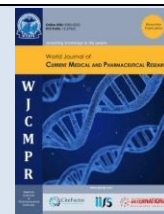




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IMAGING SPECTRUM OF FUNGAL RHINOSINUSITIS: AN UPDATED SYSTEMATIC REVIEW AND NARRATIVE SYNTHESIS OF CT AND MRI FINDINGS

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ARTICLE HISTORY	ABSTRACT
Received on: 09-07-2026 Revised on: 15-08-2026 Accepted on: 28-09-2026 Keywords: Fungal Rhinosinusitis; Acute Invasive Fungal Rhinosinusitis; Allergic Fungal Rhinosinusitis; Fungus Ball; Computed Tomography; Magnetic Resonance Imaging. Corresponding Author Dr. Manjunatha YC. Department of Radiodiagnosis, Sri Devaraj Urs Medical College, Tamaka, Kolar-563101, Karnataka, India.	Background: Fungal rhinosinusitis (FRS) includes invasive and non-invasive disorders with distinct prognoses and management. Imaging is essential for assessing disease extent, tissue invasion, and orbital or intracranial complications and for distinguishing fungal ball and allergic fungal rhinosinusitis (AFRS) from invasive disease. Objective: To synthesize CT and MRI features of major FRS subtypes, emphasizing imaging markers of invasion, extra-sinonasal spread, modality-specific strengths and limitations, and newer quantitative CT/MRI findings. Methods: An evidence synthesis used the author-provided pictorial review as the framework and an updated PubMed search through 19 September 2026. The 2024 systematic review by Chen et al., encompassing 48 studies identified through searches of PubMed/MEDLINE, Embase, CENTRAL, and ScienceDirect through May 2023, served as the principal benchmark. Relevant post-May 2023 imaging studies were additionally incorporated. Given heterogeneous study designs, populations, reference standards, and imaging protocols, findings were synthesized narratively. Results: CT best depicts sinonasal opacification, hyperattenuating fungal material, calcification, bone remodeling, and erosion, whereas MRI better characterizes soft-tissue devitalization and extra-sinonasal extension. Invasive disease commonly demonstrates bone erosion, perisinus fat infiltration, nasal cavity abnormalities, non-enhancing mucosa/turbinates, T2-hypointense fungal material, orbital involvement, and intracranial extension. The black turbinate sign is useful in context but not pathognomonic. Fungal ball typically shows focal hyperattenuation, calcification, and marked T2 hypointensity. AFRS demonstrates hyperattenuating allergic mucin, sinus expansion/remodeling, and characteristic MRI signal changes. Quantitative CT attenuation may help distinguish fungal ball from allergic fungal mucin, while pediatric studies highlight clinically relevant false-negative CT examinations. Conclusion: Imaging findings should be interpreted as patterns. CT is the primary anatomic modality; contrast-enhanced MRI is recommended when invasive, orbital, skull-base, vascular, or intracranial disease is suspected. Persistent clinical concern warrants endoscopic evaluation and biopsy despite equivocal imaging.

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1. INTRODUCTION

Fungal rhinosinusitis is a heterogeneous group of sinonasal disorders ranging from non-invasive colonization to rapidly progressive angioinvasive infection. The distinction is clinically important because invasive fungal rhinosinusitis can extend beyond the paranasal sinuses into the orbit, cavernous sinus, skull base and intracranial compartment, whereas non-invasive forms are generally characterized by fungal material or allergic inflammatory products without tissue invasion. The author-provided source manuscript

similarly classifies disease into acute invasive, chronic invasive, chronic granulomatous invasive, allergic fungal rhinosinusitis and fungus ball subtypes. [Source manuscript] Computed tomography (CT) and magnetic resonance imaging (MRI) are complementary. CT provides high spatial resolution for sinonasal anatomy, hyperattenuating contents, calcification, cortical bone and subtle osseous destruction. MRI is more sensitive to soft-tissue devitalization, orbital apex disease, vascular complications and intracranial extension. However, no single imaging sign

establishes invasive disease in isolation; diagnosis remains clinicoradiologic and ultimately depends on endoscopic evaluation and histopathologic demonstration of tissue invasion when invasive disease is suspected. A systematic review published in 2024 identified 48 eligible primary studies after searching 3,734 records through May 2023. It found that bony erosion and mucosal thickening were the most frequently reported CT features of invasive fungal rhinosinusitis, while extra-sinus extension was commonly demonstrated on MRI. [1] Since that review, additional studies have refined the role of MRI, quantitative CT attenuation and pediatric CT assessment. The present review therefore updates and broadens the imaging synthesis to cover the complete spectrum of FRS rather than invasive disease alone.

2. REVIEW QUESTION AND OBJECTIVES

Primary review question: What CT and MRI findings characterize the major subtypes of fungal rhinosinusitis, and which imaging features are most useful for recognizing tissue invasion and clinically important extra-sinonasal extension?

Secondary objectives were to: (1) compare the complementary roles of CT and MRI; (2) summarize imaging-pathology correlations; (3) identify diagnostic pitfalls, particularly the black turbinate sign; (4) summarize quantitative CT/MRI findings where available; and (5) develop a practical imaging checklist suitable for radiology reporting and multidisciplinary decision-making.

3. METHODS

3.1 Design and reporting framework

This review was structured according to the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020). The review was not prospectively registered in PROSPERO. The manuscript should therefore be described as an updated systematic evidence synthesis rather than a prospectively registered protocol-driven review.

3.2 Information sources and search strategy

The evidence base was anchored to the systematic review by Chen et al., which searched PubMed/MEDLINE, Embase, the Cochrane Central Register of Controlled Trials (CENTRAL) and ScienceDirect from database inception through May 2023 and identified 3,734 records, of which 48 studies met eligibility criteria. [1] An updated PubMed-focused search was performed for literature published after May 2023 through 19 September 2026 using combinations of the terms “fungal rhinosinusitis,” “fungal sinusitis,” “acute invasive fungal rhinosinusitis,” “chronic invasive fungal rhinosinusitis,” “granulomatous fungal sinusitis,” “allergic fungal rhinosinusitis,” “fungus ball,” “mucormycosis,” “computed tomography,” “CT,” “magnetic resonance imaging,” “MRI,” “radiology,” “imaging,” “Hounsfield units,” and “diagnostic accuracy.” Reference lists of key reviews and relevant articles were also examined.

The update specifically incorporated post-May-2023 imaging publications identified during the search, including work on early MRI diagnosis, radiographic predictors of acute invasive disease, quantitative CT attenuation in fungal ball/AFRS, radiographic variants of AFRS, MRI-versus-CT diagnostic accuracy, and pediatric CT accuracy.

3.3 Eligibility criteria

- Population: patients with clinically, surgically, microbiologically or histopathologically diagnosed fungal rhinosinusitis.
- Exposure/intervention: CT, cone-beam CT where relevant, MRI, contrast-enhanced MRI, or quantitative CT/MRI assessment.
- Outcomes: sinonasal imaging findings, evidence of tissue invasion, bone change, extra-sinonasal extension, vascular or intracranial complications, diagnostic accuracy, or imaging-pathology correlation.
- Eligible evidence: primary observational studies, diagnostic studies, retrospective/prospective cohorts and clinically relevant comparative studies; major systematic reviews and narrative reviews were used for contextual synthesis and reference harvesting.
- Exclusions: isolated non-sinonasal fungal infection, purely therapeutic studies without imaging data, editorials and correspondence without original imaging information, and duplicate reports.

3.4 Data synthesis

Data were organized by FRS subtype and imaging modality. Extracted domains included patient risk profile, disease subtype, CT attenuation and density pattern, mucosal findings, bone changes, MRI signal characteristics, enhancement, vascular findings, orbital/intracranial extension and diagnostic performance. Because the literature used different disease definitions, reference standards, imaging protocols and outcome measures, quantitative meta-analysis was not considered appropriate for the overall imaging spectrum. Where individual studies provided diagnostic performance estimates, these are reported descriptively and are not pooled.

3.5 Risk of bias and certainty

The evidence base is dominated by retrospective cohorts, case series and heterogeneous diagnostic studies. The 2024 systematic review reported variable risk of bias across its 48 included studies [1]. The present update therefore emphasizes consistency of findings across independent cohorts and explicitly identifies findings supported by diagnostic-accuracy studies versus those based primarily on descriptive case series. No formal pooled certainty grade was assigned because of substantial clinical and methodological heterogeneity.

4. RESULTS

4.1 Classification and imaging phenotype

FRS can be divided into invasive and non-invasive disease. The major invasive subtypes are acute invasive fungal rhinosinusitis (AIFRS), chronic invasive fungal rhinosinusitis (CIFRS) and chronic granulomatous invasive fungal rhinosinusitis (CGIFRS). Non-invasive disease includes fungus ball (mycetoma) and AFRS. This classification is consistent with the author-provided source manuscript and the broader radiologic literature [1-4.]

Table 01: Imaging phenotype of the major subtypes of fungal rhinosinusitis

Subtype	Pathobiologic setting	CT pattern	MRI pattern
Acute invasive FRS	Rapid tissue/vascular invasion; often immunocompromised	Mucosal thickening; unilateral/asymmetric opacification; perisinus fat infiltration; early soft-tissue invasion; variable bone erosion	Non-enhancing/devitalized mucosa or turbinate; T2 hypointensity; restricted diffusion in selected studies; orbital/intracranial spread
Chronic invasive FRS	Indolent invasion over weeks–months	Unilateral/asymmetric mass-like hyperattenuating tissue; bony erosion, sclerosis/remodeling; perisinus extension	T1 iso-/hypointensity, T2 hypointensity; variable enhancement; orbital/skull-base/cavernous sinus extension
Chronic granulomatous invasive FRS	Granulomatous invasive disease; often described in immunocompetent populations in endemic regions	Expansile or mass-forming disease; erosion/sclerosis/remodeling	T2 iso-/hypointense mass; variable/moderate-to-intense enhancement; orbital apex and intracranial extension
AFRS	Non-invasive eosinophilic/allergic inflammatory disease	Hyperattenuating heterogeneous allergic mucin; sinus expansion; smooth thinning/remodeling; polyposis	T1 relatively hyperintense and T2 hypointense allergic mucin; peripheral mucosal enhancement
Fungus ball	Non-invasive fungal concretions	Focal hyperattenuating sinus content, often calcified; usually single sinus; preserved walls	Marked T2 hypointensity with surrounding inflammatory mucosal change

4.2 Acute invasive fungal rhinosinusitis

AIFRS is the most time-critical subtype. The classic setting includes severe immunosuppression or poorly controlled diabetes, although disease can occur outside these groups. Imaging should be interpreted as evidence of tissue invasion rather than simply as sinus opacification. On CT, the most reproducible findings are mucosal thickening, sinonasal opacification, nasal soft-tissue abnormality, perisinus fat infiltration and bone erosion. Importantly, absence of bone erosion does not exclude invasion because fungi may traverse small vascular and neural channels before producing gross osseous destruction. The 2024 systematic review reported that bony erosion among included AIFRS cohorts varied widely, from 0% to 57%, illustrating its limited sensitivity as an isolated sign [1].

A seven-variable CT model developed by Middlebrooks et al. incorporated periantral fat abnormality, bone dehiscence, orbital invasion, septal ulceration, pterygopalatine fossa abnormality, nasolacrimal duct abnormality and lacrimal sac abnormality. In their retrospective cohort of 84 patients, the presence of one model variable had 95% sensitivity and 86% specificity, while two or more positive variables achieved 100% specificity and 100% positive predictive value. These estimates come from a single-center retrospective diagnostic model and should not be treated as universally validated thresholds [5].

MRI is particularly valuable when the clinical question is early tissue devitalization or extra-sinonasal spread. Reported findings include non-enhancement of involved mucosa/turbinates, T2 hypointense sinonasal material, diffusion restriction in areas of necrosis, orbital apex involvement, cavernous sinus disease and intracranial extension. The black turbinate sign should be interpreted cautiously: a dedicated study found partial turbinate non-enhancement in 30% of MR examinations in patients without invasive fungal rhinosinusitis, demonstrating that the sign is not pathognomonic. Pathologic non-enhancement is more concerning when it is irregular, extensive, associated with surrounding invasive change and concordant with the clinical context [6]. A 2025 review emphasized the value of MRI in early AIFRS, particularly for demonstrating devitalized mucosa and complications. [7] A 2026 pediatric diagnostic study of 106 at-risk children reported sensitivity of 83%, specificity of 97% and AUC of 0.90 for one or more abnormal CT findings. However, 17.5% of children with AIFRS were not detected on CT, with the middle turbinate being a common missed site, reinforcing that negative CT cannot overrule persistent clinical concern [8].

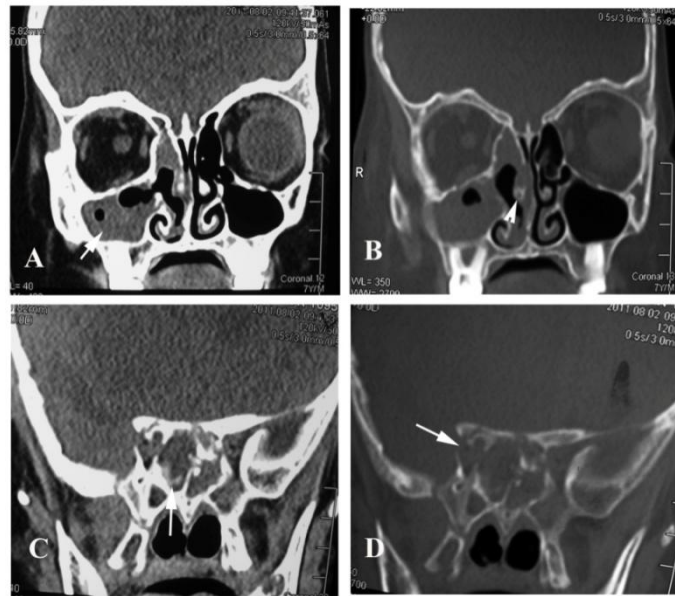


Figure 01: Coronal CT images of the paranasal sinuses demonstrating invasive fungal sinusitis.

(A) Coronal soft-tissue window image shows a heterogeneous soft-tissue density lesion (arrow) occupying the right maxillary sinus with extension into the right nasal cavity. (B) Corresponding coronal bone window image at the same level demonstrates widening of the right maxillary ostium with erosion of the middle turbinate (arrow). (C) Coronal soft-tissue window image at the level of the sphenoid sinus reveals a soft-tissue density lesion within the sphenoid sinus with erosion of the sinus walls and partial extension toward the orbital apex (arrow). (D) Coronal bone window image more clearly delineates the bony destruction of the sphenoid sinus walls (arrow), confirming aggressive invasive disease.

4.3 Chronic invasive fungal rhinosinusitis

CIFRS progresses more slowly than AIFRS and may occur in patients with diabetes or other mild immunosuppression. CT commonly shows unilateral or asymmetric sinus disease with mass-like hyperattenuating tissue, bony erosion and/or sclerosis. The pattern differs from AFRS because invasive disease is associated with destructive extension rather than purely smooth expansion and remodeling.

In a prospective study of 17 patients with chronic/granulomatous invasive fungal sinusitis and 12 with AFRS, invasive disease showed homogeneous isodense-to-hyperdense sinus contents, T1 isointensity, T2 hypointensity, lack of sinus expansion, and bone erosion concentrated around areas of extra-sinus extension [9].

MRI is particularly useful for orbital apex, skull-base, cavernous sinus and intracranial involvement. Enhancement may be heterogeneous and may reflect inflammatory tissue, fibrosis and viable fungal/inflammatory components. The distinction from neoplasm can be difficult; therefore, imaging distribution and clinical tempo should be integrated with endoscopic and histopathologic findings.



Figure 02: Imaging findings of chronic invasive fungal rhinosinusitis with cavernous sinus and intracranial extension. (A) Coronal Contrast-enhanced CT image of the paranasal sinuses coronal view demonstrates mucosal thickening within the sphenoid sinus with mild soft-tissue extension toward the orbital apex. (B) Contrast-enhanced CT image coronal view shows features of cavernous sinus thrombosis, characterized by irregularly enhancing cavernous sinus walls. (C) Coronal contrast-enhanced T1-weighted MRI image of the same patient reveals irregularly enhancing walls with central non enhancing areas, confirming cavernous sinus involvement. (D) Axial contrast-enhanced T1-weighted MRI image demonstrates a heterogeneously enhancing lesion extending from the left orbital apex to the left cerebellopontine angle, indicating extensive intracranial spread of disease.

4.4 Chronic granulomatous invasive fungal rhinosinusitis.

CGIFRS is a rare form of chronic invasive disease characterized histopathologically by granulomatous inflammation. The entity has been described particularly in India, Pakistan and parts of Africa. Imaging may be mass-forming and can mimic neoplasm. The available radiologic literature is limited. A comparison summarized in the 2024 systematic review found CT abnormalities including bony destruction, orbital/optic nerve abnormality and central nervous system abnormality, but these did not reliably distinguish granulomatous from non-granulomatous chronic invasive disease. In another cohort, homogeneous isodense-to-hyperdense sinus contents and substantial extra-sinus components were common [1,9]. MRI typically demonstrates a T2 iso-/hypointense mass with variable enhancement and may show orbital apex, skull-base or intracranial extension. Because imaging overlap with malignancy is substantial, tissue diagnosis is essential.

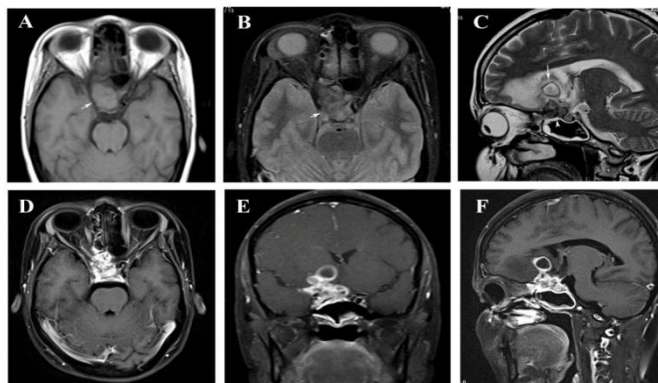


Figure 03: MRI features of Chronic Granulomatous Invasive Fungal Sinusitis (CGIFS) with orbital apex and intracranial involvement. (A) Axial T1-weighted image demonstrates an isointense soft-tissue mass involving the right orbital apex with suprasellar extension (arrow). (B) Axial T2-weighted image shows the lesion to be isointense (arrow). (C) Sagittal image reveals a hypointense suprasellar component with an associated small conglomerate abscess in the right frontal lobe and surrounding vasogenic edema, indicating intracranial spread. (D) Axial contrast-enhanced T1-weighted image demonstrates a heterogeneously and intensely enhancing mass in the right orbital apex. (E, F) Coronal and sagittal contrast-enhanced T1-weighted images show the orbital apex lesion with ring-enhancing intracranial abscess formation in the right frontal lobe, confirming intracranial extension of CGIFS.

4.5 Allergic fungal rhinosinusitis

AFRS is a non-invasive hypersensitivity-associated form of fungal rhinosinusitis, typically occurring in atopic or otherwise immunocompetent patients. The characteristic CT appearance is heterogeneous hyperattenuating sinus content associated with expansion, smooth thinning or remodeling of the sinus walls and, frequently, nasal polypsis.

MRI commonly demonstrates relatively T1 hyperintense and markedly T2 hypointense allergic mucin, with peripheral mucosal enhancement. The low T2 signal is attributed to concentrated proteinaceous material and paramagnetic elements within the mucin [3,10].

Recent quantitative work has explored objective CT attenuation. In a 120-patient retrospective study, maximum attenuation was useful for identifying fungal balls (AUC 0.868), while average attenuation and attenuation heterogeneity were highly discriminative for allergic fungal mucin (AUC 0.979 and 0.973, respectively). The authors proposed thresholds of 299 HU for fungal ball, 44 HU for allergic fungal mucin average attenuation, and 55.6 HU for its standard deviation. These cutoffs require external validation and should not yet be treated as universal diagnostic thresholds [11].

A 2025 study also emphasized radiographic variants relevant to preoperative planning in AFRS, underscoring the importance of detailed assessment of sinonasal anatomy and bony remodeling rather than relying only on the presence of hyperattenuating material [12].

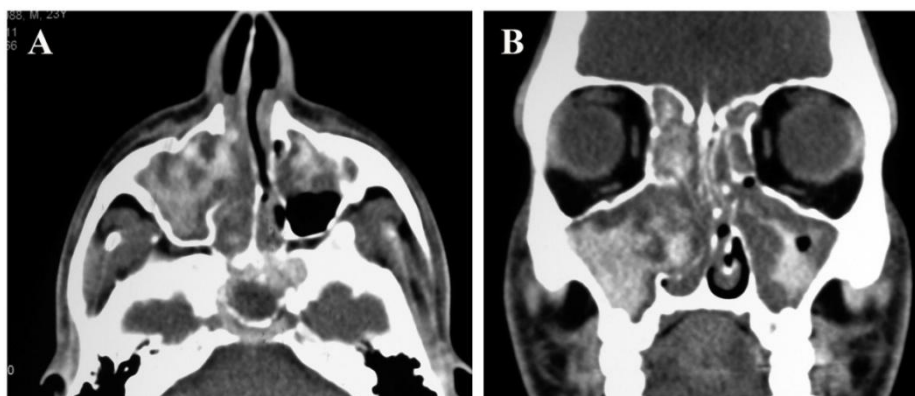


Figure 04: Imaging features of Allergic Fungal Rhinosinusitis (AFRS). (A) Axial CT image of the paranasal sinuses shows heterogeneous hyperattenuating allergic mucin filling the bilateral maxillary sinuses and ethmoid air cells, with areas of mixed density giving a characteristic "double-density" appearance, suggestive of allergic fungal debris. (B) Coronal CT image demonstrates expansile sinus opacification involving the maxillary and ethmoid sinuses with smooth bony remodeling and thinning of the sinus walls, without frank bony destruction.

4.6 Fungus ball (fungal mycetoma)

A fungus ball represents dense fungal concretions within a sinus without tissue invasion. The maxillary sinus is commonly involved. CT typically shows focal hyperattenuating material, often with intralesional calcifications, while the sinus walls remain preserved or remodeled rather than frankly destroyed.

The largest classic imaging cohort included 119 pathologically proven fungus balls. CT demonstrated calcifications in 67.2% of scanned patients; contrast-enhanced CT showed hyperattenuating fungal material in 82.8%. On MRI, the fungal ball was usually iso- or hypointense on T1 and markedly hypointense on T2, while inflamed mucosa was more conspicuous on T2-weighted images [13].

The combination of central hyperattenuating material, calcification, preserved bony walls and marked T2 hypointensity strongly favors a fungus ball, but odontogenic disease and other chronic sinus processes may produce overlapping appearances. Quantitative CT attenuation may improve discrimination in selected settings, although thresholds remain insufficiently validated for routine universal use [11,13].

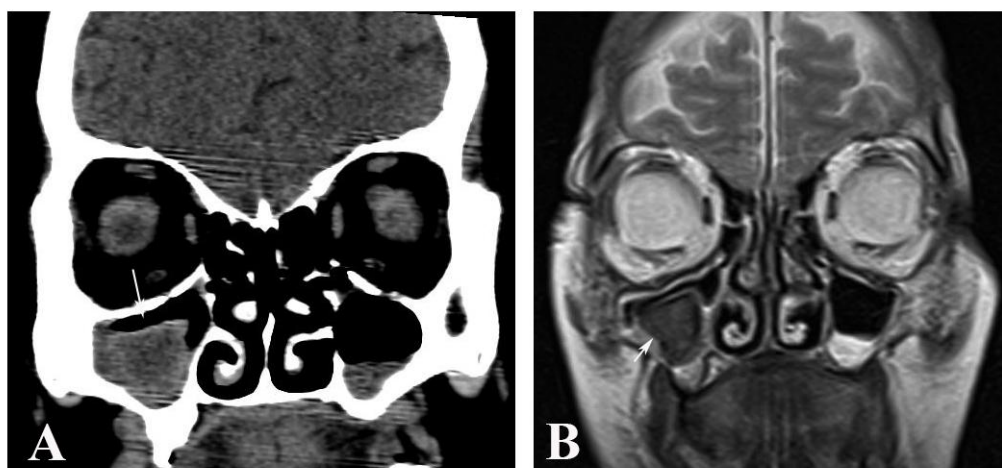


Figure 05: Imaging features of fungal ball (fungal mycetoma). (A) Coronal CT image of the paranasal sinuses demonstrates a focal hyperattenuating mass within the maxillary sinus (arrow), with associated mucosal thickening. The sinus walls are preserved, with no evidence of bony erosion or extra sinus extension, favoring a non-invasive fungal process. (B) Coronal T2-weighted MRI shows a markedly hypointense lesion within the involved maxillary sinus (arrow), characteristic of dense fungal concretions due to the presence of paramagnetic elements. The surrounding sinus mucosa shows mild inflammatory changes, consistent with a fungal ball.

4.7 Comparison of CT and MRI.

Table 02: Comparison of computed tomography and magnetic resonance imaging in fungal rhinosinusitis

Domain	CT	MRI
Primary strength	High-resolution bone and sinus anatomy	Soft-tissue, orbital, skull-base and intracranial characterization
Best for	Bony erosion; sclerosis/remodeling; hyperattenuating fungal material; calcification; surgical roadmap	Devitalized/non-enhancing mucosa; orbital apex; cavernous sinus; intracranial spread; vascular complications
Typical invasive clue	Perisinus fat infiltration, focal bone destruction, nasal soft-tissue abnormality	Non-enhancing mucosa/turbinate, T2 hypointense material, restricted diffusion, extrasinus extension
Key limitation	Early soft-tissue invasion may precede bone destruction; radiation exposure	Longer acquisition, motion sensitivity, less direct assessment of fine cortical bone
Practical role	First-line anatomic study in most suspected sinonasal fungal disease	Problem-solving/extent study when invasive disease or complications are suspected

4.8 Extra-sinonasal extension and complications

The orbit is the most clinically important route of spread beyond the sinuses. Reported orbital findings include orbital apex involvement, extraocular muscle enlargement, orbital cellulitis, retro-orbital fat infiltration, proptosis, superior ophthalmic vein thrombosis, optic nerve/optic neuritis abnormalities, ophthalmic artery thrombosis and, in severe cases, orbital compartment syndrome [1]. Cavernous sinus involvement is another critical complication and may be associated with venous thrombosis, cranial neuropathies and intracranial extension. MRI is generally superior for defining cavernous sinus, orbital apex, skull-base, pterygopalatine fossa and intracranial disease. Invasive disease may also extend through the pterygopalatine fossa, infratemporal fossa, masticator space and facial soft tissues [1].

Intracranial complications include meningitis, cerebritis, abscess formation, infarction and vascular thrombosis. The imaging report should therefore describe the disease compartment, route of spread and neurovascular structures at risk rather than simply stating 'extension beyond the sinus.

5. PRACTICAL RADIOLOGY CHECKLIST

Table 03: Practical radiology checklist for suspected fungal rhinosinusitis

Checklist item	What to assess
1. Clinical risk	Diabetes, neutropenia, hematologic malignancy, transplant, corticosteroid/immunosuppressive therapy, recent severe viral illness or other immunocompromise
2. Sinonasal pattern	Unilateral/asymmetric versus bilateral; focal versus diffuse; single sinus versus multispatial involvement
3. Contents	Soft tissue, hyperattenuating material, calcification, air-fluid level, heterogeneous allergic mucin
4. Mucosa	Thickness, ulceration, non-enhancement, turbinate involvement, nasal septal abnormality
5. Bone	Smooth expansion/remodeling versus focal destructive erosion; sclerosis; dehiscence
6. Perisinus tissues	Periantral/retroantral fat stranding or obliteration; pterygopalatine fossa; facial soft tissue
7. Orbit	Orbital fat, extraocular muscles, orbital apex, optic nerve, globe, superior ophthalmic vein
8. Vascular	Cavernous sinus, internal carotid artery, ophthalmic artery, venous thrombosis
9. Intracranial	Dural enhancement, cerebritis, abscess, infarct, meningitis, skull-base involvement
10. MRI signal	T1, T2, DWI/ADC, post-contrast enhancement; assess for devitalized tissue
11. Impression	State whether findings favor non-invasive disease, invasive disease, or remain indeterminate; identify the highest-risk compartment and recommend urgent endoscopic/clinical correlation when appropriate

6. DISCUSSION

The central finding of this updated evidence synthesis is that imaging diagnosis of FRS is pattern-based and modality-complementary. The radiologist should distinguish three broad imaging behaviors: (1) non-invasive fungal material with preserved sinus boundaries; (2) chronic invasive or granulomatous mass-like disease with destructive or infiltrative behavior; and (3) acute invasive disease in which soft-tissue devitalization and perivascular/perisinus spread may precede obvious bone destruction.

The 2024 systematic review provides the strongest recent consolidated evidence for invasive FRS. It included 48 studies and found bony erosion and mucosal thickening to be the most common CT features, while extra-sinus extension was frequently better demonstrated on MRI [1]. Our update supports these conclusions but adds several clinically important refinements.

First, absence of bone destruction should not be used as a rule-out criterion for AIFRS. The pathophysiology of angioinvasion permits spread through vascular channels and devitalization of mucosa before gross cortical destruction develops. Second, the black turbinate sign is context-dependent. Normal or benign non-enhancing turbinate segments are common, and the sign becomes more persuasive when it is irregular, extensive and accompanied by other invasive findings [6]. Third, quantitative CT attenuation is an emerging adjunct for differentiating fungal ball and allergic fungal mucin, but available thresholds are

derived from individual retrospective cohorts and require external validation [11].

Fourth, newer pediatric data demonstrate that CT can have high specificity and good overall diagnostic accuracy while still missing a clinically meaningful minority of AIFRS cases. This is particularly relevant to nasal cavity disease and supports continued reliance on endoscopic evaluation when suspicion remains high [8].

Finally, post-COVID fungal disease has highlighted the need for radiologists to recognize early invasive patterns and to communicate them urgently. Contemporary literature continues to emphasize rapid multidisciplinary diagnosis and treatment, particularly when orbital, vascular or intracranial disease is present [7,14].

7. IMAGING DIFFERENTIAL DIAGNOSIS.

Table 04: Imaging differential diagnosis of fungal rhinosinusitis

Differential	Overlapping imaging features	Helpful discriminator
Bacterial/chronic inflammatory sinusitis	Usually mucosal thickening and fluid; bone remodeling may occur but aggressive perisinus infiltration and tissue non-enhancement are less typical	Clinical/endoscopic correlation; invasive fungal disease should be considered when risk factors and perisinus invasion are present

Differential	Overlapping imaging features	Helpful discriminator
Sinonasal neoplasm	Mass-like soft tissue, bone destruction and extrasinus extension may overlap	Look for pattern of spread, enhancement, diffusion, clinical tempo and fungal-specific hyperattenuating/T2-dark material; biopsy often required
AFRS	Expansion/remodeling, hyperattenuating contents, T2-dark mucin	Usually non-invasive; smooth remodeling rather than destructive invasion
Fungus ball	Focal hyperattenuating/calified sinus contents with preserved walls; T2-dark contents	Usually localized and non-invasive
AIFRS	Rapidly progressive infiltrative disease, perisinus fat changes, non-enhancing mucosa/turbinate, vascular/orbital/intracranial complications	Urgent clinical/endoscopic assessment and biopsy

8. LIMITATIONS

- The evidence base is heterogeneous and dominated by retrospective studies and case series. Disease definitions and the distinction between acute, chronic and granulomatous invasive disease are not uniform across studies. Imaging protocols, contrast timing, MRI sequences and reference standards vary considerably. Many studies evaluate selected high-risk populations, limiting direct generalization to unselected patients.
- The updated component of this review was based on PubMed-indexed and web-accessible literature identified through 19 September 2026 and was not accompanied by a new multi-database export from Embase/CENTRAL/ScienceDirect. Therefore, the 3,734-record/48-study PRISMA counts reported in the 2024 systematic review should not be presented as newly generated counts for this update. Before journal submission, the authors should run and archive the exact database searches, deduplicate records, document duplicate independent screening, and update the PRISMA flow diagram if the target journal requires a de novo systematic review.
- Quantitative CT thresholds reported in individual studies are promising but are not sufficiently externally validated to support universal diagnostic cutoffs.

9. CONCLUSION

Fungal rhinosinusitis has a broad imaging spectrum, and accurate classification depends on integrating CT morphology, MRI tissue characteristics, clinical risk factors and endoscopic/pathologic findings. CT is the principal modality for sinonasal anatomy, hyperattenuating fungal contents, calcification and osseous change. MRI provides superior assessment of devitalized mucosa, orbital apex, skull base, vascular structures and intracranial extension. For invasive disease, radiologists should actively search for perisinus fat infiltration, subtle bone dehiscence/erosion, nasal soft-tissue abnormality, non-enhancing mucosa or turbinates, T2 hypointense contents and extra-sinonasal spread. The black turbinate sign is supportive but not diagnostic in isolation. For non-invasive disease, focal calcified hyperattenuating contents with marked T2 hypointensity favor a fungus ball, whereas expansile heterogeneous hyperattenuating contents with smooth bony remodeling and characteristic allergic mucin favor AFRS. When imaging and clinical suspicion are discordant, imaging should not delay endoscopic evaluation and tissue diagnosis. A structured CT/MRI checklist may improve recognition of early invasive disease and more consistent communication of orbital, vascular and intracranial complications.

10. ACKNOWLEDGEMENTS

None

11. ETHICS APPROVAL

Not applicable; this study is a secondary synthesis of published literature.

12. PATIENT CONSENT

Not applicable.

13. FUNDING

Not received

14. CONFLICT OF INTEREST

None.

15. DATA AVAILABILITY

The evidence base consists of published literature. The final submission should include the exact database search strings, screening log and extraction sheet as supplementary material if required by the target journal.

16. REFERENCES

- Chen A, Pietris J, Bacchi S, Chan W, Psaltis AJ, Selva D, Lim W. Imaging Features of Invasive Fungal Rhinosinusitis: A Systematic Review. *Can Assoc Radiol J*. 2024;75(3):601-608. doi:10.1177/08465371241227424.
- Dagher R, Calle S, Learned KO. Imaging approach for fungal sinusitis. *Curr Opin Otolaryngol Head Neck Surg*. 2025;33(1):56-63. doi:10.1097/MOO.0000000000001018.
- Gavito-Higuera J, Mullins CB, Ramos-Duran L, Sandoval H, Akle N, Figueroa R. Sinonasal fungal infections and complications: a pictorial review. *J Clin Imaging Sci*. 2016;6:23. doi:10.4103/2156-7514.184010.
- Mossa-Basha M, Ilica AT, Maluf F, Karakoç Ö, Izbudak I, Aygün N. The many faces of fungal disease of the

- paranasal sinuses: CT and MRI findings. *Diagn Interv Radiol.* 2013;19(3):195-200. doi:10.5152/dir.2012.003.
5. Middlebrooks EH, Frost CJ, De Jesus RO, et al. Acute invasive fungal rhinosinusitis: a comprehensive update of CT findings and design of an effective diagnostic imaging model. *AJNR Am J Neuroradiol.* 2015;36(8):1529-1535. doi:10.3174/ajnr.A4298.
6. Han Q, Escott EJ. The black turbinate sign, a potential diagnostic pitfall: evaluation of the normal enhancement patterns of the nasal turbinates. *AJNR Am J Neuroradiol.* 2019;40(5):855-861. doi:10.3174/ajnr.A6037.
7. Voruz F, Neofytos D, Van Delden C, et al. The importance of MRI in the early diagnosis of acute invasive fungal rhinosinusitis. *Diagnostics (Basel).* 2025;15(3):311. doi:10.3390/diagnostics15030311.
8. Kralik SF, Narayanan S, Ramaswamy U, et al. Accuracy of CT Imaging for Diagnosis of Acute Invasive Fungal Rhinosinusitis in Children. *AJNR Am J Neuroradiol.* 2026 Aug 19. doi:10.3174/ajnr.A9600.
9. Ilica AT, Mossa-Basha M, Maluf F, Izbudak I, Aygun N. Clinical and radiologic features of fungal diseases of the paranasal sinuses. *J Comput Assist Tomogr.* 2012;36(5):570-576. doi:10.1097/RCT.0b013e318263148c.
10. Reddy CE, Gupta AK, Singh P, Mann SBS. Imaging of granulomatous and chronic invasive fungal sinusitis: comparison with allergic fungal sinusitis. *Otolaryngol Head Neck Surg.* 2010. doi:10.1016/j.otohns.2010.02.027.
11. Alsalem S, Alsalem M, Al Harithi I, et al. Using the Hounsfield Units Derived From Computed Tomography (CT) Scans to Differentiate Between the Subtypes of Allergic Fungal Rhinosinusitis: A Retrospective Study. *Cureus.* 2025;17(3):e80151. doi:10.7759/cureus.80151.
12. Erwin DZ, Liu MY, Krysinski MR, Choi AM, Tantiwongkosi B, Chen PG. Radiographic Variants Associated With Allergic Fungal Rhinosinusitis: Key Differences for Pre-Operative Planning. *Ann Otol Rhinol Laryngol.* 2025;134(2):65-69. doi:10.1177/00034894241293390.
13. Seo YJ, Kim J, Kim K, Lee JG, Kim CH, Yoon JH. Radiologic characteristics of sinonasal fungus ball: an analysis of 119 cases. *Acta Radiol.* 2011;52(7):790-795. doi:10.1258/ar.2011.110021.
14. Roland LT, Humphreys IM, Le CH, et al. Diagnosis, Prognosticators, and Management of Acute Invasive Fungal Rhinosinusitis: Multidisciplinary Consensus Statement and Evidence-Based Review With Recommendations. *Int Forum Allergy Rhinol.* 2023;13(9):1615-1714. doi:10.1002/alr.23132.
15. Soundarya R, Deepa HC, Prakash PY, Geetha V. Fungal Rhinosinusitis: An integrated diagnostic approach. *Ann Diagn Pathol.* 2025;75:152415. doi:10.1016/j.anndiagpath.2024.152415.
16. Ramkumar SP, Narendran N, Gallego CJ, et al. MRI Versus CT in Acute Invasive Fungal Sinusitis: Mapping Diagnostic Accuracy Across Sinonasal Subsites. *Int Forum Allergy Rhinol.* 2026;16(2):201-204. doi:10.1002/alr.70087.
17. Bahethi R, Talmor G, Choudhry H, et al. Chronic invasive fungal rhinosinusitis and granulomatous invasive fungal sinusitis: a systematic review of symptomatology and outcomes. *Am J Otolaryngol.* 2024;45(1):104064. doi:10.1016/j.amjoto.2023.104064.
18. Kim DH, Kim SW, Hwang SH. Usefulness of intraoperative frozen section for diagnosing acute invasive fungal rhinosinusitis: a systematic review and meta-analysis. *Int Forum Allergy Rhinol.* 2021;11(9):1347-1354. doi:10.1002/alr.22797.
19. Khullar T, Kumar J, Sindhu D, Garg A, Meher R. CT imaging features in acute invasive fungal rhinosinusitis—recalling the oblivion in the COVID era. *Curr Probl Diagn Radiol.* 2022;51(5):798-805. doi:10.1067/j.cpradiol.2022.02.001.
20. Akarapas C, Chaiyasate S, Chaiwarith R, Khorana J. Identifying predictors for the diagnosis of acute invasive fungal rhinosinusitis: a comprehensive analysis. *Acta Otorrinolaringol Esp (Engl Ed).* 2025. doi:10.1016/j.otoeng.2025.512294.