in the post-antibiotic era (Raja 2007) and another one citing less than 50 pediatric

cases in the past ten years (Blumfield 2010). In addition to headache, fever, nasal complaints, and neurological findings, Pott's Puffy Tumor is well recognized for the prominent frontal swelling on physical examination.

An associated intracranial abscess is encountered in approximately 60%, and other cases may involve cortical vein thrombosis or a frontocutaneous fistula. Some organisms that have been reported with Pott's Puffy Tumor include *Streptococcus milleri*, *Staphylococcus aureus*, and *Bacteroides* and *Proteus* species. A multidisciplinary approach involving the otolaryngology, neurosurgery, and infectious disease services is warranted to concurrently drain the abscess and responsible paranasal sinuses, remove the infected bone, and direct a six-week regimen of intravenous antibiotics, respectively. The frontal sinus may have to be obliterated in situations of recurrence.

CONCLUSION

The frequency of rhinosinusitis-related orbital, intracranial, and bony complications has decreased since the advent of antibiotics, but they still occur and must not be regarded lightly due to the drastic consequences that may result. Concurrent medical and surgical intervention is the best way to achieve resolution, necessitating the close cooperation of other specialties.

SOURCES

- Bailey BJ, Johnson JT, Newlands SD, eds. Head and Neck Surgery – Otolaryngology, 4th Ed. Philadelphia: Lippincott, 2006:307-11, 406, 493-503.
- Benninger MS, Ferguson BJ, Hadley JA, *et al*: Adult chronic rhinosinusitis: definitions, diagnosis, epidemiology, and pathophysiology. *Otolaryngol Head Neck Surg* 2003; 129:S1-S32.
- Benson BE, Riauba L. Sinusitis, Acute. *eMedicine* 10 Feb 2009. Accessed 21 Mar 2011
<<http://emedicine.medscape.com/article/232670-overview>>.
- Bhatia K, Jones NS. Septic cavernous sinus thrombosis secondary to sinusitis: area anticoagulants indicated? A review of the literature. *J Laryngol Otol* 2002; 116:667-76.
- Blumfield E, Misra M. Pott's puffy tumor, intracranial, and orbital complications as the initial presentation of sinusitis in healthy adolescents, a case series. *Emerg Radiol* 2011 Mar 5 [Epub ahead of print].
- Brook I. Brain abscess. *eMedicine* 26 Jun 2008. Accessed 10 Apr 2011
<<http://emedicine.medscape.com/article/212946-overview>>.
- Brook I, Bajracharya H. Sinusitis, Chronic. *eMedicine* 17 Jun 2009. Accessed 21 Mar 2011
<<http://emedicine.medscape.com/article/232791-overview>>.
- Brook I, Friedman EM. Intracranial complications of sinusitis in children: a sequela of periapical abscess. *Ann Otol Rhinol Laryngol* 1982; 91:41-3.
- Caversaccio M, Heimgartner S, Aebi C. Orbital complications of acute pediatric rhinosinusitis: medical treatment versus surgery and analysis of the computer tomogram. *Laryngorhinootologic* 2005; 84:817-21.
- Coenraad S, Buwalda J. Surgical or medical management of subperiosteal orbital abscess in children: a critical appraisal of the literature. *Rhinology* 2009; 47:18-23.
- Chandler JR, Langenbrunner DJ, Stevens ER. The pathogenesis of orbital complications in acute sinusitis. *Laryngoscope* 1970; 80: 1414-28.
- Dawodu ST, Lorenzo NY. Subdural empyema. *eMedicine* 11 Mar 2009. Accessed 10 Apr 2011
<<http://emedicine.medscape.com/article/1168415-overview>>.
- Eweiss A, Mukonoweshuro W, Khalil HS. Cavernous sinus thrombosis secondary to contralateral sphenoid sinusitis: a diagnostic challenge. *J Laryngol Otol* 2010; 124:928-30.
- Flint PW, *et al*, eds. Cummings Otolaryngology: Head and Neck Surgery, 5th Ed. Philadelphia: Mosby Elsevier, 2010. ch 47.
- Gallagher RM, Gross CW, Phillips CD. Suppurative intracranial complications of sinusitis. *Laryngoscope* 1998; 108:1635-42.
- Garcia GH, Harris GJ. Criteria for nonsurgical management of subperiosteal abscess of the orbit: analysis of outcomes 1988-1998. *Ophthalmology* 2000; 107:1454-8.
- Giannoni CM, Sulek M, Friedman EM. Intracranial complications of sinusitis: A pediatric series. *Am J Rhinol* 1998; 12:173-8.
- Goldberg AN, Oroszlan G, Anderson TD. Complications of frontal sinusitis and their management. *Otolaryngol Clin North Am* 2001; 34:211-25.
- Greenberg MF, Pollard ZF. Medical treatment of pediatric subperiosteal orbital abscess secondary to sinusitis. *J AAPOS* 1998; 2:351-5.
- Greenlee JE. Subdural empyema. In: Mandell GL, ed. Principles and Practice of Infectious Diseases, Vol 1. 4th Ed. New York: Churchill, 1994:900-3.
- Gwaltney JM Jr. Acute community-acquired sinusitis. *Clin Infect Dis* 1996; 23:1209-23; quiz 1224-5.
- Gwaltney JM, Scheld WM, Sande MA, *et al*. The microbial etiology and antimicrobial therapy of adults with acute community-acquired sinusitis: A fifteen-year experience at the University of Virginia and review of other selected studies. *J Allergy Clin Immunol* 1992; 90:457-62.
- Herrmann BW, Forsen JW Jr. Simultaneous intracranial and orbital complications of acute rhinosinusitis in children. *Int J Pediatr Otorhinolaryngol* 2004; 68:619-25.
- Hicks CW, Weber JG, Reid JR, Moodley M. Identifying and managing intracranial complications of sinusitis in children. *Pediatr Infect Dis* 2011; 30:222-6.
- Janfaza P, Montgomery WW, Salman SD. Nasal cavities and paranasal sinuses. In: Janfaza P, Nadol JB, Galla R, *et al*, eds. Surgical Anatomy of the Head and Neck. Philadelphia: Lippincott Williams & Wilkins, 2001:259-318.

- Karaman E, Hacizade Y, Isildak H, Kaytaz A. Pott's puffy tumor. *J Craniofac Surg* 2008; 19:1694-7.
- Kayhan FT, Sayin I, Yazici ZM, Erdur O. Management of orbital subperiosteal abscess. *J Craniofac Surg* 2010; 21:1114-7.
- Kuhn FA. Chronic frontal sinusitis: the endoscopic frontal recess approach. *Operat Tech Otolaryngol Head Neck Surg* 1996; 7:222-9.
- Lanza DC, Kennedy DW. Adult rhinosinusitis defined. *Otolaryngol Head Neck Surg* 1997; 117:S1-S7.
- Lee KJ, ed. *Essential Otolaryngology - Head and Neck Surgery, 9th Ed.* New York: McGraw-Hill, 2008. pp 365-6.
- Levine SR, Twyman RE, Gilman S. The role of anticoagulation in cavernous sinus thrombosis. *Neurology* 1988; 38:517-22.
- Marshall AH, Jones, NS. Osteomyelitis of the frontal bone secondary to frontal sinusitis. *J Laryngol Otol* 2000; 114:944-6.
- Miaskiewicz B, Lukomski M, Starska K, Jozefowicz-Korezynska M. Orbital complication in acute and chronic sinusitis. *H Pol Merkur Lekarski* 2005; 19:388-9.
- Oxford LE, McClay J. Complications of acute sinusitis in children. *Otolaryngol Head Neck Surg* 2005; 133:32-7.
- Pasha R. *Otolaryngology – Head and Neck Surgery, 2nd Ed.* San Diego: Plural Publishing, 2006. pp 2-6.
- Rahbar R, Petersen RA, DiCanzio J, et al. Management of orbital subperiosteal abscess in children. *Arch Otolaryngol Head Neck Surg* 2001; 127:281-6.
- Raja V, Low C, Sastry A, Moriarty B. Pott's puffy tumor following an insect bite. *J Postgrad Med* 2007; 53:114-6.
- Ramachandran TS, Ramachandran A. Intracranial epidural abscess. *eMedicine* 9 Sep 2009. Accessed 10 Apr 2011 <<http://emedicine.medscape.com/article/1165292-overview>>.
- Ramadan HH, Tewfik TL, Talavera F, et al. Pediatric sinusitis, medical treatment. *eMedicine*, 22 Apr 2009. Accessed 2 Apr 2011 <<http://emedicine.medscape.com/article/873149-overview>>.
- Remmler D, Boles R. Intracranial complications of frontal sinusitis. *Laryngoscope* 1980; 90:1814-24.
- Rosenfeld EA, Rowley AH. Infectious intracranial complications of sinusitis, other than meningitis, in children: 12-year review. *Clin Infect Dis* 1994; 18:750-4.
- Schramm VL, Myers EN, Kennerdell JS. Orbital complications of acute sinusitis: Evaluation, management, and outcome. *Otolaryngology* 1978;86:221-30.
- Souliere CR Jr, Antoine GA, Martin MP, et al. Selective non-surgical management of subperiosteal abscess of the orbit: computerized tomography and clinical course as indication for surgical drainage. *Int J Pediatr Otolaryngol* 1990; 19:109-19.
- Southwick FS, Richardson EP Jr, Swartz MN. Septic thrombosis of the dural venous sinuses. *Medicine (Baltimore)* 1986; 65:82-106.
- Stankiewicz JA, Chow JM. A diagnostic dilemma for chronic rhinosinusitis: definition accuracy and validity. *Am J Rhinol* 2002; 16:199-202.
- Vazquez E, Creixell S, Carreno JC, et al. Complicated acute pediatric bacterial sinusitis: imaging updated approach. *Curr Probl Diagn Radiol* 2004 May–Jun; 33:127-45.
- Wald E. Microbiology of acute and chronic sinusitis in children. *J Allergy Clin Immunol* 1992; 90:452-60.
- Wald E. Sinusitis in children. *N Engl J Med* 1992; 326:319-23.
- Wallace MR, Rana A, Yadavalli GK. Epidural abscess. *eMedicine* 20 Apr 2009. Accessed 10 Apr 2011 <<http://emedicine.medscape.com/article/232570-overview>>.
- Yogev R, Bar-Meir M. Management of brain abscesses in children. *Pediatr Infect Dis J* 2004; 23:157-9.
- Younis RT, Lazar RH, Anand VK. Intracranial complications of sinusitis: A 15-year review of 39 cases. *Ear Nose Throat J* 2002; 81:636-44.
- Younis RT, Lazar RH, Bustillo A, et al. Orbital infection as a complication of sinusitis: Are diagnostic and treatment trends changing? *Ear Nose Throat J* 2002; 81:7715.

###