

**American College of Radiology  
ACR Appropriateness Criteria®  
Inflammatory Ear Disease**

**Variant 1:                      Adult. Otitis externa, uncomplicated. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography skull	Usually Not Appropriate	⊗
MRI head and internal auditory canal with IV contrast	Usually Not Appropriate	○
MRI head and internal auditory canal without and with IV contrast	Usually Not Appropriate	○
MRI head and internal auditory canal without IV contrast	Usually Not Appropriate	○
MRI head with IV contrast	Usually Not Appropriate	○
MRI head without and with IV contrast	Usually Not Appropriate	○
MRI head without IV contrast	Usually Not Appropriate	○
CT head with IV contrast	Usually Not Appropriate	⊗⊗⊗
CT head without and with IV contrast	Usually Not Appropriate	⊗⊗⊗
CT head without IV contrast	Usually Not Appropriate	⊗⊗⊗
CT temporal bone with IV contrast	Usually Not Appropriate	⊗⊗⊗
CT temporal bone without and with IV contrast	Usually Not Appropriate	⊗⊗⊗
CT temporal bone without IV contrast	Usually Not Appropriate	⊗⊗⊗

**Variant 2:****Adult. Otitis externa, complicated. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head and internal auditory canal without and with IV contrast	Usually Appropriate	○
CT temporal bone with IV contrast	Usually Appropriate	⊕⊕⊕
MRI head without and with IV contrast	May Be Appropriate	○
CT temporal bone without IV contrast	May Be Appropriate	⊕⊕⊕
WBC scan with SPECT or SPECT/CT skull base	May Be Appropriate	⊕⊕⊕
Radiography skull	Usually Not Appropriate	⊕
MRI head and internal auditory canal with IV contrast	Usually Not Appropriate	○
MRI head and internal auditory canal without IV contrast	Usually Not Appropriate	○
MRI head with IV contrast	Usually Not Appropriate	○
MRI head without IV contrast	Usually Not Appropriate	○
CT head and neck with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head and neck without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head and neck without IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head without IV contrast	Usually Not Appropriate	⊕⊕⊕
CT temporal bone without and with IV contrast	Usually Not Appropriate	⊕⊕⊕

**Variant 3:****Adult. Acute otitis media, uncomplicated. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography skull	Usually Not Appropriate	☼
MRI head and internal auditory canal with IV contrast	Usually Not Appropriate	○
MRI head and internal auditory canal without and with IV contrast	Usually Not Appropriate	○
MRI head and internal auditory canal without IV contrast	Usually Not Appropriate	○
MRI head with IV contrast	Usually Not Appropriate	○
MRI head without and with IV contrast	Usually Not Appropriate	○
MRI head without IV contrast	Usually Not Appropriate	○
CT head with IV contrast	Usually Not Appropriate	☼☼☼
CT head without and with IV contrast	Usually Not Appropriate	☼☼☼
CT head without IV contrast	Usually Not Appropriate	☼☼☼
CT temporal bone with IV contrast	Usually Not Appropriate	☼☼☼
CT temporal bone without and with IV contrast	Usually Not Appropriate	☼☼☼
CT temporal bone without IV contrast	Usually Not Appropriate	☼☼☼

**Variant 4:****Adult. Complicated otitis media. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head and internal auditory canal without and with IV contrast	Usually Appropriate	○
CT temporal bone with IV contrast	Usually Appropriate	⊕⊕⊕
CTV head with IV contrast	Usually Appropriate	⊕⊕⊕
MRV head with IV contrast	May Be Appropriate	○
MRV head without IV contrast	May Be Appropriate	○
CT temporal bone without IV contrast	May Be Appropriate	⊕⊕⊕
Radiography skull	Usually Not Appropriate	⊕
MRI head and internal auditory canal with IV contrast	Usually Not Appropriate	○
MRI head and internal auditory canal without IV contrast	Usually Not Appropriate	○
MRI head with IV contrast	Usually Not Appropriate	○
MRI head without and with IV contrast	Usually Not Appropriate	○
MRI head without IV contrast	Usually Not Appropriate	○
MRV head without and with IV contrast	Usually Not Appropriate	○
CT head with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head without IV contrast	Usually Not Appropriate	⊕⊕⊕
CT temporal bone without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CTV head and neck with IV contrast	Usually Not Appropriate	⊕⊕⊕
WBC scan with SPECT or SPECT/CT skull base	Usually Not Appropriate	⊕⊕⊕

**Variant 5: Adult. Chronic otitis media. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head and internal auditory canal without and with IV contrast	Usually Appropriate	○
CT temporal bone without IV contrast	Usually Appropriate	⊕⊕⊕
Radiography skull	Usually Not Appropriate	⊕
MRI head and internal auditory canal with IV contrast	Usually Not Appropriate	○
MRI head and internal auditory canal without IV contrast	Usually Not Appropriate	○
MRI head with IV contrast	Usually Not Appropriate	○
MRI head without and with IV contrast	Usually Not Appropriate	○
MRI head without IV contrast	Usually Not Appropriate	○
CT head with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head without IV contrast	Usually Not Appropriate	⊕⊕⊕
CT temporal bone with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT temporal bone without and with IV contrast	Usually Not Appropriate	⊕⊕⊕

**Variant 6: Adult. Postoperative cholesteatoma. Surveillance Imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI head and internal auditory canal without and with IV contrast	Usually Appropriate	○
CT temporal bone without IV contrast	Usually Appropriate	⊕⊕⊕
Radiography skull	Usually Not Appropriate	⊕
MRI head and internal auditory canal with IV contrast	Usually Not Appropriate	○
MRI head and internal auditory canal without IV contrast	Usually Not Appropriate	○
MRI head with IV contrast	Usually Not Appropriate	○
MRI head without and with IV contrast	Usually Not Appropriate	○
MRI head without IV contrast	Usually Not Appropriate	○
CT head with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT head without IV contrast	Usually Not Appropriate	⊕⊕⊕
CT temporal bone with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT temporal bone without and with IV contrast	Usually Not Appropriate	⊕⊕⊕

## INFLAMMATORY EAR DISEASE

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### Summary of Literature Review

#### **Introduction/Background**

Inflammatory conditions can affect the external, middle, and inner ears. Inflammation is usually caused by infectious processes with patient demographics playing a contributory role in individual susceptibility. Otitis externa is defined as the infection of the cutis and subcutis of the external auditory canal (EAC), with variable involvement of the pinna and EAC [1]. Clinical signs and symptoms include otalgia, tenderness, fever, and ear discharge. Adults are more commonly affected, with a lifetime incidence of approximately 10% [1]. Commonly implicated organisms are *Pseudomonas aeruginosa* and *Staphylococcus aureus* [2]. Fungal infections are less common and are generally caused by *Aspergillus* or *Candida* spp [2]. Uncomplicated otitis externa is more common in swimmers because of the conversion of the normal acidic environment of the EAC to an alkaline one [3]. The diagnosis is largely clinical, and this can generally be treated with topical antibiotics and analgesics. Otitis externa can progress to necrotizing otitis externa (NOE) in individuals with poorly controlled diabetes or immunosuppression [3]. This is a fulminant infection with a high likelihood of extension of the inflammatory process beyond the EAC with frequent involvement of the skull base and adjacent soft tissues. Extension to the skull base can lead to skull base osteomyelitis (SBO), which may be complicated by involvement of cranial nerves and vascular structures at the skull base. The infectious process can progress to the intracranial compartment resulting in meningitis, cerebritis, and/or cerebral abscess. The spectrum of clinical findings includes otalgia, otorrhea, fever, headache, cranial nerve deficits, neurological symptoms, and seizures. NOE and SBO are difficult to treat with high morbidity and mortality [4]. Conservative treatment with long-term antimicrobials is the mainstay of treatment, with surgery reserved for biopsy, microbial sampling, or removal of necrotic tissue [4].

Acute otitis media (AOM) is generally a bacterial infection of the middle ear, which is more common in the pediatric population and is a consequence of upper respiratory infection [5]. *Streptococcus pneumoniae* and *Hemophilus influenzae* are the most common causative organisms [5]. Sudden onset of fever, otalgia, and otorrhea are the clinical findings. Patients may have conductive hearing loss, and a reddened and bulging tympanic membrane can be seen on otoscopy. In most cases of AOM, the infectious process resolves spontaneously with less patients requiring antibiotic treatment, and imaging studies are not indicated [5]. However, in refractory cases in which antibiotic treatment fails and the infection persists, symptoms worsen, or new symptoms, such as posterior auricular swelling, mastoid tenderness, headache, vertigo, meningismus, neck rigidity, seizures, or neurological deficits appear, complications like subperiosteal abscess, labyrinthitis, meningitis, intracranial abscess, subdural empyema, and dural venous sinus thrombosis, must be considered [6-9]. In this scenario, imaging tests play a crucial role because they enable early diagnosis of complications and immediate appropriate treatment [5].

Chronic otitis media (COM) is defined as chronic infection and inflammation of the middle ear and mastoid cavity lasting >3 months and causing ear discharge, hearing loss, and tympanic membrane perforation [10]. Recurrent upper respiratory and ear infections, ciliary dysfunction, and allergy are risk factors for COM. Besides fluid and granulation tissue in the middle ear cavity, COM can result in conductive hearing loss by causing erosion of the ear

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ossicles. COM can lead to negative pressure in the middle ear cavity, resulting in retraction of the tympanic membrane, especially the pars flaccida, where a cholesteatoma may form as keratin and keratinizing squamous epithelium debris accumulate in the epitympanum/lateral epitympanic recess and beyond, with a destructive perimatrix [11]. COM treatment involves conservative measures such as ear cleaning, water avoidance, and antimicrobial therapy, but may also entail surgical repair of tympanic membrane perforation and/or ossicular reconstruction. Cholesteatoma is progressive and destructive in nature and requires surgical removal.

### **Initial Imaging Definition**

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).

### **Discussion of Procedures by Variant**

#### **Variant 1: Adult. Otitis externa, uncomplicated. Initial imaging.**

Otitis externa is defined as the infection of the cutis and subcutis of the EAC, with variable involvement of the pinna and EAC [1]. In uncomplicated otitis externa, the infection is limited to the cutis and subcutis and has not progressed to involvement of the bone or the skull base. Clinical signs and symptoms include otalgia, tenderness, fever, and ear discharge. Adults are more commonly affected. The diagnosis is largely clinical, and this can generally be treated with topical antibiotics and analgesics. In a study for COS development, Smith et al [12] outlined the diagnostic criteria for acute otitis externa (AOE) and stated that AOE should be defined as a condition of <6 weeks duration and diagnosed by a combination of at least 1 characteristic symptom and 2 signs. The characteristic symptoms included otalgia, otorrhea, and itchiness, and the signs included tragal tenderness, ear canal edema, ear canal erythema, and wet debris. Microbiological identification of an organism was not considered key to the diagnosis.

In an update of the evidence-based clinical practice guidelines on management of AOE, the American Academy of Otolaryngology-Head and Neck Surgery Foundation assembled a working group representing the disciplines of otolaryngologists—head and neck surgeons, pediatrics, infectious disease, family medicine, dermatology, and consumer advocate [13]. Rosenfeld et al [13] stated that the diagnosis of diffuse AOE requires rapid onset with signs and symptoms of ear canal inflammation. The authors further stated that the hallmark sign of diffuse AOE is tenderness of the tragus, the pinna, or both. The authors state that AOE can mimic the appearance of AOM due to erythema involving the tympanic membrane. These can be differentiated by pneumatic otoscopy, which will demonstrate good tympanic membrane mobility with AOE but will show absent or limited mobility with AOM and associated middle ear effusion. Similarly, tympanometry will show a normal peaked curve with AOE but a flat tracing with AOM. The article does not specifically mention the use of imaging studies in the diagnosis.

#### **CT Head With IV Contrast**

Uncomplicated otitis externa is a clinical diagnosis, and imaging is not usually required to make a diagnosis. CT head with intravenous (IV) contrast, therefore, has no role in the initial imaging of uncomplicated otitis externa. CT head without IV contrast may have a role in demonstrating the osseous abnormalities that may predispose for AOE but there is no additional benefit with the use of contrast.

#### **CT Head Without and With IV Contrast**

There is no relevant literature to support the use of CT head without and with IV contrast in the initial imaging of uncomplicated otitis externa.

#### **CT Head Without IV Contrast**

There is no relevant literature to support the use of CT head without IV contrast in the initial imaging of uncomplicated otitis externa.

However, osseous abnormalities such as EAC osteoma or EAC exostosis may be predisposing factors for otitis externa. If such an osseous abnormality is suspected on clinical examination, CT without IV contrast may have a role in confirming the diagnosis, although evaluated better and to greater detail on CT of the temporal bone without IV contrast [14]. CT of the head without IV contrast may also be able to show the osseous abnormality and may have some role in the initial imaging of uncomplicated otitis externa [14]. There is no additional role of contrast-enhanced CT in demonstrating the osseous abnormalities.

#### **CT Temporal Bone With IV Contrast**

There is no relevant literature to support the use of CT temporal bone with IV contrast in the initial imaging of uncomplicated otitis externa.

#### **CT Temporal Bone Without and With IV Contrast**

There is no relevant literature to support the use of CT temporal bone without and with IV contrast in the initial imaging of uncomplicated otitis externa.

#### **CT Temporal Bone Without IV Contrast**

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However, osseous abnormalities such as EAC osteoma or EAC exostosis may be predisposing factors for otitis externa. If such an osseous abnormality is suspected on clinical examination, CT temporal bone without IV contrast may have a role in confirming the diagnosis [14]. There is no additional role of contrast-enhanced CT in demonstrating the osseous abnormalities.

#### **MRI Head and Internal Auditory Canal With IV Contrast**

There is no relevant literature to support the use of MRI head and internal auditory canal (IAC) with IV contrast in the initial imaging of uncomplicated otitis externa.

#### **MRI Head and Internal Auditory Canal Without and With IV Contrast**

There is no relevant literature to support the use of MRI head and IAC without and with IV contrast in the initial imaging of uncomplicated otitis externa.

#### **MRI Head and Internal Auditory Canal Without IV Contrast**

There is no relevant literature to support the use of MRI head and IAC without IV contrast in the initial imaging of uncomplicated otitis externa.

#### **MRI Head With IV Contrast**

There is no relevant literature to support the use of MRI head with IV contrast in the initial imaging of uncomplicated otitis externa.

#### **MRI Head Without and With IV Contrast**

There is no relevant literature to support the use of MRI head without and with IV contrast in the initial imaging of uncomplicated otitis externa.

#### **MRI Head Without IV Contrast**

There is no relevant literature to support the use of MRI head without IV contrast in the initial imaging of uncomplicated otitis externa.

#### **Radiography Skull**

There is no relevant literature to support the use of radiography skull in the initial imaging of uncomplicated otitis externa.

#### **Variant 2: Adult. Otitis externa, complicated. Initial imaging.**

Otitis externa can complicate and progress to NOE in individuals with poorly controlled diabetes or immunosuppression [3]. In this case, the inflammation extends beyond the EAC and involves the skull base and adjacent soft tissues. NOE and SBO are therefore used synonymously. Involvement of the skull base can lead to involvement of the cranial nerves and vascular structures at the skull base and can also progress intracranially resulting in meningitis, cerebritis, subdural empyema, and/or cerebral abscess. The spectrum of clinical findings includes otalgia, otorrhea, fever, headache, cranial nerve deficits, neurological symptoms, and seizures. NOE/SBO is difficult to treat and has high morbidity and mortality.



In clinical practice, imaging is frequently used to support the diagnosis of NOE and assess for response to therapy. Despite the common use of imaging in the management of this condition, there is substantial heterogeneity in the modalities used in clinical practice. The choice of which imaging study to obtain is based on many factors including the diagnostic strengths of the imaging modality and the clinician's level of suspicion. CT can be used to demonstrate bone erosion, whereas MRI has greater sensitivity for soft tissue disease and may demonstrate early marrow and dural/intracranial involvement. Tc-99m scintigraphy is highly sensitive for temporal bone osteomyelitis but remains positive after clinical resolution, whereas gallium scanning can be used to document resolution of infection [15].

#### **CT Head and Neck With IV Contrast**

There is no relevant literature to support the use of CT head and neck with IV contrast in the initial imaging of complicated otitis externa.

CT is excellent for demonstrating bone erosions in the initial imaging of complicated otitis externa [16]. When performed with IV contrast, it also helps in identifying surrounding inflammatory changes and abnormal soft tissue at the skull base. CT of the head and neck, however, has lower spatial resolution and larger field-of-view (FOV) compared to CT of the temporal bone which better demonstrates subtle changes in the temporal bone region. Also, MRI shows soft tissue abnormalities better.

In a retrospective study, Lambor et al [16] state that high-resolution CT (HRCT) is the preferred modality for defining the anatomical extension of the osteomyelitis process. Additional imaging of the head or neck has not been described in the literature.

Various other studies have used or evaluated the use of CT in the diagnosis of complicated otitis externa (malignant/NOE) and have not described the inclusion or advantage of including neck or the remainder of the head in the CT examination [2,4,17,18]. When intracranial complications are suspected, MRI has been found to be more sensitive [2,4,15-18].

#### **CT Head and Neck Without and With IV Contrast**

There is no relevant literature to support the use of CT head and neck without and with IV contrast in the initial imaging of complicated otitis externa.

#### **CT Head and Neck Without IV Contrast**

There is no relevant literature to support the use of CT head and neck without IV contrast in the initial imaging of complicated otitis externa.

#### **CT Head With IV Contrast**

CT is excellent for demonstrating bone erosions in the initial imaging of complicated otitis externa. When performed with IV contrast, it also helps in identifying surrounding inflammatory changes and abnormal soft tissue at the skull base. CT of the head, however, has lower spatial resolution and larger FOV compared to CT of the temporal bone and therefore does not demonstrate subtle changes in the temporal bone region as well. Also, MRI shows soft tissue abnormalities better.

In a retrospective study by Lambor et al [16], the authors state that HRCT is the preferred modality for defining the anatomical extension of the osteomyelitis process.

Various other studies have used or evaluated the use of CT in the diagnosis of complicated otitis externa ("malignant"/NOE) and have not described the inclusion or advantage of including the remainder of the head in the CT examination [2,4,17,18]. When intracranial complications are suspected, MRI has been found to be more sensitive [2,4,15-18].

In conclusion, CT head with IV contrast has no significant role in the initial imaging of complicated otitis externa.

#### **CT Head Without and With IV Contrast**

There is no relevant literature to support the use of CT head without and with IV contrast in the initial imaging of complicated otitis externa.

#### **CT Head Without IV Contrast**

There is no relevant literature to support the use of CT head without IV contrast in the initial imaging of complicated otitis externa.

### **CT Temporal Bone With IV Contrast**

CT is excellent for demonstrating bone erosions in the initial imaging of complicated otitis externa. When performed with IV contrast, it also helps in identifying surrounding inflammatory changes and abnormal soft tissue at the skull base. CT of the temporal bone has high spatial resolution and demonstrates subtle changes well. MRI is complementary in demonstrating and characterizing soft tissue abnormalities and intracranial complications.

In a cross-sectional survey study by Cooper et al [15], the authors found that CT was the most frequent examination used for diagnosis of NOE and found that 73.1% of the survey respondents always used CT in the management of their patients. In a retrospective chart review of 30 patients, Auinger et al [19] found that CT was the most commonly used imaging method to diagnose and monitor SBO, with the assessment of bone erosion and demineralization shown best on CT imaging. In a 10-year retrospective study, Kamalden and Misron [20] found literature supporting that a CT scan is excellent in predicting the severity of NOE.

In a retrospective study, Hodgson et al [21] stated that EAC bone erosion on CT, in the presence of a fitting clinical syndrome, is consistent with the diagnosis of osteomyelitis of the temporal bone and therefore NOE. In a retrospective review, Lim et al [22] studied the diagnostic accuracy of the imaging and found CT to be of high sensitivity. In their retrospective study, Balakrishnan et al [23] found CT to be being one of the most useful imaging modalities for early detection of NOE.

In a retrospective study by Lau et al [24], nonenhanced CT scans were performed. According to the authors, the main benefit of contrast-enhanced CT was the localization of fluid collections, however, MRI is also able to accomplish this and has a greater contrast resolution compared to CT.

In a retrospective review, Hopkins et al [25] state that the bulk of the evidence suggests that contrast-enhanced CT of the temporal bone should be used as the reference standard for the detection of SBO. The authors further state, however, that there is evidence that CT may miss early stages of disease, therefore they recommend MRI for further investigation in cases in which clinical and radiological findings are incongruous.

From the above discussion it can be deduced that, although CT of the temporal bone with IV contrast has an important role in the detection of SBO, MR is complementary. Although contrast-enhanced CT may detect soft tissue abnormalities, they would be better evaluated with MRI.

### **CT Temporal Bone Without and With IV Contrast**

There is no relevant literature to support the use of CT temporal bone without and with IV contrast, especially if a CT without IV contrast has been obtained because the information gleaned from the CT with IV contrast is better seen on MRI.

### **CT Temporal Bone Without IV Contrast**

CT is excellent for demonstrating bone erosions in the initial imaging of complicated otitis externa. When performed with IV contrast, it also helps in identifying surrounding inflammatory changes and abnormal soft tissue at the skull base. CT of the temporal bone has high spatial resolution and demonstrates subtle bony changes well. MRI is complementary in demonstrating and characterizing soft tissue abnormalities and intracranial complications.

In a retrospective chart review of 30 patients, Auinger et al [19] found that CT was the most commonly used imaging method to diagnose and monitor SBO, with the assessment of bone erosion and demineralization shown best on CT imaging. In several studies [22-24], CT was found to be of high diagnostic accuracy in the detection of bone erosion in the setting of NOE and SBO. According to Lau et al [24], the main benefit of CT contrast studies in SBO/NOE is the localization of any collections. In a retrospective review, Hopkins et al [25] state that contrast-enhanced CT of the temporal bone should be used as the reference standard for the detection of SBO.

From the above discussion, it can be deduced that, although CT of the temporal bone without IV contrast has an important role in the detection of SBO, CT with IV contrast can give similar information with the additional benefit of delineating soft tissue abnormalities, fluid collections, and involvement of vascular structures.

### **MRI Head and Internal Auditory Canal With IV Contrast**

There is no relevant literature to support the use of MRI head and IAC with IV contrast in the initial imaging of complicated otitis externa. An MRI head and IAC without IV contrast will usually be required in conjunction.

### **MRI Head and Internal Auditory Canal Without and With IV Contrast**

MRI head and IAC without and with IV contrast is an excellent modality to show soft tissue and marrow changes associated with NOE at the skull base. The spread of infection in NOE can be in multiple directions. Anterior spread

of infection can involve the temporomandibular joint and masticator space, medial spread can involve the parapharyngeal space, particularly the poststyloid parapharyngeal space. Posterior spread can involve the jugular foramen region and the lower cranial nerves, inferior spread can involve the parotid and infratemporal regions, and superior spread can involve the brain and meninges.

MRI of the IAC usually includes a thin slice (1 mm) axial heavily T2-weighted sequence through the IAC with a small FOV, with addition of thin slice (3 mm) pre- and postcontrast axial and coronal T1-weighted images. The MRI head portion of the examination may include a complete whole brain axial fluid-attenuated inversion-recovery, diffusion-weighted imaging (DWI), and pre- and postcontrast T1-weighted images.

Noncontrast nonfat-suppressed T1-weighted images are useful in demonstrating fat and fascial plane infiltration, as well as infiltration of fat-containing bone marrow. The contrast portion of the study shows enhancing inflammatory soft tissue and bone marrow and also shows nonenhancing necrotic tissue that may be associated with SBO. MRI is also very useful in showing intracranial complications such as meningitis, cerebritis, subdural empyema, brain abscess, venous sinus thrombosis, and thrombophlebitis. DWI is especially useful in showing focal purulent fluid collections.

Review of literature revealed that several studies [2,15,19] showed advantages of MRI in the detection of NOE because it can detect bone marrow changes and better demonstrates soft tissue changes and intracranial involvement. In a cross-sectional survey study, Cooper et al [15] found that MRI was the preferred modality for assessing the extent of disease. DWI MRI was described as an important tool in the assessment of treatment response in NOE.

MRI was also demonstrated to be superior to CT in the assessment of skull base involvement [26]. Soft tissue changes in this study were also reported to be more prominent on MRI in comparison with CT. The multidirectional pattern of the spread of infection and inflammation in NOE was also identified better on MRI in another study [27].

In a systematic review, Khan [28] concluded that MRI is the method of choice in determining intracranial extension. The review also found studies that concluded that MRI is superior to CT. A study in this review concluded that MRI studies that included a DWI sequence were superior to those without DWI.

From the above discussion, it can be concluded that MRI of the head and IAC without and with IV contrast has an important role in the initial imaging of complicated otitis externa. Of note, the above studies described MRI of the head, and none of the studies mentioned dedicated sequences focusing on the IAC in their methods or review section. Because MRI as a modality is useful in detecting skull base soft tissue and intracranial complications, for areas outside of the EAC proper, whole brain MRI may allow for visualization of some of the other regions potentially involved in the setting of NOE. Dedicated sequences through the skull base can be obtained for further assessment as needed.

#### **MRI Head and Internal Auditory Canal Without IV Contrast**

There is no relevant literature to support the use of MRI head and IAC without IV contrast in the initial imaging of complicated otitis externa. An MRI head and IAC with IV contrast will usually be required in conjunction.

#### **MRI Head With IV Contrast**

There is no relevant literature to support the use of MRI head with IV contrast in the initial imaging of complicated otitis externa. An MRI head without IV contrast will usually be required in conjunction. As well, focused examination of the temporal bone/IAC region, which has a higher resolution for the temporal bone and skull base region, would be required for showing inflammatory changes around the EAC.

#### **MRI Head Without and With IV Contrast**

MRI head without and with IV contrast may show some of the soft tissue changes associated with NOE at the skull base. Noncontrast nonfat-suppressed T1-weighted images are useful in demonstrating fat and fascial plane infiltration, as well as the infiltration of fat-containing bone marrow. The contrast portion of the study shows enhancing inflammatory soft tissue and bone marrow and also shows nonenhancing necrotic tissue that may be associated with SBO. MRI is also very useful in showing intracranial complications such as meningitis, cerebritis, subdural empyema, brain abscess, venous sinus thrombosis, and thrombophlebitis. DWI is especially useful in showing focal purulent fluid collections. However, a focused examination with 3-mm slices and small FOV including the IAC would have higher spatial resolution.

Many studies have shown the advantages of MRI in the detection of NOE because it can detect bone marrow changes and better demonstrates soft tissue changes and intracranial involvement [2,15,19,26]. The multidirectional pattern of the spread of infection and inflammation in NOE was also found to be identified better on MRI in another study [27].

Because MRI as a modality is useful in detecting skull base soft tissue and intracranial complications, for areas outside of the EAC proper, whole brain MRI may allow for visualization of some of the other regions potentially involved in the setting of NOE. MRI head without and with IV contrast has the imaging strengths described in MRI head and IAC without and with IV contrast, with the difference being a bigger FOV used in MRI head, which allows visualization of structures outside EAC, which can limit visualizing things in detail at the IAC/skull base area. Dedicated sequences through the skull base can be obtained for further assessment as needed.

### **MRI Head Without IV Contrast**

There is no relevant literature to support the use of MRI head without IV contrast in the initial imaging of complicated otitis externa. The lack of IV contrast will limit visualization of inflammatory soft tissue, especially areas of necrosis.

### **Radiography Skull**

There is no relevant literature to support the use of radiography skull in the initial imaging of complicated otitis externa.

In a systematic review, Khan et al [28] aimed to focus on studies that would not only help understand evolving trends in imaging of NOE but also discuss their impact on the timely diagnosis and better management of disease. The authors concluded that conventional radiography does not have any use in the diagnosis of NOE and that radiological diagnosis of the disease is commonly made on CT in clinical practice, with MRI often used for complementary assessment.

### **WBC Scan With SPECT or SPECT/CT Skull Base**

Nuclear medicine studies are highly sensitive in detecting inflammatory changes at the skull base but lack specificity because neoplastic, degenerative, and traumatic processes can also show uptake. Additionally, Tc-99m studies remain positive after the resolution of infection because they localize to osteoblastic activity. Ga-67 studies are better in this regard because they normalize as infection subsides. These studies, however, have the disadvantage of low spatial resolution, which can be overcome to some degree by using single-photon emission CT (SPECT).

In a retrospective study, Spielman et al [2] stated that radionuclide imaging is the diagnostic modality of choice. Tc-99m localizes to areas of osteoblastic activity and thus is a sensitive indicator of osteomyelitis and becomes positive earlier in the course of infection because bone demineralization is not required to see activity. Ga-67 scintigraphy is used to monitor progress because this scan normalizes early after the resolution of infection. The authors performed Ga-67 scintigraphy after 6 weeks of antimicrobial treatment, and, if still positive, antimicrobials were continued, and the scan repeated at intervals of 6 weeks until resolution.

In another retrospective study, Bock and Ovesen [18] state that bone scan using Tc-99m is extremely sensitive because it is capable of detecting a 10% increment in osteoclast activity, and it is thus instrumental in early diagnosis of NOE. Ga-67 scintigraphy detects dividing cells such as activated granulocytes and osteoclasts. It is used for early diagnosis as well as for treatment monitoring. The authors stated, however, that both bone scan and Ga-67 scintigraphy are impeded by a relatively poor specificity and need to be combined with CT or MRI.

Bhat et al [17] stated that Tc-99m bone scan is a more sensitive investigation because it is positive in all cases of NOE. However, because the test is based on binding to osteoblasts, which are also seen in neoplasms and during trauma, the technique is not specific to NOE. A Ga-67 scan is positive in soft tissue and bone infections, where it binds to lactoferrin. The uptake returns to normal after the infection is cleared. Hence, a Ga-67 scan is more specific than Tc-99m scan in the diagnosis.

In a cross-sectional survey study, Cooper et al [15] found that Tc-99m scintigraphy is a sensitive modality for diagnosing NOE. In this study, SPECT imaging was found to have significant value in the diagnosis and management of NOE. SPECT/CT combines the functional information of nuclear medicine studies with the anatomic detail of CT, allowing for precise anatomic location of tracer accumulation. In a retrospective study, Peled et al [26] found that nuclear scintigraphy using Tc-99m and Ga-67 has been traditionally considered as the main imaging modality for the diagnosis of NOE. However, the main disadvantage of these modalities is the limited spatial resolution and anatomic localization, which can be improved by the concomitant use of SPECT/CT. In a

retrospective chart review of 30 patients, Auinger et al [19] found that a Tc-99m scan was the most frequently used tracer and was combined with SPECT in most cases.

In a retrospective review, Lim et al [22] stated that, when considering individual imaging performance for all admissions, the study found Ga-67 to be the most accurate.

In a retrospective study, Lau et al [24] found that nuclear medicine studies using Tc-99m and Ga-67 can also aid an initial diagnosis. However, changes in Tc-99m scan lag behind clinical improvement because it maps osteoblastic activity and not active infection and therefore does not help with surveillance. Ga-67 can monitor treatment response.

In a systematic review, Khan et al [28] showed the usefulness of Ga-67 and Tc-99m bone scanning and concluded that these are more sensitive than radiographs and CT scans for early detection of NOE, and hence both are important imaging tools in the diagnosis as well as management of the disease.

### **Variant 3: Adult. Acute otitis media, uncomplicated. Initial imaging.**

The diagnosis of AOM requires moderate to severe bulging of the tympanic membrane, new onset of otorrhea not caused by otitis externa, or mild bulging of the tympanic membrane associated with recent onset of ear pain or erythema.

Otitis media occurs much more commonly in children, and available literature is focused on the pediatric population. Initial presentation and symptoms are slightly different, but assessment and management is overall similar in adults.

In a clinical update, a study suggested that AOM should be suspected in children with ear pain or more subtle ear symptoms with or without fever. The authors stated that the presence of middle ear effusion confirms the diagnosis. The literature does not mention the use of imaging for the diagnosis of AOM [29-33]. In 2013 the American Academy of Pediatrics revised the evidence-based clinical practice guidelines for AOM and provided recommendations to primary care clinicians for the management of children from 6 months through 12 years of age with uncomplicated AOM [27]. The guidelines recommended that clinicians should diagnose AOM in children who present with moderate to severe bulging of the tympanic membrane or new onset of otorrhea not due to AOE, or mild bulging of the tympanic membrane and <48 hours onset of otorrhea of acute onset with intense erythema of the tympanic membrane. The authors did not mention the use of imaging in the diagnosis. In April of 2020, authors from Japan published a 2018 update on the clinical practice guidelines for the diagnosis and management of AOM in children [34] and reiterated the above recommendations. In a clinical update, Venekamp et al [33] stated that AOM should be suspected in children with ear pain or more subtle ear symptoms with or without fever. The authors stated that the presence of middle ear effusion confirms the diagnosis. This document did not mention the use of imaging in the diagnosis of AOM.

In an original article published in 2017, Tamir et al [31] studied unifying and diverging points in guidelines from selected developing and developed countries in order to detect common elements as well as differences. In this document the authors stated that current guidelines from developed countries recommend that diagnosis should be based on 3 major criteria, 1) constitutional signs and symptoms, 2) tympanic membrane bulging, and 3) presence of middle ear effusion. This document did not mention the use of imaging studies in the diagnosis of AOM.

#### **CT Head With IV Contrast**

Uncomplicated AOM is a clinical diagnosis made by symptoms, physical examination, and otoscopy. There is no role for imaging in the diagnosis of uncomplicated otitis media.

#### **CT Head Without and With IV Contrast**

Uncomplicated AOM is a clinical diagnosis made by symptoms, physical examination, and otoscopy. There is no role of imaging in the diagnosis of uncomplicated otitis media.

#### **CT Temporal Bone With IV Contrast**

Uncomplicated AOM is a clinical diagnosis made by symptoms, physical examination, and otoscopy. There is no role for imaging in the diagnosis of uncomplicated otitis media.

#### **CT Temporal Bone Without and With IV Contrast**

There is no relevant literature to support the use of CT temporal bone without and with IV contrast in the initial imaging of uncomplicated AOM.

### **CT Temporal Bone Without IV Contrast**

Uncomplicated AOM is a clinical diagnosis made by symptoms, physical examination, and otoscopy. There is no role for imaging in the diagnosis of uncomplicated otitis media.

### **MRI Head and Internal Auditory Canal With IV Contrast**

There is no relevant literature to support the use of MRI head and IAC with IV contrast in the initial imaging of uncomplicated AOM.

### **MRI Head and Internal Auditory Canal Without and With IV Contrast**

There is no relevant literature to support the use of MRI head and IAC without and with IV contrast in the initial imaging of uncomplicated AOM.

### **MRI Head and Internal Auditory Canal Without IV Contrast**

There is no relevant literature to support the use of MRI head and IAC without IV contrast in the initial imaging of uncomplicated AOM.

### **MRI Head With IV Contrast**

There is no relevant literature to support the use of MRI head with IV contrast in the initial imaging of uncomplicated AOM.

### **MRI Head Without and With IV Contrast**

There is no relevant literature to support the use of MRI head without and with IV contrast in the initial imaging of uncomplicated AOM.

### **MRI Head Without IV Contrast**

There is no relevant literature to support the use of MRI head without IV contrast in the initial imaging of uncomplicated AOM.

### **Radiography Skull**

There is no relevant literature to support the use of radiography skull in the initial imaging of uncomplicated AOM.

### **Variant 4: Adult. Complicated otitis media. Initial imaging.**

In cases in which antibiotic treatment fails and infection persists, symptoms worsen, or new symptoms such as postauricular swelling, mastoid tenderness, headache, vertigo, meningismus, neck rigidity, seizures, or neurological deficits appear, complications like subperiosteal abscess, labyrinthitis, meningitis, intracranial abscess, subdural empyema, and dural venous sinus thrombosis, must be suspected [6-9]. In this scenario, imaging tests play a crucial role because they enable early diagnosis of complications and immediate appropriate treatment [5].

### **CT Head With IV Contrast**

Otitis media can be complicated by mastoiditis. The infected material can spread to overlying soft tissues and result in mastoid or Bezold abscess. Infection can also spread intracranially and result in meningitis, cerebritis, subdural empyema, or brain abscess. Dural venous sinuses may be involved and result in sinus thrombosis. CT head can demonstrate temporal bone and soft tissue complications but lacks the spatial resolution of temporal bone CT. Intracranial complications can be seen on CT head with IV contrast but are best seen on MRI without and with IV contrast.

In a retrospective medical record review spanning a 15-year period, Mattos et al [30] stated that the workup of complications of AOM has evolved toward using fine-cut CT of the temporal bones. The authors stated that, although acute mastoiditis is usually clinically apparent, CT is important for demonstrating other intratemporal or intracranial complications and to assist in surgical planning. Furthermore, the authors stated that intracranial complications are not always clinically apparent and are often detected on CT imaging even when there is low clinical suspicion for an intracranial process.

The majority of studies [6,9,35-37] that mention the use of CT have described the role of temporal bone CT rather than head CT for evaluation of cases with complicated otitis media/acute mastoiditis, with IV contrast-enhanced head CT used mainly when intracranial complications are suspected. MRI is however superior at demonstrating intracranial complications.

### **CT Head Without and With IV Contrast**

There is no relevant literature to support the use of CT head without and with IV contrast in the initial imaging of complicated AOM.

### **CT Head Without IV Contrast**

There is no relevant literature to support the use of CT head without IV contrast in the initial imaging of complicated AOM.

### **CT Temporal Bone With IV Contrast**

CT temporal bone provides the high spatial resolution to adequately assess for intratemporal complications of AOM such as coalescent mastoiditis. Erosion of bony structures such as the lateral wall of the mastoid and the tegmen tympani are well seen on CT and herald complications such as mastoid and intracranial involvement. Addition of IV contrast improves detection of inflammatory tissue and abscesses.

In a retrospective medical record review spanning a 15-year period, Mattos et al [30] stated that the workup of complications of AOM has evolved toward using fine-cut CT of the temporal bones. The authors stated that, although acute mastoiditis is usually clinically apparent, CT is important for demonstrating other intratemporal or intracranial complications and to assist in surgical planning. Furthermore, the authors stated that intracranial complications are not always clinically apparent and are often detected on CT imaging even when there is low clinical suspicion for an intracranial process.

In a retrospective study, on 31 patients with acute mastoiditis, Saat et al [9] stated that imaging plays an important role in acute mastoiditis especially in complicated cases due to its high sensitivity in detecting bone destruction.

In a Triological Society Best Practice review, Chesney et al [29] proposed that in patients who fail to improve in 48 hours or if there is clinical deterioration, a CT scan of the temporal bones should be obtained. In a 19-year retrospective study, Palma et al [32] stated that HRCT is the imaging of choice for the diagnosis of mastoiditis.

In a retrospective study, on 53 contrast-enhanced CT scans of patients with acute mastoiditis, Saat et al [38] stated that when intracranial complications are clinically suspected, MRI is the preferred imaging method over CT due to its higher sensitivity and specificity for intracranial complications.

From the above discussion, it can be concluded that, although CT of the temporal bone with IV contrast has an important role to play in the initial imaging of complicated otitis media, MR is complementary and demonstrates intracranial complications better.

### **CT Temporal Bone Without and With IV Contrast**

There is no relevant literature to support the use of CT temporal bone without and with IV contrast in the initial imaging of complicated AOM.

### **CT Temporal Bone Without IV Contrast**

CT temporal bone without IV contrast shows bone erosions and other osseous abnormalities to the same advantage as CT temporal bone with IV contrast but has the disadvantage of not delineating inflammatory soft tissue changes and fluid collections as well as CT temporal bone with IV contrast.

### **CTV Head and Neck With IV Contrast**

There is no relevant literature to support the use of CT venography (CTV) head and neck with IV contrast in the initial imaging of complicated AOM.

### **CTV Head With IV Contrast**

AOM can be complicated by dural venous sinus thrombosis. CTV head with IV contrast adequately demonstrates dural venous sinuses and intraluminal filling defects, or lack of contrast filling of the dural venous sinuses in cases of dural venous sinus thrombosis.

In a retrospective study in 8 patients with venous sinus thrombosis, Zanoletti et al [37] stated that imaging is the method of choice for diagnosing venous sinus thrombosis in patients with acute mastoiditis. The authors stated that HRCT of the temporal bone reveals mastoiditis, areas of coalescence in the tegmen region, sinus wall, and bone erosion. Contrast-enhanced imaging can also detect the so-called empty delta sign suggestive of venous thrombosis.

### **MRI Head and Internal Auditory Canal With IV Contrast**

There is no relevant literature to support the use of MRI head and IAC with IV contrast in the initial imaging of complicated otitis media.

MRI of the head and IAC without IV contrast is required in conjunction with a contrast study for the assessment of complicated otitis media.

### **MRI Head and Internal Auditory Canal Without and With IV Contrast**

In a retrospective study on 31 patients with acute mastoiditis, Saat et al [9] stated that, in comparison with CT, MRI performs better in differentiating among normal and involved soft tissues and in showing juxta-osseous contrast enhancement. The authors found evidence indicating the superiority of MRI over CT in the detection of labyrinth involvement and intracranial infection.

In a retrospective study on 53 contrast-enhanced studies of patients with acute mastoiditis, Saat et al [38] stated that when intracranial complications are clinically suspected, MRI is the preferred imaging method over CT because of its higher sensitivity and specificity for intracranial complications.

In conclusion, MRI head and IAC without and with IV contrast has an important role in the initial imaging of complicated otitis media.

### **MRI Head and Internal Auditory Canal Without IV Contrast**

There is no relevant literature to support the use of MRI head and IAC without IV contrast in the initial imaging of complicated otitis media.

MRI of the head and IAC with IV contrast is required in conjunction with a noncontrast study for the assessment of complicated otitis media.

### **MRI Head With IV Contrast**

There is no relevant literature to support the use of MRI head with IV contrast in the initial imaging of complicated otitis media.

MRI of the head with IV contrast may show intracranial complications but noncontrast MRI sequences are required in conjunction. As well, a thin-slice small-FOV MRI examination focused at the IACs is required, and an MRI head alone may not demonstrate details at the IAC region as well.

### **MRI Head Without and With IV Contrast**

There is no relevant literature to support the use of MRI head without and with IV contrast in the initial imaging of complicated otitis media.

MRI of the head with IV contrast may show intracranial complications. However, a thin-slice small-FOV MRI examination focused at the IACs is required in conjunction for more accurate visualization.

### **MRI Head Without IV Contrast**

There is no relevant literature to support the use of MRI head without IV contrast in the initial imaging of complicated otitis media.

MRI of the head without IV contrast may show intracranial complications. However, a thin-slice small-FOV MRI examination focused at the IACs is required in conjunction for more accurate visualization. MRI sequences performed with IV contrast are also required.

### **MRV Head With IV Contrast**

AOM can be complicated by dural venous sinus thrombosis. MR venography (MRV) with IV contrast adequately demonstrates the dural venous sinuses and intraluminal filling defects of dural venous sinus thrombosis.

In a retrospective study, in 8 patients with venous sinus thrombosis, Zanoletti et al [37] stated that MR imaging is the method of choice for diagnosing venous sinus thrombosis in patients with acute mastoiditis. Contrast-enhanced MRI is mandatory to assess the brain and intracranial vascular system and to rule out intracranial complications. The combination of MRI and MRV techniques enables a more definitive diagnosis of otogenic venous thrombosis.

### **MRV Head Without and With IV Contrast**

There is no relevant literature to support the use of MRV head without and with IV contrast in the initial imaging of complicated otitis media.

### **MRV Head Without IV Contrast**

Noncontrast MRV can be useful in demonstrating venous sinus thrombosis but has lower sensitivity and spatial resolution than contrast enhanced MRV in this regard.

### **Radiography Skull**

There is no relevant literature to support the use of radiography skull in the initial imaging of complicated otitis media.



### **WBC Scan With SPECT or SPECT/CT Skull Base**

There is no relevant literature to support the use of white blood cell (WBC) scan with SPECT or SPECT/CT skull base in the initial imaging of complicated otitis media.

### **Variant 5: Adult. Chronic otitis media. Initial imaging.**

Imaging is frequently used for imaging COM. On initial imaging, entities such as cholesteatoma may be found, in which case this imaging can also be used for preprocedure planning.

### **CT Head With IV Contrast**

There is no relevant literature to support the use of CT head with IV contrast in the initial imaging or presurgical planning of COM.

Most studies found in the literature evaluating the role of CT in cases of COM have described HRCT of the temporal bone.

### **CT Head Without and With IV Contrast**

There is no relevant literature to support the use of CT head without and with IV contrast in the initial evaluation or presurgical planning of COM.

### **CT Head Without IV Contrast**

There is no relevant literature to support the use of CT head without IV contrast in the initial imaging or presurgical planning of COM.

Most studies found in the literature evaluating the role of CT in cases of COM have described HRCT of the temporal bone.

### **CT Temporal Bone With IV Contrast**

In a retrospective study on 50 patients with COM, Tatlipinar et al [36] aimed to assess the role of routine CT scanning before surgery. The results of CT scanning and intraoperative findings were compared, with the parameters of comparison, including presence of cholesteatoma, granulation tissue, attic blockage, presence of malleus, incus necrosis, lateral semicircular canal erosion, facial canal dehiscence, erosion of tegmen, erosion of scutum or external ear bony canal, and integrity of the ossicular chain. According to the authors, the most important advantage of CT is its ability to provide excellent anatomic detail of both bony and soft tissue structures. The authors said that CT is helpful in determining the anatomy of the middle ear and mastoid and the extent of the disease, CT is useful for follow-up of residual or recurrent cholesteatoma after ear surgery, and it is helpful to aid in decision-making regarding revision surgery. CT may affect the decision regarding the type of operation and can provide surgeons with a warning about possible difficulties due to anatomic variations.

It was not mentioned in this study whether the technique used was with or without IV contrast. Images provided in the article appear to be without IV contrast. Other studies on this topic [35,39] describe CT without IV contrast. There is no clear literature to support the use of IV contrast for this indication.

In conclusion, CT temporal bone is very useful but there is no specific literature to support the use of IV contrast in the initial imaging of COM.

### **CT Temporal Bone Without and With IV Contrast**

There is no relevant literature to support the use of CT temporal bone without and with IV contrast in the initial evaluation or presurgical planning of COM.

### **CT Temporal Bone Without IV Contrast**

In a retrospective study on 50 patients with COM, Tatlipinar et al [36] aimed to assess the role of routine CT scanning before surgery. The results of CT scanning and intraoperative findings were compared, with the parameters of comparison, including presence of cholesteatoma, granulation tissue, attic blockage, presence of malleus, incus necrosis, lateral semicircular canal erosion, facial canal dehiscence, erosion of tegmen, erosion of scutum or external ear bony canal, and integrity of the ossicular chain. According to the authors, the most important advantage of CT is its ability to provide excellent anatomic detail of both bony and soft tissue structures.

In a cross-sectional study by Kucur et al [39], the results of noncontrast preoperative CT with operative findings during mastoidectomy in 50 patients with COM were analyzed; the authors were of the opinion that it provides invaluable anatomical information. The authors believe that CT scans in axial and coronal planes before tympanoplasty have an important role in helping to prevent possible intraoperative complications and provide

preoperative medicolegal documentation. HRCT of the temporal bone could be used in preoperative diagnosis of the Koerner septum, the delayed identification of which may lead to insufficient mastoidectomy [35]. CT provides excellent anatomic detail in presurgical planning given its use in many studies that use measurements in presurgical planning [35,40-42]. In a retrospective study on 32 patients with mastoidectomy for cholesteatoma, Ng et al [43] correlated CT and intraoperative findings on the status of structures, including the ossicles, semicircular canals, facial canal, and tegmen tympani, and concluded that there was good to excellent radiosurgical agreement in the assessment of the status of various middle ear structures by CT, and that with technological advancements, CT of the temporal bone appears even more valuable for evaluation of patients prior to cholesteatoma surgery.

In conclusion, CT temporal bone without IV contrast has an important role in the initial imaging of COM and for presurgical planning if a cholesteatoma is found.

#### **MRI Head and Internal Auditory Canal With IV Contrast**

There is no relevant literature to support the use of MRI head and IAC with IV contrast in the initial evaluation or presurgical planning of COM. MRI sequences without IV contrast are required in conjunction.

#### **MRI Head and Internal Auditory Canal Without and With IV Contrast**

With DWI MRI, scar tissue, inflamed granulation tissue, and cholesteatoma can be differentiated from each other with high sensitivity and specificity [44]. In a study, the authors found that nonechoplanar DWI MRI was suggested as a valid method in the diagnosis and follow-up of cholesteatoma [44].

In a review on preoperative imaging assessment of COM, Stasolla et al [45] found literature suggesting that determining the nature of soft tissues detected in the middle ear is not possible by densitometric CT analysis and that the use of MRI with DWI and delayed postcontrast sequences may be required to increase specificity.

In a prospective study on 5 patients, the authors found that nonechoplanar DWI provided high sensitivity and specificity for differentiating between scar tissue, inflamed granulation tissue, and cholesteatoma [46,47]. Imaging in the coronal plane is preferred [47].

In conclusion, MRI head and IAC without and with IV contrast, especially with inclusion of nonechoplanar DWI in the coronal plane, has an important role in the initial imaging of COM with regards to detection of cholesteatoma.

#### **MRI Head and Internal Auditory Canal Without IV Contrast**

There is no relevant literature to support the use of MRI head and IAC without IV contrast in the initial evaluation or presurgical planning of COM. It is preferable to have MRI with IV contrast in conjunction.

#### **MRI Head With IV Contrast**

There is no relevant literature to support the use of MRI head with IV contrast in the initial evaluation or presurgical planning of COM.

Most studies found in the literature evaluating the role of MRI in cases of COM have described MRI without specific mention as to whether the MRI was focused at the IAC or the whole brain. Evaluation of images in these articles, however, suggests use of focused IAC MRI along with MRI brain.

#### **MRI Head Without and With IV Contrast**

There is no relevant literature to support the use of MRI head without and with IV contrast in the initial evaluation or presurgical planning of COM.

Most studies found in the literature evaluating the role of MRI in cases of COM have described MRI without specific mention as to whether the MRI was focused at the IAC or the whole brain. Evaluation of images in these articles, however, suggests use of focused IAC MRI along with MRI brain.

#### **MRI Head Without IV Contrast**

There is no relevant literature to support the use of MRI head without IV contrast in the initial evaluation or presurgical planning of COM.

Most studies found in the literature search evaluating the role of MRI in cases of COM have described MRI without specific mention as to whether the MRI was focused at the IAC or the whole brain. Evaluation of images in these articles, however, suggests use of focused IAC MRI along with MRI brain.

## **Radiography Skull**

There is no relevant literature to support the use of radiography skull in the initial evaluation or presurgical planning of COM.

In a retrospective study on 50 patients with COM, Tatlipinar et al [36] aimed to assess the role of routine CT scanning before surgery. According to the authors, the most important advantage of CT over traditional radiographic techniques is its ability to provide excellent anatomic detail of both bony and soft tissue structures.

### **Variant 6: Adult. Postoperative cholesteatoma. Surveillance Imaging.**

Cholesteatomas may recur after surgery. Assessment for potential recurrence used to be conducted via surgical exploration termed “second-look surgery.” This is now often supplanted by imaging. Recurrent lesions are seen as lobulated nonenhancing soft tissue that may show progressive bone erosion on CT and restricted diffusion on nonechoplanar DWI MRI in the coronal plane preferably.

#### **CT Head With IV Contrast**

There is no relevant literature to support the use of CT head with IV contrast in surveillance imaging for postoperative cholesteatoma recurrence.

Most studies found in the literature search evaluating the role of CT in cases of postoperative surveillance for recurrent cholesteatoma have described HRCT of the temporal bone.

#### **CT Head Without and With IV Contrast**

There is no relevant literature to support the use of CT head without and with IV contrast in surveillance imaging for postoperative cholesteatoma recurrence.

#### **CT Head Without IV Contrast**

There is no relevant literature to support the use of CT head without IV contrast in surveillance imaging for postoperative cholesteatoma recurrence.

#### **CT Temporal Bone With IV Contrast**

There is no relevant literature to support the use of CT temporal bone with IV contrast in surveillance imaging for postoperative cholesteatoma recurrence.

#### **CT Temporal Bone Without and With IV Contrast**

There is no relevant literature to support the use of CT temporal bone without and with IV contrast in surveillance imaging for postoperative cholesteatoma recurrence.

#### **CT Temporal Bone Without IV Contrast**

CT temporal bone without IV contrast provides good spatial resolution to evaluate for abnormal, new, or enlarging lobulated material in the temporal bone region due to recurrent cholesteatoma. CT also provides excellent bone detail and is helpful in locating subtle osseous erosions that may increase the suspicion for recurrent cholesteatoma on surveillance scans.

In a prospective study on 41 patients with cholesteatoma, Plodpai et al [44] evaluated preoperative HRCT scan of the temporal bone and compared them with intraoperative endoscopic findings. The authors concluded that a combination of preoperative temporal bone HRCT and preoperative audiological assessments can provide a good estimate of the degree of ossicular erosion.

In conclusion, CT temporal bone without IV contrast has an important role in postoperative surveillance for cholesteatoma recurrence by providing excellent anatomic detail and detecting bone erosions.

#### **MRI Head and Internal Auditory Canal With IV Contrast**

There is no relevant literature to support the use of MRI head and IAC with IV contrast in the surveillance imaging of postoperative cholesteatoma.

#### **MRI Head and Internal Auditory Canal Without and With IV Contrast**

In a prospective study on 30 patients who underwent MRI to detect cholesteatoma, Wiesmueller et al [48] stated that for recurrent cholesteatoma, MRI is suitable for postsurgical assessment using DWI and delayed postcontrast T1-weighted spin echo imaging, which enable differentiation between keratinous debris and noncholesteatoma findings such as granulation tissue or scar.

In a retrospective study on 59 patients with middle ear cholesteatoma performed for the assessment of efficacy of nonecho planar DWI, Baba et al [49] stated that MRI is useful for the preoperative diagnosis of cholesteatomas and to assess for recurrence and residual. The authors stated that nonechoplanar DWI sequences produce less imaging distortion and allow for better spatial resolution of the middle ear structures compared with echo planar DWI sequence.

In a review article, Barath et al [50] stated that MRI with conventional spin echo sequences provides information for distinguishing different pathologic entities and for accurately diagnosing primary and residual/recurrent cholesteatomas. Higher diagnostic specificity is achieved by introducing DWI and delayed postcontrast imaging. Studies using nonechoplanar and DWI PROPELLER sequences show promising results related to improved diagnostic sensitivity and specificity for even small (<5 mm) cholesteatomas.

In conclusion, MRI head and IAC without and with IV contrast has an important role in postoperative surveillance for cholesteatoma recurrence.

### **MRI Head and Internal Auditory Canal Without IV Contrast**

Although a noncontrast technique with DWI may suffice for the detection of cholesteatoma, studies suggest that the use of IV contrast helps in differentiating postoperative granulation tissue and scar from cholesteatoma.

In a review article, Barath et al [50] stated that MRI with the conventional spin echo sequences provides information for distinguishing different pathologic entities and for accurately diagnosing primary and residual/recurrent cholesteatomas. Higher diagnostic specificity is achieved by introducing DWI and delayed postcontrast imaging. Studies using nonecho planar and DWI PROPELLER sequences show promising results related to improved diagnostic sensitivity and specificity for even small (<5 mm) cholesteatomas.

### **MRI Head With IV Contrast**

There is no relevant literature to support the use of MRI head with IV contrast in surveillance imaging for postoperative cholesteatoma recurrence.

### **MRI Head Without and With IV Contrast**

Most studies found in the literature evaluating the role of MRI in cases of postoperative cholesteatoma have described MRI without specific mention as to whether the MRI was focused at the IAC or was of the whole brain. Evaluation of images in these articles, however, suggests use of focused IAC MRI along with MRI whole brain sequences.

There is no relevant literature to support the use of MRI head without and with IV contrast in surveillance imaging for postoperative cholesteatoma recurrence.

### **MRI Head Without IV Contrast**

There is no relevant literature to support the use of MRI head without IV contrast in surveillance imaging for postoperative cholesteatoma recurrence.

### **Radiography Skull**

There is no relevant literature to support the role of radiography of the skull in surveillance evaluation for postoperative cholesteatoma recurrence.

### **Summary of Highlights**

This is a summary of the key recommendations from the variant tables. Refer to the complete narrative document for more information.

- **Variants 1 and 3:** The diagnosis of adult uncomplicated AOE and otitis media is clinical. Therefore, no imaging is necessary for initial diagnosis in Variants 1 and 3. This document does not recommend any imaging for adult uncomplicated AOE and otitis media.
- **Variation 2:** MRI head and IAC without and with IV contrast and CT temporal bone with IV contrast are recommended for imaging of complicated otitis externa to delineate potential extension into the adjacent soft tissues and skull base and to assess for intracranial complications. CT temporal bone without and with IV contrast is considered inappropriate because the osseous changes seen on the noncontrast portion of the examination can be seen equally well on the postcontrast examination. MRI without IV contrast alone or with IV contrast alone are not considered appropriate because these individual examinations are suboptimal in

evaluation of enhancing inflammatory tissue. WBC scan with SPECT or SPECT/CT skull base may be appropriate in the initial imaging due to its high sensitivity.

- **Variants 4:** MRI head and IAC without and with IV contrast and CT temporal bone with IV contrast are recommended for imaging of complicated otitis media to delineate potential extension into the adjacent soft tissues and to assess for intracranial complications. CTV with IV contrast is considered appropriate to detect venous sinus thrombosis. CT temporal bone without and with IV contrast is considered inappropriate because the osseous changes seen on the noncontrast portion of the examination can be seen equally well on the postcontrast examination. MRI without IV contrast alone or with IV contrast alone are not considered appropriate because these individual examinations are suboptimal in evaluation of enhancing inflammatory tissue.
- **Variants 5 and 6:** MRI head and IAC without and with IV contrast is recommended for initial imaging of COM and for postoperative surveillance imaging of cholesteatoma, for evaluation of soft tissue abnormalities in the middle ear cavity, and differentiation of enhancing granulation tissue from cholesteatoma, the latter of which shows reduced diffusivity on DWI MRI. CT temporal bone without IV contrast is recommended for accurate assessment of bone erosion from cholesteatoma and for osseous changes due to COM.

### Supporting Documents

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to [www.acr.org/ac](http://www.acr.org/ac).

### Gender Equality and Inclusivity Clause

The ACR acknowledges the limitations in applying inclusive language when citing research studies that pre-dates the use of the current understanding of language inclusive of diversity in sex, intersex, gender and gender-diverse people. The data variables regarding sex and gender used in the cited literature will not be changed. However, this guideline will use the terminology and definitions as proposed by the National Institutes of Health [51].

### Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel’s recommendation. “May be appropriate” is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

## Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document [52].

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
○	0 mSv	0 mSv
☼	<0.1 mSv	<0.03 mSv
☼☼	0.1-1 mSv	0.03-0.3 mSv
☼☼☼	1-10 mSv	0.3-3 mSv
☼☼☼☼	10-30 mSv	3-10 mSv
☼☼☼☼☼	30-100 mSv	10-30 mSv

\*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as “Varies.”

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The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria, however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.