Chapter

Infectious Causes of Acute and Chronic Sinusitis

Jana I. Preis, Anna W. Maro, Sophie Hurez and Sneha Pusapati

Abstract

Paranasal sinuses anatomy is paired in 4 parts which includes frontal, maxillary, ethmoid, and sphenoid. Their relevant function is to secrete mucous for moisture, humidify inspired air, impart vocal resonance, and act as shock absorber for intracranial contents. Retention of secretions in the nasal cavity and sinuses can cause inflammation of the mucosa of paranasal sinuses and lead to infection. Classification of sinusitis is based on duration of symptoms. Diagnosis can be achieved clinically, however other diagnosis modalities such as cultures or radiology can help to achieve accurate diagnosis. Depending on the etiology management can be supportive or pharmacological. In some cases, long term monitoring and prevention therapy may be required.

Keywords: Sinusitis, rhinosinusitis

1. Introduction

Sinusitis is the inflammation of the mucosa of Paranasal sinuses (frontal, ethmoidal, sphenoid, maxillary sinuses). Rhinitis is the inflammation of the mucosal membranes of the nose. Rhino sinusitis refers to the inflammation of the mucosal membranes of the nose and at least one of the Paranasal sinuses. Sinusitis is almost always preceded by rhinitis and often occurs together. Hence rhinosinusitis and sinusitis are often used interchangeably.

Rhinosinusitis is one of the 10 most common conditions seen by primary care physicians. The prevalence of Acute rhinosinusitis (ARS) varies between 6 and 15%. The prevalence of chronic sinusitis is 12.5%. Yearly incidence: sinusitis affects 1 in 7 adults and is diagnosed in 31 million patients. Acute bacterial infection occurs in only 0.5 to 2.0 percent of episodes of ARS. The incidence is higher in women and among those aged 45 to 64 years. The direct costs of sinusitis, including medications, outpatient and emergency department visits, and ancillary tests and procedures, are estimated to be $3 billion per year in the United States. Rhinosinusitis is the fifth most common diagnosis for which antibiotics are prescribed. It causes a wide array of symptoms, negatively affects quality of life, and can cause significant impairment in daily functioning.

2. Risk factors

Rhinosinusitis often occurs in the early spring (often associated with upper respiratory tract infection which occurs in colder months). The incidence of URTI

is itself extensive, averages to 2–3 episodes in adults and 6–8 episodes in children. 0.5% of patients proceed to rhinosinusitis. Ventilation disorders of the sinuses can also lead to sinusitis; nasal polyps, deviated nasal septum, cystic fibrosis, primary ciliary dyskinesia, or granulomatosis with polyangiitis- odontogenic infections, bronchial asthma, and analgesic (NSAIDs, aspirin) intolerance. Foreign bodies caught in the nasal cavity, particularly seen in children, also puts them at risk for rhinosinusitis. Other important risk factors for the development of sinusitis, include age as described above, female gender, smoking, and immunodeficiency, air travel, exposure to changes in atmospheric pressure (eg, deep sea diving), swimming, and even anxiety and depression.

3. Classification

Sinusitis is classified based on duration of symptoms (**Table 1**). Acute rhinosinusitis (ARS) as mentioned lasts less than 4 weeks in duration. Underlying etiology is most often viral from URTI and less commonly bacterial. The challenge in treating ARS is based on the physician's ability to distinguish the etiology between bacterial and viral and determine if the patient will benefit from antibiotics. Bacterial and prolonged viral illnesses have similar presentations, complicating the assessment. Majority of patients with viral sinusitis have a complete recovery in a week. Even in patients with bacterial etiology, 2/3rdrecover without any antibiotic therapy although the duration of symptoms may be prolonged. Based on the underlying etiology ARS can be further classified based on the etiology and complications.

1. Acute viral rhinosinusitis (AVRS) – ARS with viral etiology.

2. Uncomplicated acute bacterial rhinosinusitis (ABRS) – ARS with bacterial etiology without clinical evidence of extension outside the paranasal sinuses and nasal cavity (e.g., without neurologic, ophthalmologic, or soft tissue involvement).

3. Complicated ABRS – ARS with bacterial etiology with clinical evidence of extension outside the paranasal sinuses and nasal cavity.

The most common viral pathogens are rhinovirus, coronavirus, adenovirus, influenza, and parainfluenza virus. Other less common pathogens causing this disease are bacteria. The most common community acquired bacterial organisms are *Streptococcus Pneumoniae* and Haemophilus influenza, both accounting for 75% of cases. On the other hand, nosocomial infections are associated with gram-negative organisms, noted in prolonged intubation. Dental procedures and infections are associated with anaerobic and microaerophilic bacteria. Fungal infections are

Classification	Duration of symptoms
Acute	Up to 4 weeks
Subacute	At least four weeks but less than twelve weeks
Recurrent	Four or more episodes per year with complete resolution between episodes; each episode lasts at least seven days
Chronic	12 weeks or longer

Table 1.
Showing classification of sinusitis based on duration of symptoms [1].

seen in immunocompromised individuals, often caused by aspergillus and Mucor. *Staphylococcus aureus*, *Moraxella catarrhalis* and gram-negative organisms which predominate in chronic rhinosinusitis.

4. Anatomy and pathophysiology

There are 4 paired paranasal sinuses (frontal, maxillary, ethmoid, and sphenoid). The sinuses impart various functions. Relevant functions include imparting vocal resonance, filter, and humidify inspired air, warm the inspired air, act as shock absorbers for intracranial contents, and secrete mucus for moisture. The mucosal lining of the sinuses is pseudostratified ciliated columnar epithelium. Below the epithelium lies the basement membrane, below that is the lamina propria with lymphoid tissue and secretory glands. Goblet cells are also present interspersed with the epithelial cells.

The ostium of the maxillary sinus drains into the middle meatus in the hiatus semilunaris. Accessory ostia can be present in 25–30% of the population. Anterior ethmoid cells also drain into the hiatus semilunaris through the infundibulum. Posterior ethmoid cells drain through the superior meatus. The frontal sinus drains via the nasofrontal duct into the infundibulum of the middle meatus. The sphenoid sinus opens into the sphenoethmoid recess above the superior concha (**Figure 1**).

The primary pathogenesis that leads to infection is retention of secretions in the nasal cavity and the sinuses. There are various defense mechanisms in place. The mucous blanket which travels at 1 cm/min traps and propels any irritants towards the nasopharynx with the help of cilia, together known as the mucociliary system. Around 1liter per day of mucus is produced. Secretory IgA is also present to protect against pathogens. The breakdown of these defense systems is followed by retention of secretions. Various factors impeding the mucociliary system include mucosal swelling with closing of ostia, ciliary abnormalities, and overproduction of the secretions. The disruption of the mucociliary system and retention of secretions results in closing of the draining ostia, especially maxillary and sphenoid sinuses which drain upwards against gravity. As the ostial size reduces, the movement of air is reduced, and oxygen tensions drop. Along with that, the carbon dioxide levels increase, and pH is lowered. All these conditions favor further pathogen growth. The pathogens produce a vicious cycle as they further cause ciliary dyskinesia and thickened secretions.

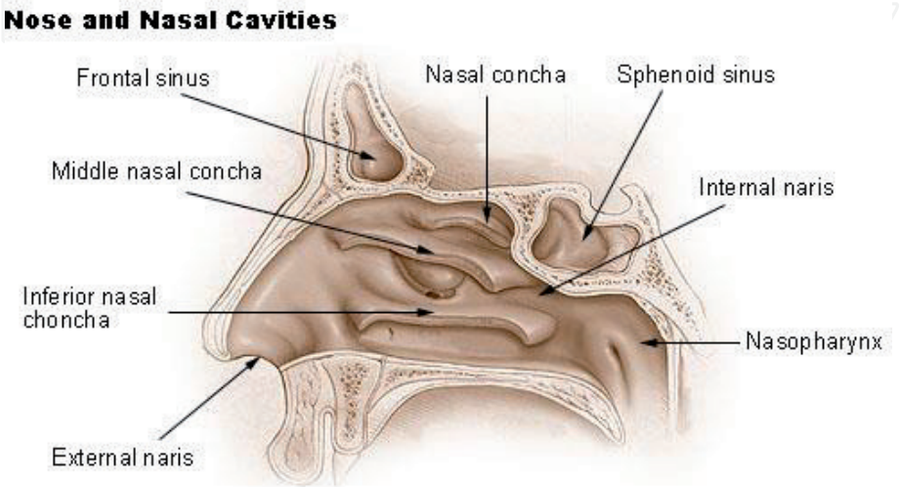

Figure 1.
Showing the anatomy of nose and nasal cavities. Image courtesy of [2, 3].

Acute viral rhinosinusitis (AVR) is transmitted by direct contact with conjunctival or nasal mucosa and viral levels can be detected within 10 hours and symptoms often develop within one day in a non-immune individual. Acute bacterial rhinosinusitis (ABRS) occurs in 0.5–2% of all ARS due to secondary infection of the already inflamed cavity by a viral infection. It can also be associated with any other condition impairing the defense mechanism mentioned above. ABRS is often caused by high concentration of a single pathogens but noted to be two pathogens in approximately 25% of the patients.

5. Clinical presentation

5.1 Symptoms

ARS symptoms include (a) nasal congestion or obstruction (b) purulent nasal discharge (c) maxillary tooth discomfort (d) facial pain or pressure that is worse or localized to sinuses when bending forward. Various other possible symptoms are listed below. Note the symptoms associated with middle ear infection and eustachian tube dysfunction (**Table 2**).

Purulent discharge must be present for the diagnosis of acute rhinosinusitis. Purulent discharge is cloudy or colored which is not seen in the case of an upper respiratory tract infection (clear discharge-rhinorrhea). It is a helpful distinction.

The facial pain or pressure most commonly involves the maxillary sinuses- over the cheeks- and often mimics dental pain. Other sinuses involved are the frontal sinuses-lower forehead- ethmoidal sinuses-nasal bridge and/or between the eyes or retro-orbital pain and sphenoid sinus- near sphenoid bones, most posterior sinuses.

Distinguishing AVRS from ABRS as we discussed is essential and relies on the clinical course of the conditions (**Table 3**). Only 50% of cases are accurately diagnosed with bacterial sinusitis. In ABRS, symptoms often persist beyond 10 days with failure to improve. Or there are at least 3 initial days of severe symptoms, fever (> 39°or 102°F), facial pain, or purulent nasal discharge. Or the symptoms initially improve and then worsen after 5–6 days (double worsening). In AVRS, symptoms often improve by day 10 although may persist for days after. Fever may be present but often disappears within 24–48 hours with respiratory symptoms becoming more prominent after. Purulent discharge is a sign of inflammation and cannot be used to distinguish between the two.

Symptoms of acute rhinosinusitis
Purulent nasal discharge
Facial fullness or congestion
Nasal congestion or obstruction
Hyposmia or anosmia
Fever
Headache
Ear pain, pressure, or fullness
Halitosis
Dental pain
Fatigue

Table 2.
Showing symptoms of acute rhinosinusitis.

Term	Definition
Acute rhinosinusitis (ARS)	Lasting up to 4 weeks of purulent nasal discharge with associated nasal obstruction, facial pain/pressure/fullness, or both. Cloudy or colored purulent nasal discharge, as oppose to clear secretions that typically seen in upper respiratory viral infection, may be reported, or seen on physical examination. Facial pain-pressure-fullness may manifest as diffuse or localized headache and may involve anterior face or periorbital region
Viral rhinosinusitis (VRS)	Acute rhinosinusitis that is caused by viral infection, usually diagnosed when signs and symptoms of acute rhinosinusitis are present less than 10 days and not worsening
Acute bacterial rhinosinusitis (ABRS)	signs or symptoms of acute rhinosinusitis fail to improve within 10 days or more beyond the onset of upper respiratory symptoms, or Signs or symptoms of acute rhinosinusitis worsen within 10 days after initial

Table 3.
Distinguishing between ASR, VRS and ABRS based on signs and symptoms.

The below diagram is a helpful guide to distinguish between the various phenotypes (**Figure 2**).

Chronic rhinosinusitis (CRS) may present acutely without improvement of symptoms or insidiously over months to years. Must be present for at least 12 weeks with at least two of the following symptoms: mucopurulent drainage, nasal congestion (obstruction), facial pain-pressure-fullness, anosmia or hyposmia. Following signs of inflammation must also be present with 1 or more findings such as purulent mucus or edema in the middle meatus/anterior ethmoidal area during anterior rhinoscopy, polyps in the nasal cavity/middle meatus and imaging showing inflammation of the paranasal sinuses. Additional symptoms of CRS may include halitosis, dental pain, or other non-specific features. Therefore, the differential diagnosis of CRS is broad and includes allergic rhinitis, nonallergic rhinitis, vasomotor rhinitis, eosinophilic nonallergic rhinitis or nasal septal deformity. CRS is further divided between CRS with nasal polyps and CRS without nasal polyps.

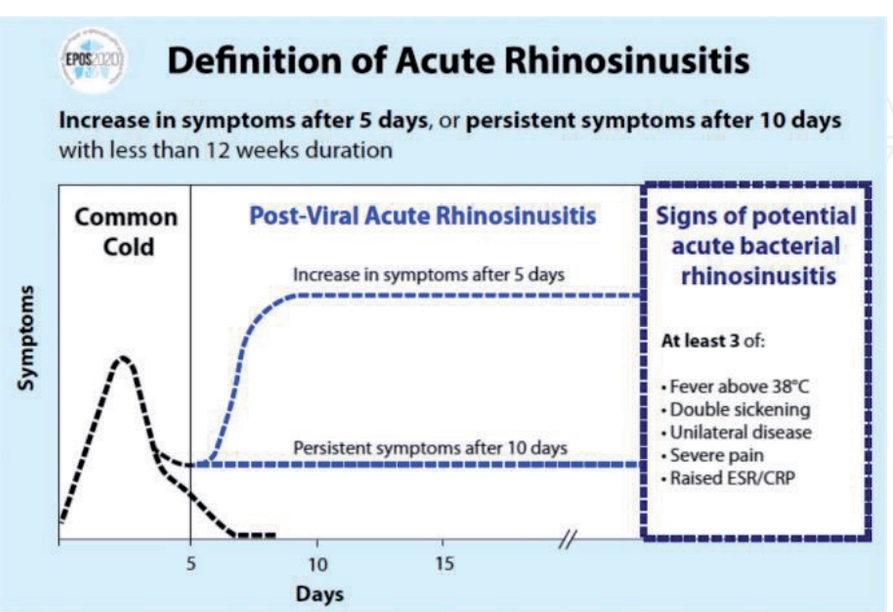

Figure 2.
Duration of symptoms to differentiate ARS (common cold) which is 5 days and Post-viral ARS which is longer than 10 days. Bacterial ARS should be suspected in presence of 3 or more symptoms [4].

Term	Definition
Chronic rhinosinusitis	Twelve weeks or longer of two or more of the following symptoms • Mucopurulent drainage (posterior, anterior, or both) • Nasal congestion or obstruction • Facial pain-pressure-fullness, or • Decrease sense of smell PLUS, Inflammation documented by one or more of the following findings: • Purulent mucous or edema in the middle meatus, and or • Radiographic evidence for inflammation of the paranasal sinuses
Recurrent acute rhinosinusitis	Four or more episodes per year of acute bacterial rhinosinusitis (ABRS) without signs or symptoms of rhinosinusitis between episodes

Table 4.
Distinguishing between chronic rhinosinusitis and recurrent acute rhinosinusitis.

Recurrent acute rhinosinusitis presents with 4 or more episodes per year of ABRS without signs or symptoms of rhinosinusitis between episodes. Each episode lasts at least 7 days (**Table 4**).

6. Physical findings

Signs of ARS include cardinal signs of inflammation. Erythema and edema may be seen over the cheek bones or periorbital area. Tenderness may be present at the site of the sinuses which aggravates with percussion. Transillumination, which is the process of using a bright light applied to the skin over a lesion to assess for transmission of light, can be used over the maxillary or frontal sinuses. In the case of rhinosinusitis, it may show opacification. Both percussion and transillumination have low sensitivity and specificity and are not useful in making a diagnosis. Anterior rhinoscopy examination using an otoscope may show swelling and hypertrophy of the turbinate and reflex narrowing of the meatus. Purulent discharge may be noted. Anatomic abnormalities such as polyps or septal deviation may be visualized.

7. Complications

Although rare, complications of ARBS can include pre septal cellulitis, orbital cellulitis, subperiosteal abscess, osteomyelitis of the sinus bones, meningitis, intracranial abscess, and septic cavernous sinus thrombosis. Symptoms that should prompt immediate evaluation include severe and persistent headache, periorbital inflammation, vision changes, proptosis or abnormal extraocular movements, cranial nerve palsies, AMS, signs of meningitis or any signs of increased intracranial pressure.

8. Diagnostics/role of radiology in diagnostics of ID sinusitis

The diagnosis of acute rhinosinusitis (ARS) is achieved clinically. Getting adequate sinus cultures from sinus aspiration ($\geq 10^4$ colony-forming units per milliliter, non-contaminated) remains problematic. In addition, sinus aspiration is invasive

and time-consuming. Diagnosing ARS relies first on ruling out upper respiratory tract infection (URTI), then accurately distinguishing ABRS from AVRS.

ARS differentiates itself from URTI based on signs and symptoms with the former presenting with purulent nasal drainage accompanied by nasal obstruction, facial pain-pressure-fullness, or both. URTI lacks such features and instead will present with features of rhinitis (sneezing, post-nasal drip, rhinorrhea) and pharyngitis (sore throat, cough). Such features are often present in ARS.

Once ARS has been clinically diagnosed, the etiology of ARS must be characterized, and this is done by looking at the temporal pattern and the severity of the illness. ABRS persists beyond 10 days and there is failure to improve in 10 days. Double worsening may also be seen where the symptoms initially improve and then worsen after 5–6 days. In AVRS, symptoms are present for less than 10 days and symptoms are not worsening.

Imaging and endoscopy are not indicated for diagnosis of ARS and cannot be used to distinguish ABRS from AVRS. They are only indicated when there are suspected complications such as red flag symptoms (focal neurological deficits, severe headache, facial numbness, proptosis, blurry vision, swelling, impaired ocular movements, symptoms not improving despite adequate antibiotics therapy). Imaging and endoscopy are also indicated when risk factors for invasive fungal rhinitis are present (immunocompromised, diabetes mellitus) or in the case of recurrent ARS or CRS. In CRS, presence of inflammation seen in anterior rhinoscopy, nasal endoscopy or sinus CT is needed for diagnosis.

When imaging is indicated, sinus computed tomography (CT) is the gold standard. Sinus X-ray is no longer recommended due to low sensitivity and specificity. Sinus CT helps quantify the extent of inflammation, identify polyps or anatomical abnormalities, and rule out neoplasm or severe fungal infections. Sinus CT is required if endoscopic sinus surgery is planned.

When red flag symptoms are present, CT with contrast is preferred whereas CT without contrast is sufficient for recurrent ABRS and CRS. Findings of ARS on sinus CT are non-specific (opacification, mucosal thickening, air-fluid levels, soft tissue swelling). In CRS, sinus CT may show etiology of CRS ranging from anatomic abnormalities to polyposis. Unilateral polyps are less common than bilateral polyps and when seen should raise suspicion for other conditions such as carcinoma, inverting papilloma or allergic fungal sinusitis. In fungal infection or neoplasm, osseous destruction may be seen on sinus CT. MRI is indicated when fungal infection or neoplasm is suspected.

In CRS, nasal endoscopy and anterior rhinoscopy both offer direct visualization of sinusoidal mucosa. While anterior rhinoscopy allows for visualization of anterior ⅓ of nasal cavity, nasal endoscopy allows visualization of posterior nasal, nasopharynx, and often the sinus drainage pathways in the middle meatus and superior meatus. Nasal endoscopy also allows aspiration of nasal secretions for analysis and culture. In cases where suspicion for CRS is high, nasal endoscopy can be used alone without sinus CT for diagnosis. CT in these cases being reserved for complicated or prolonged clinical course (**Table 5**).

Modality	Method	Risk	Cost	Sensitivity
Nasal endoscopy	Direct visualization	Minimal	Moderate	Good
Anterior rhinoscopy	Direct visualization	Minimal	Minimal	Fair
CT scan	Radiographic	Radiation exposure	High	Excellent

Table 5.
Showing modality of diagnostics with associated cost, risk, and sensitivity.

9. Long term monitoring and prevention

Management of AVRS is supportive and focuses on symptom relief with analgesics or antipyretic drugs (NSAIDS, acetaminophen), decongestants (oxymetazoline), intranasal steroids (mometasone) and saline irrigation. AVRS is self-limited and typically peaks within 3 days then resolves within 10 to 14 days [5].

Management of ABRS also includes symptom relief with the same pharmacological therapy as AVRS. In addition to supportive treatment, antibiotic therapy also plays a role in treating ABRS. Antibiotics can either be started at time of diagnosis or after the watchful waiting period. If ABRS fail to improve after 7 days of the watchful waiting period, antibiotics should be started.

When antibiotics are used, first-line therapy is amoxicillin for 5–10 days. High dose amoxicillin is used to cover penicillin non susceptible *Streptococcus pneumoniae*. High dose amoxicillin with clavulanate is also used if bacterial resistance is suspected (antibiotic use in the past month, treatment failure or worsening of symptoms, high prevalence of resistance bacteria in the community), presence of moderate to severe infection (symptoms for extended time), presence of comorbidity (diabetes mellitus, immunocompromised, older than 65). Doxycycline or a respiratory fluoroquinolone (levofloxacin or moxifloxacin) is used in type I hypersensitivity penicillin-allergic patients [6].

When managing CRS and recurrent ARS, it is important to identify the risk factors that contribute to the persistence or recurrence of the illness since the burden of the comorbidities often decreases with prompt initiation of CRS therapy. Such risk factors/ comorbidities as already mentioned earlier in the chapter are asthma, cystic fibrosis, immunocompromised state, ciliary dyskinesia, or anatomic deformities. For instance, immunodeficiencies in IgA and IgG have been documented in patients with CRS and recurrent ARS. In such cases quantitative immunoglobulin measurements may be considered in patients presenting with CRS and recurrent ARS, especially in those that have failed aggressive management or when sinusitis is associated with bronchiectasis or otitis media. Chronic antibiotic therapy or intranasal steroids have not shown benefits in reducing episodes of recurrent ARS. Patients presenting with recurrent ARS should undergo allergy testing and/or immunologic testing to test for coexisting allergic rhinitis or immunodeficiency. Management of recurrent ARS in the setting of these comorbidities should focus on treating the coexisting illness. Sinus surgery is also an option in such patients.

Treatment of CRS, like AVRS and ABRS, relies on symptom control with saline irrigation. Topical intranasal steroids such as mometasone also play a role in treating CRS due to their anti-inflammatory properties and for symptom relief. These benefits have been seen especially in CRS with polyps. Topical nasal steroids should be used for at least 8–12 weeks to show benefits. If no response is seen within 3 months, a short course of oral corticosteroids can be initiated. As for antibiotics, macrolides where found to be beneficial in CRS with polyps due to their anti-inflammatory properties.

10. Future research

Differentiating AVRS from ABRS clinically can be difficult. Positive sinus aspiration and culture would be helpful in diagnosis ABRS but also problematic due to contaminants from the nose.

Efficacy of antibiotic therapy for ABRS could be further analyzed via pre and post therapy sinus cultures which may open the door for the use of endoscopic middle meatus cultures or sinus puncture. These invasive methods are indicated

for patients who failed to respond to first line and second line therapy. It is recommended to perform sinus aspiration (rather than nasopharyngeal swab) since it was shown to be the most accurate. Endoscopically directed cultures of the middle meatus are also acceptable although less accurate than sinus cultures obtained by sinus puncture.

High dose amoxicillin-clavulanate is used to treat penicillin non-susceptible *Streptococcus pneumoniae*, severe infection etc. But more studies are warranted to compare the efficacy of respiratory fluoroquinolones over that of high dose amoxicillin-clavulanate.

Macrolides, second and third generation oral cephalosporins and TMP/SMX are not recommended as antibiotics therapy due to high rates of resistance among *Streptococcus pneumoniae*. If an oral cephalosporin must be used, third generation in combination with clindamycin is recommended. Among the third-generation oral cephalosporin, cefditoren seems to be the one with the best activity against penicillin non susceptible *Streptococcus pneumoniae*. Doxycycline on the other hand can be used as an alternative to amoxicillin-clavulanate for adults at low risk of penicillin non susceptible *Streptococcus pneumoniae*. More randomized controlled trials are warranted to assess efficacy of doxycycline and cefditoren.

Resistance patterns vary based on geography, but also based on the time of the surveillance study. It is necessary that antimicrobial susceptibility profiles of pathogens in questions be studied nationally, locally, and temporally.

The recommended duration of antibiotic treatment in adults is 5–10 days, which is somewhat arbitrary. Most clinical trials have excluded severely ill patients and included patients with maxillary sinusitis without involvement of other sinuses. More research is needed for the optimal duration of treatment.

Conflict of interest

Authors declares no conflict of interest.

Abbreviations

ARS	Acute rhinosinusitis
AVRS	Acute viral rhinosinusitis
ABRS	Acute bacterial rhinosinusitis
CRS	Chronic rhinosinusitis
CT	Computed tomography
NSAIDs	Non-steroidal ant-inflammatory
URTI	Upper respiratory tract infection

Author details

Jana I. Preis[1*†], Anna W. Maro[2†], Sophie Hurez[2†] and Sneha Pusapati[2†]

1 Division of Infectious Diseases and Clinical Epidemiology, Brooklyn VA Medical Center, SUNY Downstate Health Science University, Brooklyn, New York, USA

2 SUNY Downstate Health Science University, Brooklyn, New York, USA

*Address all correspondence to: info@idcq.org

† These authors contributed equally.

References

[1] Scheid D. & Hamm R : Acute Bacterial Rhinosinusitis in Adults. *American Family Physician*, 2004 1 ;70 (9) : 1685-1692, https://www.aafp.org/afp/2004/1101/p1685.html

[2] Mr Gray's Illustrations, Radiopaedia.org, Gray's Anatomy 20th US edition. https://radiopaedia.org/cases/nose-and-nasal-cavities?lang=us

[3] https://www.uptodate.com/contents/acute-sinusitis-and-rhinosinusitis-in-adults-clinical-manifestations-anddiagnosis?search=epidemiology%20of%20rhinosinusitis&source=search_result&selectedTitle=1~150&usage_type=default&display_rank=1

[4] Jaume F, Valls-Mateus M & Mullol J : Common Cold and Acute Rhinosinusitis, 2020 ; *Current allergy and Asthma Reports,* Article number :28 (2020) https://link.springer.com/article/10.1007/s11882-020-00917-5#Sec3. DOI: 10.1007/s11882-020-00917-5 PMID: 32495003 PMCID: PMC7266914

[5] Aring A, Chan M : Acute Rhinosinusitis in Adults ; *American Family Physician* https://www.aafp.org/afp/2011/0501/p1057.html

[6] Chow A, Benninger S, Brook I : IDSA Clinical Practice Guideline for Acute Bacterial Rhinosinusitis in Children and Adults. *Clinical Infectious Disease*, 2012, Vol 54, pages e72-e112, https://doi.org/10.1093/cid/cis370