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Diagnostic imaging of maxillofacial infections

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Diagnosis and management of head and neck infections are common clinical challenges for the oral and maxillofacial surgeon. Symptoms, signs, and laboratory data are often suggestive of an infectious or inflammatory process. Given the right clinical conditions, however, several noninfectious conditions can mimic these processes. Based on clinical examination and occasionally laboratory data, the examining surgeon must determine the need for advanced imaging studies.

Opinions still vary as to whether computed tomography (CT) or magnetic resonance imaging (MRI) is the best imaging modality for acute neck infections [1–4]. When imaging is needed, it is the authors' opinion that the least invasive and least expensive examination that adequately evaluates the patient should be used. When an odontogenic origin (necrotic pulp) is suspected as the source of a localized infection, intraoral films or panoramic radiographs are usually adequate. Ultrasound also has been used in the evaluation of superficial neck infections, especially to determine fluid accumulation, but is not recommended for deep neck infections because it cannot penetrate bone or the airway space. Conventional films still can be used for a preliminary survey, especially of the retropharyngeal space and evaluation of the airway.

Although most maxillofacial infections remain localized and are managed successfully by antibiotic therapy or surgical intervention, serious and potentially life-threatening complications, such as airway compromise [5], cavernous sinus thrombosis [4,6], cerebral empyema [4,7], internal jugular vein thrombophlebitis [8], Ludwig's angina [9], or necrotizing fasciitis [10–12], can occur.

This article discusses mainly CT and MRI as they relate to localization of infectious processes and the evaluation of abscess cavities.

Techniques

Computed tomography

Traditional or single slice acquisition CT uses a gantry that houses an x-ray tube and a row of detectors. Images are produced by data collected from the detectors after a 360° rotation. After each tomographic image the patient table is moved and another image obtained. A time delay of 10 to 15 seconds between each slice is necessary. Spiral CT involves the simultaneous movement of the patient table and the x-ray tube, which results in a volume acquisition of data from which individual tomographic images can be reconstructed. Because a volume data set is acquired, excellent multiplanar reformations are possible when using thin image slices (3 mm or less). Picture archival communication systems are becoming more common in hospitals. Some of these systems allow viewing multiplanar reformation in any plane desired, not just the standard sagittal and coronal planes. In the past, CT reformation programs, such as DentaScan, were recommended for true cross-sectional images of the jaws, not only for implant planning but also for evaluation of tumors, osteomyelitis, or other pathologic conditions [13,14]. Picture

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archival communication systems with multiplanar reformation capability obviate the need for such programs in the evaluation of pathologic conditions.

Other advantages of spiral CT in applications to the head and neck include one breath hold, which minimizes artifacts because of swallowing, and improved vascular opacification and lesion enhancement using a smaller contrast bolus [15]. Multidetector CT is yet another improvement over spiral CT. Whereas spiral CT uses a single row of detectors, multidetector CT uses a matrix of detectors that allows the acquisition of multiple tomographic images per revolution, which greatly increases the speed of imaging.

Accuracy of computed tomography

Deep neck infections in adult patients

Miller et al [16] performed a prospective study that compared the efficacy of contrast-enhanced CT (CECT) to clinical examination in detecting the presence of a drainable fluid collection in suspected deep neck infections. The accuracy (frequency of a test to diagnosis correctly the presence or absence of disease) of clinical examination alone in identifying a drainable collection was 63%, the sensitivity (ability of a test to identify correctly a disease when it is truly present) was 55%, and the specificity (ability of a test to identify correctly the absence of disease when it is truly absent) was 73%. The accuracy of CECT alone was 77%, the sensitivity was 95%, and the specificity 53%. When CECT and clinical examination were combined, the accuracy in identifying a drainable collection was 89%, the sensitivity was 95%, and the specificity was 80% [16].

Deep neck infections in pediatric patients

Nagy et al [3] compared the sensitivity of lateral neck films and CECT in evaluating children with a high index of suspicion for a deep neck infection, based on clinical presentation. More than 25% of lateral neck radiographs were unable to determine the presence of a deep neck infection, whereas CECT had a sensitivity of 100%. They concluded that CECT is the study of choice in the evaluation of children strongly suspected of having a deep neck infection based on clinical presentation [3].

Fig. 1. (A) Chronic dentoalveolar granuloma. Axial T1-weighted MRI without contrast shows the normal bright signal from fatty marrow in the maxillary alveolar ridge. There is a focal area with low signal surrounding the maxillary canine root (*arrow*), which indicates replacement of normal fatty marrow by either a neoplastic or inflammatory process. (B) Parasagittal T1-weighted MRI with contrast and fat saturation demonstrates enhancement of tissue surrounding the root of the right maxillary canine. The uniform enhancement indicates a granuloma rather than an abscess, which would exhibit only peripheral enhancement.

Wetmore et al [17] evaluated the use of CT in children with deep neck infections. CECT demonstrated an accuracy of 92% for detection of an abscess confirmed by surgery. In children with superficial neck infections, only 24% of those who were treated surgically showed definite CT evidence of an abscess. The decision to perform surgery was based on clinical findings, such as palpable fluctuance and skin changes [17]. As with adults, the combination of clinical examination and radiographic data yielded the best results.

NewTom

A new development in maxillofacial imaging is the NewTom (Schick NIM S.r.l., Verona, Italy). This machine performs axial panoramic and multiplanar imaging of the maxillofacial region and produces images similar to those acquired by the DentaScan (General Electric Medical Systems, Milwaukee, WI) as viewed in bone windows. Image acquisition by the NewTom is fundamentally different from conventional CT. The images are derived from a three-dimensional data set acquired from multiple planar images (ie, multiple digital projections), which renders excellent high tissue contrast resolution (bony detail). Because of this ability, the NewTom is excellent for detection of lytic bony lesions; however, it lacks the ability to demonstrate the low tissue contrast resolution needed to detect subtle soft tissue changes as seen with cellulitis, soft tissue abscess, cerebral empyema, or retropharyngeal fluid/edema. The lower neck cannot be imaged. For these reasons, conventional CECT is recommended for the evaluation of head and neck inflammatory processes.

Magnetic resonance imaging

A disadvantage of MRI is the lack of availability. Most MRI units are ‘‘tightly booked’’ with long waiting periods for appointments. Even a 1-day wait is not acceptable for a patient with a potentially life-threatening head and neck infection. Over the years, MRI scanners have become more numerous and are more available for emergent scans. Some imaging centers have time reserved each day for emergency scanning, and some large medical centers have MR scanners in the emergency department. Even with emergency time reserved, however, maxillofacial and neck infections would have a lower priority for the MRI scanner than examinations to evaluate for acute spinal cord compression or acute stroke.

An MRI is obtained by placing the patient in a strong and uniform magnetic field. Smaller gradient coils distort the uniform field, which causes only those hydrogen protons in a certain plane to resonate when excited by a specific radiofrequency. These excited protons emit a signal that, when analyzed by a two-dimensional Fourier, is transformed into an image.

Accuracy of magnetic resonance imaging

Munoz et al [2] prospectively evaluated 47 patients with neck infections. Each patient underwent CT and MRI with contrast of the area of interest using similar slice thickness. MRI was superior to CT in regard to lesion conspicuity, number of anatomic spaces involved, extension, and source. CT was superior to

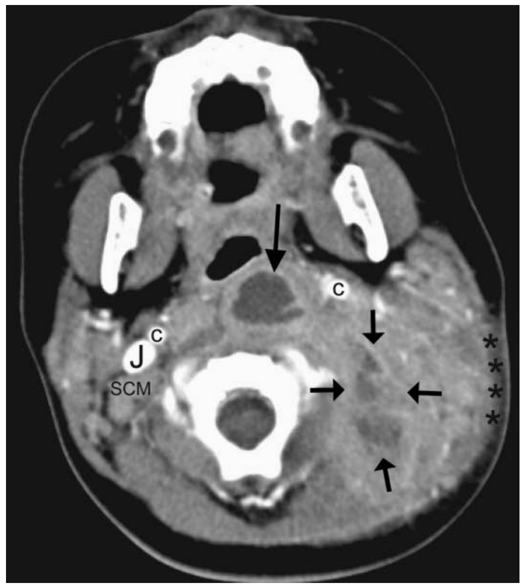

Fig. 2. Retropharyngeal abscess. Axial image of CT scan with contrast obtained at the level of the maxilla. A 1.5-cm retropharyngeal abscess is present (*large arrow*). This is seen as a fluid density collection surround by a rim of enhancing tissue. Notice that the density or attenuation of this fluid collection is the same as the cerebrospinal fluid that surrounds the cord. A second area of fluid density, which is not as well defined (*smaller arrows*), is seen in the lateral neck. This represents a multiloculated abscess. Notice that normal fat on the soft tissue windows is dark. There is an area of edema or infiltration in the fat (*stars*). This appearance is referred to as dirty fat. Compared to the right sternocleidomastoid muscle (SCM), the left sternocleidomastoid muscle cannot be distinguished from the surrounding inflammatory process. The left jugular vein is compressed and is not visualized. The right jugular vein and the right carotid artery are in their normal location (*J,C*). The left carotid artery (*c*) is displaced anteriorly by the inflammatory process.

MRI in the detection of intralesional gas and calcium and showed fewer motion artifacts. On this basis, MRI was considered superior to CT in the initial evaluation of neck infections. These findings suggest that MRI should be used as the first and perhaps only modality to evaluate patients initially with neck infections [2].

Interpretation

Computed tomography

Computed tomography uses the differences in attenuation of the x-ray beam by different tissues to form an image. The lowest attenuation occurs in air, and the highest attenuation occurs in bone, dentin, enamel, or metal. Fat has a lower attenuation than water, which in turn has lower attenuation than muscle. When edema occurs, there is an increase in water content. Edematous fat increases in attenuation, whereas muscle decreases in attenuation on noncontrasted CT [18]. Increased blood flow occurs in inflamed tissue. After administration of iodinated contrast medium, areas of increased blood flow demonstrate enhancement. Intravenous iodinated contrast is indicated for CT evaluation of a patient with suspected cellulitis or abscess.

Magnetic resonance imaging

The MRI parameters can be manipulated to produce several different appearances. As an oversimplification, T1-weighted images produce images in which fat is bright and fluid such as cerebrospinal fluid is dark. The presence or absence of the bright signal from fat can help detect pathologic processes. Normally fatty marrow is bright. Any pathologic process, such as metastatic disease or infection, that has replaced the normal fatty marrow appears abnormally dark (Fig. 1A). Gadolinium contrast medium is

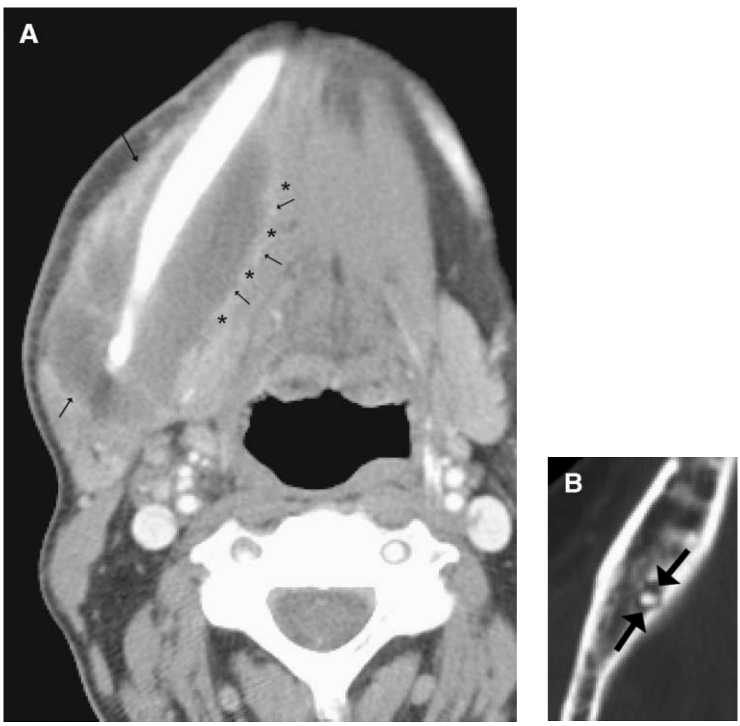

Fig. 3. (A) Subperiosteal abscess. Axial CT image with contrast at the level of the inferior border of the mandible in a 43-year-old man with painful swelling of the neck. There is a fluid mass density surrounding the angle of the mandible and extending along the inferior border (*arrows*). This abnormal fluid collection extends on both sides of the mandible. The geniohyoid muscle (*asterisks*) is displaced medially. (B) Bone window demonstrates a small periapical radiolucency around the distal root of the mandibular right second molar. The next inferior image demonstrates a small break in the cortex. The source of the large subperiosteal abscess was from the necrotic second molar.

used only with T1-weighted images. When concentrated in tissues, gadolinium contrast medium demonstrates an increase in signal intensity. Unlike imaging the brain, where (usually) no fat is located, in maxillofacial, orbital, or neck imaging, fat saturation is critical when using gadolinium contrast medium. Fat saturation makes the normal fat dark, and normal and abnormal enhancement is much more conspicuous (Fig. 1B). When evaluating a contrasted T1-weighted image of the head and neck, there should be an avid enhancement of the nasal mucosa. If it does not enhance, there is a problem with the contrast bolus and pathologic processes also would fail to enhance. This occurrence could lead to a false-negative examination result. The ocular muscles normally enhance, but the larger muscles, such as paraspinal muscles or muscles of mastication, do not enhance.

With T2-weighted images, the "juicier or squishier" [19] the tissue, the brighter it is. Stationary fluid, such as cerebrospinal fluid, appears bright. Edematous or inflamed tissues demonstrate increased signal intensity, especially when fat saturation is used.

Pathology

Odontogenic infections

In a retrospective study of 210 patients with neck infections, the most common cause was dental infection (43%). Dental infection was the cause of 76% of Ludwig's angina [20]. In patients with deep neck space infections, airway compromise was more frequent and severe in odontogenic than in nonodontogenic deep neck space infections. The parapharyngeal, submandibular, and masticator spaces are more vulnerable in odontogenic deep neck space infections than in nonodontogenic infections. The predilection for certain spaces of the neck to be involved in

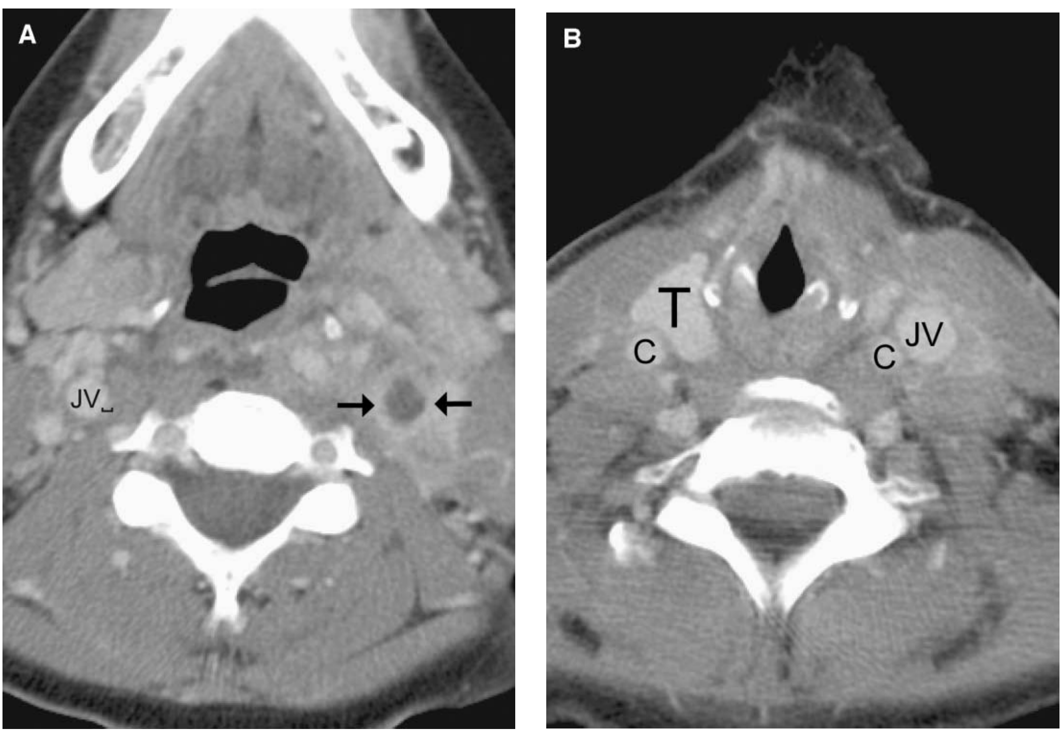

Fig. 4. (A) Septic thrombophlebitis. Axial CT examination with contrast performed at the level of the inferior border of the mandible in a 31-year-old woman with a painful swollen left neck. There is an area of low attenuation surrounded by avid enhancement (*arrows*). Compared to Fig. 1, this has the appearance of an abscess, but the hypodensity extends in a craniocaudal dimension from the skull base to the level of the hyoid bone. This represents a low-density thrombus surrounded by enhancing vasovasorum. Note the normally enhancing jugular vein on the right (*JV*). (B) Axial enhanced CT scan at the level of the thyroid gland (*T*). Note the normally enhancing jugular vein at this level on the left and the normal carotid arteries (*C*).


A
SMG
B
C

odontogenic deep neck space infection originates from the intimate relationship of the mandibular molars to the adjacent deep neck spaces [5] (Fig. 2).

Retropharyngeal abscess versus cellulitis

On CT, cellulitis appears as soft tissue swelling, increased density of surrounding fat, enhancement of involved muscles, and obliteration of fat planes [3,5]. An abscess is considered to be present if there is a low (fluid) density area with a peripheral rim of enhancement (Fig. 3) [3,5]. Symptoms include fever, neck swelling, sore throat, dysphasia, and cervical rigidity. Sometimes small children present with nonspecific symptoms [21]. Children younger than 5 years who present with poor oral intake, high fever, drooling, and trismus should be suspected of having a peritonsillar abscess. A CT scan of the neck is usually required to confirm a suspected diagnosis [22].

Recurrent deep neck infections

Most deep neck infections are the result of suppurative adenitis. The location of the primary focus is usually from the mucosa of the upper aerodigestive tract or from an odontogenic source. Recurrence in these situations is unusual. Less commonly, congenital lesions can present as deep neck infections, and recurrences are common. In patients with recurrence of deep neck infections, the possibility of an underlying congenital lesion, such as branchial cleft cyst, infected lymphangioma, or thyroglossal duct cyst, should be considered [23].

Nontuberculous and tuberculous mycobacteria infection

Nontuberculous mycobacteria infection most often presents in children as an asymmetric adenopathy with contiguous low-density ring-enhancing masses, minimal or absent inflammatory stranding of the subcutaneous fat, and cutaneous extension

Fig. 6. Periorbital abscess. Coronal CT scan with contrast in a 14-year-old boy who experienced orbital swelling and pain. Notice the subperiosteal fluid collection adjacent to the orbital roof on the left (*arrows*). There is opacification of the maxillary sinuses and left ethmoid sinuses. Also notice is the periorbital soft tissue swelling. The left medial rectus (*asterisk*) is displaced laterally from the lamina propria. The cause for this orbital abscess was spread of infection from ethmoid sinusitis.

[24]. Cervical tuberculous lymphadenitis is also an important cause of a neck mass in many countries. Multilocular low densities with peripheral enhancement and a large confluent low density with a lesser degree of fat plane obliteration than a pyogenic abscess are suggestive features of advanced cervical tuberculous lymphadenitis.

Septic thrombophlebitis

Septic thrombophlebitis of the jugular vein (Lemierre's syndrome) is an uncommon cause of painful neck swelling [8]. On CT, a thrombus within the jugular vein appears as an area of low attenuation with peripheral enhancement (Fig. 4), which easily could be mistaken for abscess. Normal enhancing vascular structures of the neck must be identified

Fig. 5. (A) Sialadenitis with abscess formation. The patient presented with painful swelling in the left floor of the mouth. Clinically, an odontogenic source of infection was suspected. Axial CT scan performed at the level of the submandibular gland showed multiple small locules of gas present as low attenuation or dark areas (*arrows*). Notice that gas has extended into the submandibular space, buccal space, and parapharyngeal space. Compare to the normal submandibular gland (*SMG*) on the right. (B) Axial CT image performed superior to the submandibular gland at the level of the floor of the mouth. Note the presence of gas in the fascial plane of the floor of the mouth, with some crossing the midline. The gas is the product of gas-producing organisms. The appearance is concerning for early development of Ludwig's angina. (C) Axial CT scan performed at the level of the maxillary sinuses. Gas in the parapharyngeal space (*black arrow*) has tracked up toward the skull base. There is also a large amount of gas in the buccal space (*white arrow*), anterior to the left masticator space.

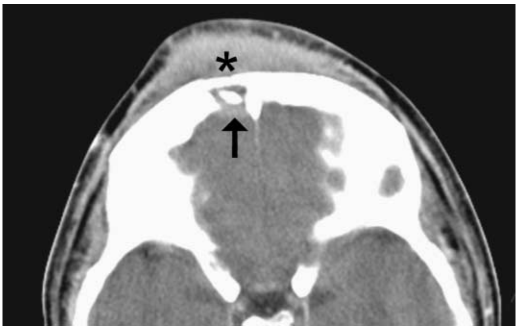

Fig. 7. Pott's puffy tumor. A CT image with contrast at the level of the frontal sinus of a 14-year-old boy with painful frontal swelling. A subperiosteal abscess is present (*asterisk*). There is erosion of the inner wall of the frontal sinus and abnormal dural enhancement (*arrow*). A bony sequestrum is present.

and traced in the craniocaudal direction. Tracing of other neck structures also is important. Necrotic lymph nodes also can mimic cervical abscesses on CT scans and result in negative surgical findings [22].

Sialadenitis

In general, CT has supplanted sialography for the evaluation of inflammatory processes in the salivary glands (Fig. 5). If salivary calculi are suspected as the cause of an inflammatory process, a noncontrasted CT to detect calculi followed by contrasted CT to evaluate for abscess/cellulitis is recommended. Frequently, inflammatory processes in the salivary glands present as a mass and clinically are difficult to distinguish from malignancy. In such cases, contrasted CT or MRI can be used to determine if the mass is intrinsic or extrinsic to the gland [25].

Acute suppurative bacterial sialadenitis is associated with painful, swollen glands. The parotid gland is most commonly involved [1]. Salivary calculi are best seen on CT and appear as a high-density mass along the course of the duct. CT also demonstrates gas in the tissue better than MRI [5].

Necrotizing fasciitis

Craniocervical necrotizing fasciitis is a rapidly progressive, severe bacterial infection of the superficial fascial planes of the head and neck. Group A beta-hemolytic *Streptococcus*, *Staphylococcus aureus,* and obligate anaerobic bacteria are commonly involved pathogens. The disease usually results from a dental source or facial trauma. Extensive fascial necrosis and severe systemic toxicity are common manifestations of craniocervical necrotizing fasciitis. Most patients have an underlying medical problem that created an immunocompromised state, usually diabetes mellitus or chronic alcoholism [26]. Constant CT features of necrotizing fasciitis are diffuse cellulitis, diffuse enhancement or thickening of the superficial and deep

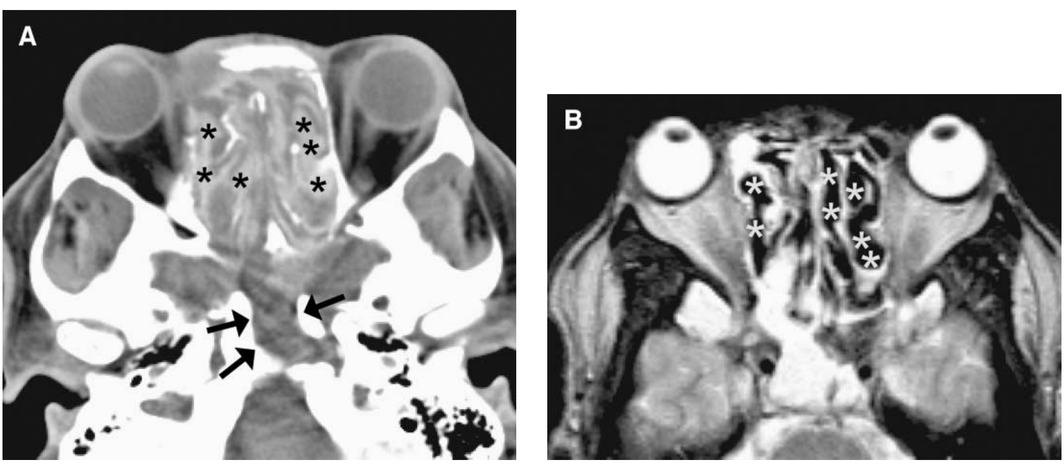

Fig. 8. (A) Chronic fungal sinusitis. Axial CT image without contrast at the level of the orbits. Notice the high-density material in the ethmoid sinuses (*asterisks*). This is a chronic process and has caused expansion of the ethmoid sinuses, which resulted in hypertelorism. The fungal sinusitis also caused erosion of the clivus (*arrows*). The high-density material in the ethmoid sinus is characteristic of fungal sinusitis. The surrounding lower density material represents mucosa. (B) Axial T2-weighted MRI at the same level as (A). Notice the signal void (*asterisk*), which corresponds to the high-density material seen on the CT examination. This signal void could be mistaken for normal, aerated ethmoid sinus. The lack of signal is highly characteristic of fungal sinusitis.

cervical fasciae (fasciitis), enhancement and thickening of the neck muscles (myositis), and fluid collections in multiple neck compartments.

Sinusitis

The paranasal sinuses are a common source of maxillofacial infection. Occasionally, paranasal sinusitis can have devastating sequelae from involvement of the orbits (Fig. 6), cavernous sinuses, or brain parenchyma [4]. Orbital spread is most commonly secondary to bacterial or fungal sinus infections. Optic neuritis that arises from such infections requires prompt recognition and aggressive treatment if vision is to be preserved [27]. Intracranial empyema secondary to sinusitis is generally a disease of young adult men without an antecedent history of sinus disease [7]. The dominant clinical features are fever, intense headache, and facial swelling. The patient should receive an immediate noncontrasted and contrasted head CT and MRI. If CT is used, additional thin cuts (3 mm or less) in the axial and coronal planes of the paranasal sinuses should be obtained.

Because of the late development of the frontal sinuses, frontal sinus infection in children is rare. When present, it can lead to osteomyelitis associated with forehead swelling (Pott's puffy tumor) (Fig. 7). Early diagnosis and active treatment prevent progression to life-threatening intracranial spread [28].

In fungal disease of the paranasal sinuses, expansion of the bony walls occurs by increased mucus secretion and fungal growth (Fig. 8). The fungus is confined to the lumen and does not invade the tissues. Within the lumen of the sinus, fungus appears as areas of high attenuation on the CT scan because of the presence of calcium and traces of metallic elements. On MRI, the fungus-filled lumen appears as an area of low signal intensity because of

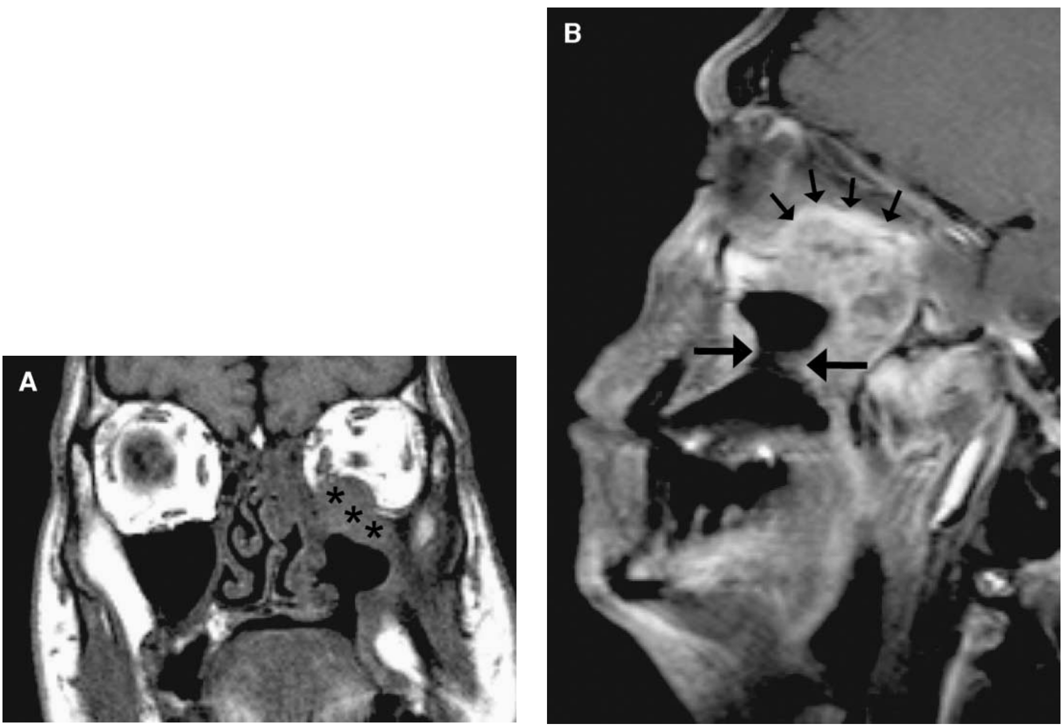

Fig. 9. (A) Invasive fungal sinusitis. Coronal nonenhanced T1-weighted MRI in a 33-year-old immunocompromised man. There is an oroantral fistula in the region where maxillary teeth were removed because of loss of all bony support. On removal of teeth, there was no normal tissue with which to close the sinus opening. Abnormal tissue along the left infraorbital rim has eroded the bone and replaced the normal bright orbital fat (*asterisk*). (B) Sagittal postcontrast T1-weighted MRI with fat saturation shows the oroantral fistula (*large arrows*). Abnormal enhancing tissue extends back to the orbital apex along the expected route of the infraorbital nerve (*small arrows*). Not imaged on this slice is the abnormal enhancing tissue that extends into the cavernous sinus. This is an example of perineural spread of a fungus infection.

the presence of ferromagnetic elements (Fig. 8) [29]. Invasive fungal sinusitis involves destruction of the bony walls and spread into surrounding structures (Fig. 9) [29].

Summary

Computed tomography and MRI are quick and accurate methods for the evaluation of complex head and neck infections. Because of new spiral CT scanners and picture archival communication systems, multiplanar imaging is common with CT. CT has supplanted sialography for the evaluation of inflammatory processes in the salivary glands. In the search for a drainable abscess collection, MRI is superior to CT in regard to lesion conspicuity and determining the number of anatomic spaces involved and the degree of extension and the source. MRI is also superior to CT for detection of intracranial extension of infection. CT is superior to MRI in the detection of intralesional gas, calcifications, and cortical destruction.

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