Extracranial Head and Neck Infections

Denise Jaworsky, MD, Steven Reynolds, MD, FRCPC, Anthony W. Chow, MD, FACP, FRCPC,*

INTRODUCTION

The head and neck contain several potential spaces that can become infected and can result in life-threatening complications, including airway compromise, neurologic sequelae, and dissemination of infection. Many early presentations are subtle and may be missed even by an astute clinician. This article outlines infections in the submandibular, lateral pharyngeal, retropharyngeal, danger, and prevertebral spaces, in conjunction with infections of the sinuses and mediastinum. By understanding the anatomy and pathophysiology, the reader will gain insight into the rationale for various therapeutic options.

KEYWORDS

- Submandibular space infection
- Lateral pharyngeal space infection
- Retropharyngeal space infection
- Danger space infection
- Prevertebral space infection
- Mediastinitis
- Sinusitis
- Ludwig angina

KEY POINTS

- Management of extracranial head and neck infections is often 2-pronged, involving appropriate antibiotic therapy and source control such as surgical drainage.
- Most extracranial head and neck infections are either odontogenic or rhinogenic, and usually polymicrobial; initial therapy should include agents active against oral aerobes and anaerobes (both β-lactamase-producing anaerobic and facultative gram-negative bacilli).
- Methicillin-resistant Staphylococcus aureus and fungal causes should also be considered, depending on local epidemiology and patients’ risk factors.

INTRODUCTION

The head and neck contain several potential spaces that can become infected and can result in life-threatening complications, including airway compromise, neurologic sequelae, and dissemination of infection. Many early presentations are subtle and may be missed even by an astute clinician. This article outlines infections in the submandibular, lateral pharyngeal, retropharyngeal, danger, and prevertebral spaces, in conjunction with infections of the sinuses and mediastinum. By understanding the anatomy and pathophysiology, the reader will gain insight into the rationale for various therapeutic options.

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a Department of Medicine, University of British Columbia, 2775 Laurel Street, 10th Floor, Vancouver, British Columbia V5Z 1M9, Canada; b Division of Critical Care, Department of Medicine, University of British Columbia, British Columbia, Canada; c Division of Infectious Diseases, Department of Medicine, University of British Columbia, British Columbia, Canada; d Intensive Care Unit, Department of Critical Care, Royal Columbian Hospital, 330 Columbia Street, New Westminster, British Columbia V3L 3W7, Canada; e Division of Infectious Diseases, Department of Medicine, Vancouver Hospital, University of British Columbia, 2773 Heather Street, Vancouver, British Columbia V5Z 3J5, Canada

* Corresponding author.
E-mail address: tonychow@mail.ubc.ca

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INFECTIONS OF THE SUBMANDIBULAR SPACE

Anatomy and Pathophysiology

The submandibular space is a potential space whose boundaries include the fascial and muscular attachments of the hyoid bone rostrally, the mandible anteriorly and laterally, and the superficial layer of the deep cervical fascia inferiorly. It is divided into 2 freely communicating spaces, the sublingual and submylohyoid spaces, by the mylohyoid muscles (Fig. 1A).

Most infections of the submandibular space are odontogenic in nature and originate from the spread of periapical abscesses of the mandibular molars (Table 1). Less common causes include mandibular fractures, lacerations of the mouth floor, foreign bodies, sialadenitis, lymphadenitis, lingual or mandibular malignancies, and iatrogenic causes from inferior alveolar nerve blocks.

Diagnosis

Infections of the submandibular space most frequently present with mouth pain, neck stiffness, drooling, and dysphagia. The differential diagnosis includes cellulitis, hematoma (particularly in anticoagulated patients), lymphadenitis, salivary gland abscess, and malignancy. Dysphagia and dyspnea suggest bilateral involvement. Patients often speak with difficulty and a muffled voice. Lymphadenopathy is usually absent. Trismus is characteristically absent, as the submandibular space does not communicate with the muscles of mastication. If present, trismus indicates extension into the lateral pharyngeal space. Systemic symptoms including malaise, fever, and chills are present.

Ludwig Angina

- Bilateral submandibular space infection involving sublingual and submylohyoid spaces
- Rapidly spreading “woody” inflammation of the submandibular space; “woody” firmness is due to loss of normal soft-tissue compliance constrained by the surrounding fascia
- No lymph node involvement
- Usually odontogenic, originating from a periapical abscess of the second or third mandibular molar
- Careful monitoring is required, as its aggressive course may lead to airway obstruction
- Physical examination: protruding tongue (displaced by swelling that is constricted by the deep cervical fascia); tender, raised, and erythematous oropharyngeal floor ± epiglottal inflammation

Early imaging helps to assess the degree of extension or necrosis, to differentiate between cellulitis and abscesses, and to identify collections requiring surgical drainage. Contrast-enhanced computed tomography (CT) is generally adequate when magnetic resonance imaging (MRI) is not available or feasible. Patients without abscesses have a better prognosis and may be managed conservatively with intravenous antibiotics, whereas abscesses may require surgical drainage. Clinical assessment, combined with contrast-enhanced CT imaging, has sensitivity of 95% and specificity of 80% for identifying collections suitable for drainage.

Antimicrobial Management

- Most infections of the submandibular space are odontogenic and polymicrobial, including gram-negative bacilli and β-lactamase–producing oral anaerobes.
Anaerobes constitute up to two-thirds of isolated organisms.\textsuperscript{13,14} Antimicrobials should target typical oral flora in immunocompetent hosts (Table 2). In more severely ill patients, broader-spectrum agents should be used. Methicillin-resistant\textit{Staphylococcus aureus} (MRSA) should be considered,\textsuperscript{15,16} as there is growing incidence of hospital-acquired and community-acquired MRSA infections\textsuperscript{17,18}; penicillin-resistant pneumococcus should be considered in high-endemic geographic areas.\textsuperscript{19} Although rare,\textit{Candida} and\textit{Aspergillus} should be considered if there is an inadequate response to broad-spectrum antibiotics and adequate source control.\textsuperscript{11,15,20} If risk factors exist, tuberculosis (TB) should be included in the differential diagnosis; in endemic countries, TB has been found to be the third most common cause of deep neck infections, after dental and tonsil infections.\textsuperscript{7}

\textbf{Surgical Indications and Therapy}

- Source control is of key importance in managing infections of the submandibular space.
- Purulent collections (evident by 24–36 hours) can be drained with radiographic guidance.
- Surgical exploration and debridement may be needed if response to initial antimicrobial therapy is poor.
- Source control may require tooth extraction/drainage of periapical abscesses.

\textbf{Outcomes and Complications}

Life-threatening complications of infections of the submandibular space include airway compromise and mediastinal spread (Table 3). Early involvement of anesthesia and critical care is prudent. Ominous signs suggesting impending airway obstruction...
<table>
<thead>
<tr>
<th>Space</th>
<th>Pain</th>
<th>Trismus</th>
<th>Swelling</th>
<th>Dysphagia</th>
<th>Dyspnea</th>
<th>Other Associated Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submandibular</td>
<td>Present</td>
<td>Minimal</td>
<td>Mouth floor (tender), submylohyoid</td>
<td>Present if bilateral involvement</td>
<td>Present if bilateral involvement</td>
<td>Muffled voice; woody induration and protruding tongue in Ludwig angina</td>
</tr>
<tr>
<td>Anterior lateral pharyngeal</td>
<td>Severe, intensified by neck side flexion to contralateral side</td>
<td>Prominent</td>
<td>Anterior lateral pharynx, angle of jaw</td>
<td>Present</td>
<td>Occasional</td>
<td></td>
</tr>
<tr>
<td>Posterior lateral pharyngeal</td>
<td>Minimal</td>
<td>Minimal</td>
<td>Posterior lateral pharynx (hidden)</td>
<td>Present</td>
<td>Severe</td>
<td></td>
</tr>
<tr>
<td>Retropharyngeal and danger</td>
<td>Present</td>
<td>Minimal</td>
<td>Posterior pharynx</td>
<td>Present</td>
<td>Present</td>
<td>Odynophagia, neck, head tilted toward contralateral side</td>
</tr>
</tbody>
</table>

include the patient assuming the “sniffing position” to maximize airway patency, dysphagia, odynophagia, drooling, stridor, and features of respiratory distress. Deterioration of voice quality such as hoarseness or barking voice suggests glottis edema, and a weak cough can be a sign of laryngeal compromise.21

A retrospective study identified the presence of diabetes mellitus, multiple potential space involvement, and a total leukocyte count of at least $15 \times 10^9/L$ to be independent risk factors for life-threatening complications including airway obstruction and necrotizing fasciitis.22

### Table 2

<table>
<thead>
<tr>
<th>Space</th>
<th>Likely Pathogens</th>
<th>Suggested Antimicrobial Therapy&lt;sup&gt;a,b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submandibular Lateral pharyngeal Retropharyngeal Danger Mediastinum originating from head and neck infections or esophageal rupture Sinuses (odontogenic origin)</td>
<td>Oral anaerobes (including gram-positive cocci and β-lactamase–producing gram-negative bacilli) Facultative gram-negative bacilli</td>
<td>1. Extended-spectrum penicillin and β-lactamase inhibitor (piperacillin/tazobactam or ticarcillin/clavulanic acid) 2. Carbapenem (imipenem, meropenem, ertapenem) 3. Cephalomycins (cefoxitin or cefotetan) with a second agent with gram-positive coverage 4. Third- or fourth-generation cephalosporins + metronidazole 5. Moxifloxacin alone or clindamycin + ciprofloxacin in less critically ill patients</td>
</tr>
<tr>
<td>Prevertebral</td>
<td>Gram-positive organisms MRSA ± Gram-negative bacilli</td>
<td>Vancomycin 1. Third- or fourth-generation cephalosporin 2. Extended-spectrum penicillin and β-lactamase inhibitor combinations 3. Carbapenem</td>
</tr>
<tr>
<td>Postsurgical mediastinitis</td>
<td>Gram-positive organisms Facultative gram-negative bacilli</td>
<td>1. Extended-spectrum penicillin and β-lactamase inhibitor 2. Carbapenem 3. Third- or fourth-generation cephalosporin Vancomycin, linezolid, or daptomycin should be added to cover MRSA or coagulase-negative Staphylococcus species</td>
</tr>
<tr>
<td>Sinuses (nonodontogenic)</td>
<td>Gram-positive organisms Facultative gram-negative bacilli</td>
<td>1. Respiratory fluoroquinolone (levofloxacin or moxifloxacin) 2. Third-generation cephalosporin (ceftaxime or ceftriaxone) + metronidazole</td>
</tr>
</tbody>
</table>

<sup>a</sup> Host factors and local epidemiology should be considered in selecting initial empiric therapy.

<sup>b</sup> Consider addition of vancomycin if there is a risk of MRSA colonization, severe sepsis, or rapid deterioration.

Not all patients will progress to requiring intubation; however, all patients require careful monitoring within an intensive care setting where frequent airway evaluation is possible. There is a growing body of retrospective reports favoring conservative management of intravenous antibiotic therapy and close airway monitoring over conventional preemptive airway management in patients with no evidence of significant airway compromise. Airway considerations in complicating intubation include altered airway anatomy, friability of oropharyngeal tissue, and epiglottal edema. As paralytic agents may precipitate airway occlusion, awake intubation techniques under direct visualization, such as awake fiberoptic intubation via bronchoscopy, should be considered. If fiberoptic bronchoscopy is not successful or possible, tracheostomy under local anesthesia may be necessary. In the direst situations where catastrophic loss of airway patency is possible, it is wise to have a surgeon comfortable with tracheostomies or, at least, an emergency cricothyroidotomy kit available at the bedside along with physicians skilled in this procedure.

Infections of the submandibular space can also spread locally to other fascial planes of the neck and mediastinum, causing cervical necrotizing fasciitis. Spread to contiguous spaces is discussed in subsequent sections.

**INFECTIONS OF THE LATERAL PHARYNGEAL SPACE**

*Anatomy and Pathophysiology*

The lateral pharyngeal space is a potential space extending from the hyoid to sphenoid bones and bordered laterally by the parotid gland, mandibles, and internal
pterygoid muscle. Laterally, it is covered by a superficial layer of deep cervical fascia, with the exception of adjacent to the parotid gland. Inferiorly, by the angle of the jaw, a blind-cul-de-sac is formed where lateral space infections may present with swelling. Posteriorly, it communicates freely with the retropharyngeal space (Fig. 2).

The styloid process divides the lateral pharyngeal space into 2 communicating compartments (see Fig. 1B). The anterior muscular compartment contains no vital structures. The posterior neurovascular compartment contains the carotid sheath, cranial nerves IX to XII, and the cervical sympathetic trunk. A noteworthy complication of infections of the lateral pharyngeal space is suppurative jugular thrombophlebitis, or Lemierre syndrome.

Sources yielding an infection in the lateral pharyngeal space include the pharynx, teeth, tonsils, parotid gland, adenoids, submandibular space, retropharyngeal space, masticator space, and local lymph nodes.\(^3\)\(^,\)\(^27\) The fascial gap over the parotid gland allows easy communication; thus suppurative parotitis is a common cause of infections of the lateral pharyngeal space. The free communication between the lateral pharyngeal space and the retropharyngeal space facilitates spread of infection between these 2 anatomic spaces. Peritonsillar abscesses are also a frequent source of infections of the lateral pharyngeal space, particularly in children.

**Diagnosis**

Clinical manifestations of infections of the lateral pharyngeal space can be subtle, and are based on involvement of the anterior or posterior compartment (see Table 1).
Systemic symptoms such as fevers, chills, rigors, and malaise can be present. Signs or symptoms of the precipitating infection, such as pharyngitis or tonsillitis, may have resolved, and are often mild on history. However, signs and symptoms of suppurative parotitis include tender erythematous swelling of the preauricular and postauricular regions with extension to the angle of the mandible and associated trismus, dysphagia, and evidence of systemic toxicity. Peritonsillar abscesses may manifest as fever, muffled voice, unilateral sore throat with possible ipsilateral ear pain, trismus, and drooling. In some cases, patients may experience only a minor upper respiratory tract infection or malaise several weeks before presentation with an infection of the lateral pharyngeal space.

Classic signs of anterior compartment infection include dysphagia, trismus, and ipsilateral neck and jaw pain with possible referral to the ipsilateral ear. This pain can be intensified by side flexion of the neck to the contralateral side, which compresses the lateral pharyngeal space and sternocleidomastoid muscles. Examination may reveal swelling and induration at the ipsilateral angle of the jaw. Trismus suggests inflammation of the internal pterygoid muscle, which lies close to the lateral pharyngeal space. On pharyngeal examination, the lateral pharyngeal wall is often distorted medially, but the overlying mucosa appears normal. However, thorough examination may be limited by pain and trismus.

Posterior compartment infections in isolation lack trismus. Patients may not have localizing signs because the infection is deep-seated, but may first present with sepsis of unknown origin. The diagnosis may only become evident after the development of neurologic or vascular complications, or when appropriate imaging is performed. Swelling of the parotid space may be present, with parotid involvement. Epiglottal and laryngeal edema can cause significant dyspnea; however, edema of the pharyngeal wall may be difficult to detect on oropharyngeal examination because it may be hidden by the palatopharyngeal arch.

An ipsilateral Horner syndrome or palsies of cranial nerves IX to XII are suggestive of carotid-sheath involvement. A devastating potential complication is erosion and rupture of the carotid artery, which is often preceded by smaller “herald bleeds.”

### Lemierre Syndrome (Suppurative Jugular Thrombophlebitis)

- Rare condition, but most common vascular complication of infections of the lateral pharyngeal space
- Induration and swelling behind the sternocleidomastoid muscle
- Occlusive anaerobic septic thrombus of the internal jugular vein, often associated with bacteremia and metastatic foci of infection, most commonly in the lung and large joints
- For a more detailed discussion, the reader is directed to the review by Kuppalli and colleagues

Contrast-enhanced CT or duplex ultrasonographic imaging of the neck can help identify complications of infections of the lateral pharyngeal space such as Lemierre syndrome. Ultrasonography can reveal occlusive and nonocclusive thrombus of large veins, although contrast-enhanced CT is superior in defining the extent of the underlying infection such as a peritonsillar abscess. MRI provides comparable imaging, but availability limits its utility in urgent management.
Antimicrobial Management

- Antimicrobial coverage is similar to that for infections of the submandibular space (see Table 2).
- If there is no airway compromise, limited data suggest that posterior compartment infections (lower tendency to spread) can be treated with antibiotics alone.33–36
- Suppurative jugular thrombophlebitis can usually be treated with 4 to 6 weeks of antibiotics (duration supported by case reports and series).
- *Fusobacterium necrophorum* (pathognomonic organism of Lemierre syndrome) is usually penicillin sensitive.
- Anticoagulation in Lemierre syndrome is controversial, with limited data; some experts suggest consideration, particularly with poor initial response to antibiotics.37,38

Surgical Indications and Therapy

- Adequate, early drainage of pus (if present), in addition to appropriate antibiotic therapy, can prevent spread of infection to contiguous anatomic spaces.
- Contrast CT can identify lateral pharyngeal infections amenable to surgical drainage.
- Impending rupture of the carotid artery requires emergent surgical management and is historically associated with very high morbidity and mortality, even with intervention.27,39
- Lemierre syndrome with ongoing septic embolic events/thrombus propagation may require surgical ligation of the internal jugular vein.
- Poor surgical candidates may benefit from percutaneous mechanical thrombectomy plus thrombolytic therapy.40

Outcomes and Complications

The anatomy of the lateral pharyngeal space makes it a hub for deep space infections of the head and neck (see Table 3). Anterior infections of the lateral pharyngeal space have a tendency to liquefy the fat of the anterior compartment, creating pus and necrotic debris that can easily spread to other compartments. Life-threatening complications of posterior compartment infection include laryngeal edema and obstruction, sudden death secondary to vagal nerve involvement, Lemierre syndrome, and carotid artery erosion.

INFECTIONS OF THE RETROPHARYNGEAL AND DANGER SPACES

Anatomy and Pathophysiology

Layers of the deep cervical fascia between the pharynx and esophagus create 3 separate spaces (see Fig. 2). From anterior to posterior, these are the retropharyngeal, danger, and prevertebral spaces.

The retropharyngeal space extends from the base of the skull to approximately the C7/T1 level. The extension of the fascial planes allows for infection to easily spread to the superior anterior and posterior mediastinum. The middle layer of the deep cervical fascia extends anteriorly, and fuses with the parietal pericardium and adventitia of the great vessels. Risk factors for retropharyngeal abscess include foreign bodies, esophageal instrumentation (endoscopy, nasogastric tubes, frequent suctioning, intubation attempts), supplicative adenitis in children, and spread from contiguous spaces.41 In adults, infections of the retropharyngeal space often result from contiguous spread of a coexisting infection of the lateral pharyngeal space. In children, infections of
the retropharyngeal space may exist in isolation, owing to hematogenous seeding of the retropharyngeal lymph nodes from a distant source.

Between the alar fascia and the prevertebral fascia lies the danger space, which extends from the base of the skull to the diaphragm, passing through the posterior mediastinum. Infections of the danger space often originate from contiguous spread from neighboring anatomic locations. The third and most posterior space is the prevertebral space, which is discussed in a subsequent section as it does not share the same microbiology and pathophysiology.

Diagnosis

Infections of the danger space and retropharyngeal space, including retropharyngeal abscesses, can present with a wide spectrum of clinical signs and symptoms ranging from mild retropharyngeal pain and malaise to respiratory distress and sepsis (see Table 1). Patients may present with odynophagia, dysphagia, and dyspnea. The patient may also have a stiff neck and may tilt the head up and backwards to maximize air intake. The pharyngeal wall and supraglottic structures may be displaced, leading to respiratory distress and noisy breathing. Pleuritic chest pain suggests mediastinal involvement. Examination of the oropharynx may reveal bulging of the posterior oropharynx, and a pharyngeal mass may be observed or palpated. Clinicians must be aware that palpation of the mass may result in abscess rupture with subsequent aspiration or asphyxiation.

In children, a radiograph of the lateral soft tissue of the neck can help to identify a retropharyngeal collection; however, this is less sensitive than a contrast-enhanced CT scan. Imaging is not able to adequately differentiate between infections of the retropharyngeal and danger spaces; however, extension below the T4 level suggests involvement of the danger space. Infections in these spaces may be evident as phlegmon, suppurative lymphadenitis, or abscesses. Retropharyngeal abscesses secondary to suppurative lymphadenitis will reveal large paramedian lymph nodes that have a low central density and are ring-enhancing on contrast-enhanced CT.

Antimicrobial Management

- Antibiotic therapy is similar to that of infections of the submandibular space (see Table 2).
- Empiric therapy should include coverage for oral anaerobes, including β-lactamase–producing organisms.

Surgical Indications and Therapy

- Early antibiotics, before abscess formation, may prevent the need for surgical drainage.44–46
- However, there is disagreement regarding the optimal timing for surgical drainage.47
- If drainage is needed, minimally invasive drainage in addition to washout techniques may be used.48

Outcomes and Complications

Complications of infections of the retropharyngeal and danger spaces include spread to neighboring spaces and structures, as well as direct local effects (see Table 3).

The fascial extension of the pretracheal or anterior visceral fascia allows for spread of infections of the retropharyngeal space to the visceral space containing the esophagus and trachea, and to the superior anterior mediastinum, which can progress to
purulent pericardial and pleural infections. Infections of the danger space can spread to the posterior mediastinum, pericardium, and, occasionally, the retroperitoneal space.

Infections of the retropharyngeal and danger spaces with severe laryngeal inflammation can result in life-threatening airway occlusion. A retropharyngeal abscess can rupture into the posterior oropharynx, causing aspiration of purulent contents, which can lead to pneumonia or asphyxiation. A potentially lethal complication of infections of the retropharyngeal and danger spaces is descending necrotizing mediastinitis. A retrospective review of deep neck infections requiring surgical drainage and admission to the intensive care unit (ICU) found retropharyngeal abscesses to be more likely to result in septic shock, severe sepsis, mediastinitis, empyema, or necrotizing fasciitis than deep neck abscesses in other locations.

INFECTIONS OF THE PREVERTEBRAL SPACE

Background and Epidemiology

The prevertebral space is bounded anteriorly by the prevertebral fascia and posteriorly by the vertebral bodies. The fascial planes are as described earlier. The prevertebral space extends from the base of the skull to the coccyx and is contiguous with the psoas muscle sheath. Infections of the prevertebral space generally originate from the cervical or thoracic spine, including vertebral osteomyelitis and discitis, which are usually hematogenous in origin. Risk factors for hematogenous spread include injection drug use, diabetes mellitus, immune suppression, and alcohol abuse.

Diagnosis

The presentation of infections of the prevertebral space depends on the degree of spinal cord compression and neurologic dysfunction (see Table 1), and the diagnosis of prevertebral abscesses is often difficult. Nearly half of cases are initially misdiagnosed. Roughly 75% of patients experience back or neck pain, 50% present with fever, and 33% have neurologic deficits, ranging in severity from nerve root pain to paralysis. Sixty percent of patients with epidural abscesses are bacteremic on presentation. The prevertebral space is contiguous with the psoas muscle sheath, so a psoas abscess raises suspicion of an underlying infection of the prevertebral space. As infections of the prevertebral space often arise from discitis or spinal osteomyelitis, a thorough assessment should also look for signs for spinal involvement and instability.

MRI is the imaging modality of choice for infections of the prevertebral space, to assess involvement of the epidural space or spinal cord.

Antimicrobial Management

- The most common organism identified in infections of the prevertebral space is *S. aureus* (see Table 2).
- Other organisms, including oral anaerobes, enteric gram-negative rods, *brucella*, *nocardia*, *mycobacteria*, fungi, and, rarely, parasites have also been found.
- Empiric antimicrobial therapy should be broad, including coverage for MRSA and facultative gram-negative bacilli, and guided by local antimicrobial resistance patterns.
- Coverage of gram-negative rods is important, particularly if risk factors (eg, injection drug use, urinary tract infection) are present.
Surgical Indications and Therapy

- Surgical drainage is required for source control and to minimize neurologic sequelae.
- There is controversy regarding combined surgical-medical management versus medical management alone:
  - Older literature advocated for conservative treatment in stable patients with minimal neurologic findings and easy access to MRI.\(^6\)
  - More recent reports have found that early surgical intervention is associated with lower morbidity and mortality than medical therapy alone.\(^5\)

Outcomes and Complications

Infections of the prevertebral space and spinal epidural abscesses can lead to cord compression and neurologic deficits. Irreversible paralysis occurs in 4% to 22% of patients (see Table 3).\(^5\)

MEDIASTINAL INFECTIONS

Background and Epidemiology

Infections of the mediastinum are most commonly postsurgical.\(^5\) Risks for poststernotomy mediastinitis include both host and surgical factors. Host factors include advanced age, obesity, chronic obstructive pulmonary disease, diabetes mellitus, peripheral vascular disease, renal failure, and decreased cardiac function. Surgical factors include prolonged operative time, emergency surgery, bilateral grafting of the internal mammary artery, use of intra-aortic balloon pumping, increased need for blood transfusion, and extracardiac vascular intervention.\(^5\)

Other predisposing procedures of risk include insertion of left ventricular assist device, insertion of central venous catheter, biopsy of local tissue and lymph nodes, tracheostomy, and traumatic intubations.\(^5\) Other etiologic factors include contiguous spread from descending necrotizing mediastinitis and esophageal rupture (Fig. 3). The fascial planes of the retropharyngeal and danger spaces freely communicate with the mediastinum, facilitating contiguous spread. Hematogenous seeding and spread from the abdomen, chest wall, lungs, and lymph nodes may also occur.

Diagnosis

The clinical presentation of mediastinitis is broad, and ranges from indolent disease to septic shock whereby patients can deteriorate rapidly over several hours (see

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**Fig. 3.** Esophageal rupture in Boerhaave syndrome. A 45-year-old man with chest pain and dyspnea. (A) Initial chest radiograph (CXR) reveals left lower lobe consolidation and costophrenic angle blunting. (B) Symptoms worsen, and repeat CXR reveals left pleural effusion with an air-fluid level and pneumothorax. (C) A chest tube is inserted, and frank food particulates and pus are evacuated from the pleural space.
Historical features such as recent surgery or instrumentation, head and neck infections, caustic ingestions, emesis, and dysphagia may help to identify an underlying cause. Patients may experience chest pain, dysphagia, odynophagia, dyspnea, nausea, and, occasionally, abdominal pain. Physical examination often reveals a fever and tachycardia, and possible septic shock. Chest-wall crepitus may be palpated and a Hamman crunch may be auscultated. Hamman crunch, a sign of pneumomediastinum, is a systolic crunching or clicking sound best heard over the cardiac apex. In esophageal rupture a history of emesis, chest pain, and subcutaneous emphysema may be present. Poststernotomy mediastinitis is commonly associated with sternal osteomyelitis and associated failure of sternal closure wires. Poststernotomy patients may or may not have incision-site infections, chest pain, wound dehiscence, sternal instability, or sepsis with no alternative source.

Chest radiography may show subcutaneous, mediastinal, or pericardial air, a widened mediastinum, or pleural effusions with or without air-fluid levels. Contrast-enhanced CT of the chest is imperative in the diagnostic workup, and can identify localized infection and complications. Within 2 weeks of a sternotomy, MRI may be required owing to extensive postoperative edema. CT of the neck and lower skull may identify a source of descending necrotizing mediastinitis.

**Antimicrobial Management**

- The cornerstone of treatment is early broad-spectrum antibiotics (see Table 2) plus consideration of surgical debridement.
- Microbiology is largely determined by the source of infection:
  - Head and neck origin: polymicrobial, oropharyngeal organisms
  - Esophageal perforation: similar, but more gram-negative bacilli
  - Postsurgical: more likely to be caused by Staphylococcus aureus, although *Enterococcus* spp and facultative gram-negative bacilli should be considered
- Indolent infections may be caused by coagulase-negative staphylococci.
- Anaerobic organisms are less common.
- If there is poor response to broad-spectrum antibacterial agents, other pathogens such as Candida and Aspergillus should be considered.

**Surgical Indications and Therapy**

- Historically, surgical drainage and debridement has been a mainstay of treatment.
- Appropriate surgical services (thoracic, oromaxillofacial, cardiac, or otolaryngology) may be consulted.
- Thoracotomy with cervicotomy has been the technique of choice for mediastinal drainage and debridement.
- Some evidence indicates that aggressive surgical debridement leads to better outcomes in necrotizing mediastinitis.
- Recent literature supports more conservative measures, including percutaneous catheter drainage and drainage via video-assisted thoracoscopic surgery.
- Recurrent abscesses may require subsequent drainage, percutaneous or otherwise.

**Outcomes and Complications**

Complications of mediastinitis include pericardial spread causing pericardial effusion and possible tamponade, aspiration pneumonia, and rupture into the pleural cavity with subsequent pyothorax and pleural effusions (see Table 3). Acute mediastinitis is associated with mortality rates ranging from 12% to 50%.
Factors associated with mortality due to poststernotomy mediastinitis include age older than 70 years, surgical procedures other than coronary artery bypass graft alone, McCabe class 2/3, APACHE II score, persistent bacteremia, and failure to wean from mechanical ventilation by postoperative day 3.\textsuperscript{80}

**SINUSITIS**

*Background and Epidemiology*

The maxillary, ethmoid, frontal, and sphenoid sinuses make up the paranasal sinuses (Fig. 4, Table 4). These air-filled cavities are connected via sinus ostia, which drain into the nasal cavity. The posterior ethmoid and sphenoid sinuses drain into the superior meatus of the nasal cavity. The frontal, anterior ethmoid, and maxillary sinuses drain into the middle meatus. Drainage from the paranasal sinuses converges in the osteomeatal complex, which lies between the middle and inferior nasal turbinates.

Though generally sterile, the paranasal sinuses can be transiently colonized by flora from the upper respiratory tract. The most common sinus infection occurs in the maxillary sinuses. The apices of the first, second, and third maxillary molars rest just beneath the inferior aspect of the maxillary sinus. As a result, odontogenic infection can lead to maxillary sinusitis. Traumatic head injury is also a risk factor for maxillary sinusitis.\textsuperscript{82}

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**Fig. 4.** Anatomic relationships of the paranasal sinuses. (Netter illustration from www.netterimages.com. © Elsevier Inc. All rights reserved.)
The frontal sinus is a less common site of sinusitis, but because of its anatomic location, subsequent spread to the intracranial space or orbit can occur. The ethmoid sinuses lie adjacent to the orbit, with only a thin orbital plate separating the 2 compartments. The sphenoid sinus is bordered superiorly by the pituitary gland, rostrally by the optic nerve and optic chiasm, and laterally by the internal carotid arteries, cavernous sinuses, and temporal lobes of the brain.

In critically ill patients, nasal foreign bodies and irritation contribute to nosocomial sinusitis. Risk factors for ICU-associated sinusitis include nasal colonization with gram-negative bacilli, nasoenteric-tube feeding, sedation, and Glasgow Coma Scale score of 7 or less. Prevalence of rhinosinusitis in the ICU varies broadly and ranges from 7.7% to 58%, making this a significant source of ICU-associated infection.

**Diagnosis**

Sinusitis in critically ill patients can range in presentation from an indolent chronic sinusitis to rare instances of severe and complicated infection (see Table 1). Sinusitis secondary to nasotracheal or nasogastric intubation may be difficult to detect clinically. Signs may include purulent rhinorrhea or a middle-ear effusion. In critically ill intubated patients, sinusitis can manifest as only an unexplained fever. Signs of ethmoid sinusitis include eyelid edema and excess lacrimation. Proptosis and retro-orbital pain suggest involvement of the orbit. In sphenoid sinusitis, severe headache can resemble trigeminal neuralgia or an ophthalmic migraine.

Endoscopy can identify purulent discharge from the middle meatus and edematous, hyperemic nasal turbinates, and endoscopically directed middle meatal cultures have a high yield for detecting causative organisms. In ICU patients, visualization of purulence in the middle meatus has been found to be more sensitive than CT for predicting positive cultures on antral lavage.

Imaging studies are required if there is a concern for orbital or intracranial extension and in cases that fail initial empiric therapy. Plain sinus radiographs may reveal signs of acute sinusitis; however, CT imaging allows for better visualization of the sinuses and their contents, particularly the ethmoid and sphenoid sinuses. Orbital or intracranial complications are best visualized with contrast-enhanced CT. Air-fluid levels are the most sensitive CT sign of sinusitis. Although CT is very sensitive for detecting evidence of sinusitis, its specificity is poor and findings must be interpreted within the given clinical context. MRI is limited in evaluating cortical bone, but is valuable for investigating intracranial suppurative and intraorbital complications. B-mode ultrasonography can be used to diagnose maxillary sinusitis, although it is not a useful modality for imaging the other sinuses. Bedside A-mode ultrasonography can also be used to detect maxillary sinusitis, although its sensitivity is low.

Mucormycosis sinusitis, commonly caused by fungi in the order Mucorales (eg, *Mucor, Rhizopus*), can also be caused by other molds such as *Aspergillus* spp.
Mucormycosis is most common in immunocompromised and diabetic patients, and is characterized by a rapidly progressive and invasive infection that can often be complicated by intracranial and intraorbital spread. Presenting signs and symptoms may include headache, fever, facial swelling, and unilateral orbital apex syndrome with involvement of cranial nerves III to VI, caused by invasion of the apex of the orbit. If there is intracranial involvement, patients may experience seizures, decreased level of consciousness, stroke, and coma. CT findings of sinonasal mucormycosis include hyperdense opacification of the soft tissue, nodular mucosal thickening, and an absence of fluid levels in the paranasal sinuses. Bony change and destruction with focal masses can also be seen. Orbital invasion from the ethmoid sinus is characterized by thickening and lateral displacement of the medial rectus muscle.91

Antimicrobial Management

- In patients admitted to the ICU, the most commonly isolated pathogens are gram-negative organisms, although gram-positive organisms are also frequently isolated.
- Anaerobic and fungal isolates are less common.82,83,87,92
- Cultures (sinus puncture + aspiration) can help guide antimicrobial therapy (see Table 2).92
- Antifungals should be considered in severely immunocompromised patients with invasive disease.
- Noninvasive fungal sinusitis may respond to surgical debridement.
- In immunocompromised hosts, high-dose intravenous amphotericin B plus surgical debridement is often needed.
- Once the fungal pathogen is known, alternatives to amphotericin (toxicity) can be used.
- Careful consideration needs to be given to the antimicrobial susceptibility to and intracranial penetration of the antifungal chosen.

Surgical Indications and Therapy

- Invasive fungal infections (eg, mucormycosis), orbital involvement, intracranial complications, and refractory sinusitis secondary to osteomeatal obstruction warrant surgical intervention.
- Functional endoscopic sinus surgery can be used to relieve ostial obstruction and to access ethmoid and sphenoid sinuses.
- Initial management for patients diagnosed with sinusitis in a critical care setting consists of antibiotics, saline nasal irrigation, aspiration of secretions, and removal of nasal catheters.
- If conservative therapy fails, sinus puncture with drainage, irradiation, and possible temporary drain insertion is indicated, although rarely done.
- Most of the literature is restricted to the use of sinus puncture for maxillary sinusitis; however, emerging evidence suggests a role for sphenoid sinus puncture.92

Outcomes and Complications

Although rare in the postantibiotic era, suppurative complications of sinusitis can occur (see Table 3).

Frontal sinusitis can lead to intracranial or orbital spread, frontal bone osteomyelitis (Pott puffy tumor), or superior sagittal sinus thrombosis. Compromise of the plate between the ethmoid sinus and the orbital space can facilitate spread of infection to the retro-orbital space. In addition, ethmoid sinusitis can be complicated by cavernous
venous or superior sagittal sinus thrombosis and intracranial spread. Maxillary or ethmoid sinusitis can result in osteomyelitis of the facial bones and subsequent prolapse of the orbital antral wall. Maxillary sinusitis rarely leads to intracranial spread, except in rhinocerebral mucormycosis. Because of its anatomic location and proximity to essential structures, sphenoid sinusitis can result in meningitis, epidural or subdural empyema, temporal lobe abscesses, orbital fissure syndromes, and cavernous sinus thrombosis.

REFERENCES


