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TECHNICAL NOTE

Split-bolus, single-phase contrast enhanced CT: a one-stop shop for invasive fungal sinusitis

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Abstract

Contrast-enhanced magnetic resonance imaging is considered the imaging modality of choice for invasive fungal sinusitis (IFS); however, it is not feasible to perform emergency CEMRI especially in the setting of COVID-19. The CECT protocol for evaluation of suspected IFS can be modified by using split-bolus, single-phase CT as it provides an optimal soft tissue demonstration of sinonasal disease; extrasinus spread to orbit, and intracranial involvement along with simultaneous opacification of the internal carotid artery and cavernous sinus. The extent of bone erosion can also be well delineated on the multiplanar reconstructions (MPRs) in the bone window. Further a structured reporting format can help provide optimal surgical guidance in cases of IFS.

Keywords Invasive fungal infections · COVID-19 · Mucormycosis · Sinusitis · Computed tomography

For the imaging of paranasal sinuses, often non-contrast computed tomography (NCCT) is the investigation of choice [1]. However, in the context of invasive fungal sinusitis (IFS), though NCCT does delineate bone erosions and extrasinus spread, a contrast-enhanced study (CT/MRI) has the additional advantage of demonstrating the vascular complications. Contrast-enhanced MRI is considered the modality of choice for suspected orbital and intracranial complications in acute IFS. In this technical note, the authors propose utilization of split-bolus single-phase CECT and a structured reporting format for the evaluation of IFS.

Recently, there was an outbreak of COVID-19-associated rhino-orbito-cerebral mucormycosis (ROCM) in several countries, with many patients requiring surgical debridement [2, 3]. Performing CEMRI for these patients was challenging, in view of the non-availability of MRI in emergency setup, long acquisition times, and difficulty in sanitization. Hence, it was imperative to optimize CT protocols to answer most of the clinical queries relevant to management of ROCM [4].

The authors have explored the use of split-bolus single-phase CT technique to optimally demonstrate the vascular (arterial and venous) as well as mucosal extent of the disease. This protocol was performed with 1 ml/kg of non-ionic contrast medium of concentration 300 mg iodine/mL (Iohexol) administered through an 18 to 20 G cannula in the antecubital vein using a pressure injector. Two-thirds of contrast was given @ 4mL/sec followed by 30-s gap and then rest of the contrast was given @ 3.5mL/sec followed by automatic bolus tracking and image acquisition. The automated bolus triggering was applied with the circular region of interest (ROI) positioned at the level of ascending aorta and the threshold set at 100 HU. When the HU value reached 100, the scan was automatically acquired from the C2 vertebral level to the vertex in an axial plane. According

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to our protocol, images were acquired as 0.6 mm-thick sections with pitch of 1.2, field of view 140–160 mm and reconstructions performed at a section thickness of 1.0 mm with 1.0-mm spacing using bone and soft tissue algorithm. Multiplanar reformations were also completed in the coronal and sagittal plane. The details of the CT protocol have been summarized in Table 1. This delivered optimal image quality with superior demonstration of vascular structures (internal carotid artery, internal jugular vein, and dural sinuses) compared to routine CECT PNS and no loss of information of other areas (Fig. 1). The mean effective dose of this technique was approximately 1.7mSv, which is comparable to the effective dose in CECT PNS (1 to 1.2 mSv) [5].

The aim of the technique was to achieve a simultaneous opacification of the ICA along with the cavernous sinus; two of the most critical structures in the delineation of the extent of IFS. In addition, there was optimal soft tissue demonstration of the extrasinus spread of disease to orbit, infratemporal

Table 1 Split-bolus single-phase CECT PNS protocol for invasive fungal sinusitis

CT scanner	Siemens SOMATOM Definition AS+ 128 slice
Peak kilovoltage (kV)	120
Tube current (effective mAs)	151 to 167
Section thickness	0.6 mm
Pitch	1.2
Position	Supine
Scan range	From C2 vertebra to the vertex
Contrast used	Iohexol (300 mg iodine/mL)
Amount of contrast injected	1 mL/kg
Trigger	Automatic bolus tracking with trigger at ascending aorta and threshold of 100 HU
Injection technique	Two-third of the contrast injected @ 4mL/sec followed by 30-second gap and then the remaining one-third contrast injected @ 3.5 mL/sec followed by automatic bolus tracking and acquisition

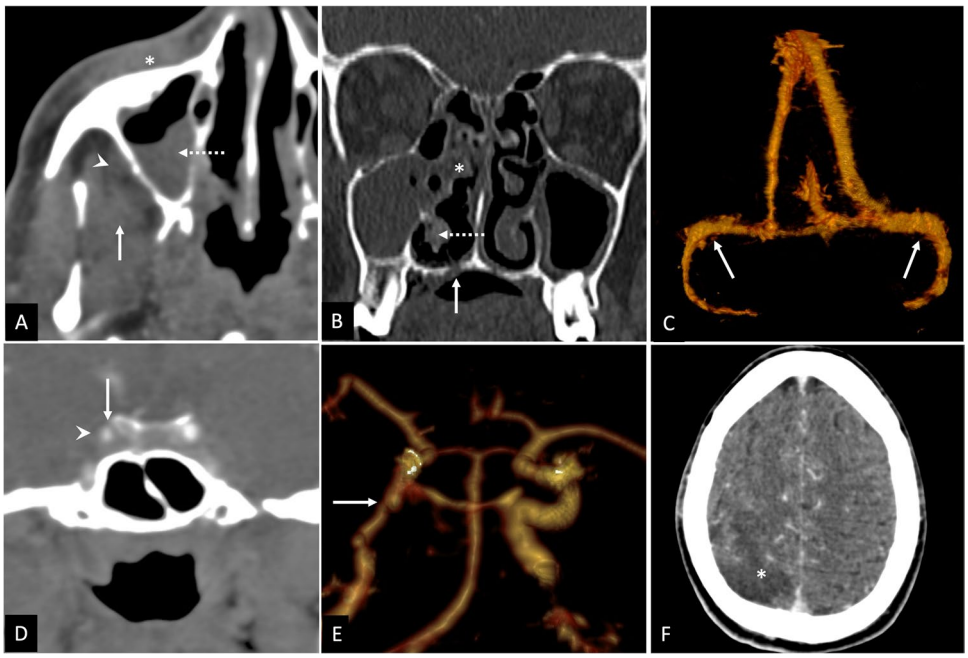

Fig. 1 Split-bolus single-phase CECT acquisition in a case of rhino-orbito-cerebral mucormycosis. **A** Axial soft tissue window shows mucosal disease in the right maxillary sinus (dotted arrow) with extension into anterior periantral fat (*), posterior periantral fat (arrowhead), and infratemporal fossa (arrow). **B** Coronal bone window reveals erosion of middle (*) and inferior (dotted arrow) turbinates. There is also erosion of hard palate on right side (arrow). **C** Volume rendered image of the dural venous sinuses reveals normal bilateral transverse and sigmoid sinuses (arrows). **D** Coronal section at level of cavernous sinuses shows bulky right cavernous sinus with filling defect (arrowhead), the caliber of right ICA (arrow) is narrow. **E** Volume rendered image shows the narrowing of the cavernous, horizontal, and vertical segments of right ICA (arrow). **F** Hypodensity suggestive of infarct seen in right high parietal lobe (*)

Table 2 Structured reporting format (CECT) for suspected invasive fungal sinusitis

Structure evaluated	Right	Left
Mucosal disease		
1. Mucosal disease in sinuses (absent/partial/complete opacification)		
• Frontal sinus		
• Maxillary sinus		
• Sphenoid sinus		
• Anterior ethmoidal cells		
• Middle ethmoidal cells		
• Posterior ethmoidal cells		
2. Mucosal disease in nasal cavity and nasopharynx (absent/present)		
• Anterior nasal cavity		
• Posterior nasal cavity		
• Nasopharynx		
Signs of invasion:		
3. Soft tissue infiltration in PPF/ITF/periantral region (present/absent)		
• Anterior periantral fat		
• Posterior periantral fat		
• Sphenopalatine foramen		
• Pterygopalatine fossa		
• Superior orbital fissure		
• Inferior orbital fissure		
• Orbital apex		
• Infratemporal fossa muscles and fat		
4. Skull base invasion		
• Anterior skull base (intact/erosion)		
• Middle cranial fossa (dural enhancement present/absent)		
5. Orbit (bone erosion present/ absent)		
• Medial wall (lamina papyracea)		
• Inferior wall		
• Superior wall		
6. Orbit (soft tissue/fat stranding)		
• Nasolacrimal duct, lacrimal sac		
• Medial orbital fat		
• Inferior orbital fat		
• Extraconal soft tissue		
• Intraconal soft tissue		
• Any abnormal signal in globe		
7. Orbital muscles (normal/soft tissue thickening)		
• Superior rectus		
• Inferior rectus		
• Medial rectus		
• Lateral rectus		
• Superior oblique/LPS complex		
• Uveoscleral thickening		
8. Optic nerve		
• Bony canal		
• Soft tissue thickening		
9. Submucosa/bone of the hard palate (intact/ erosion)		
10. Nasal septum (intact/erosion)		
11. Turbinates (any erosion/soft tissue hypertrophy)		
• Inferior turbinate		
• Middle Turbinate		

Table 2 (continued)

Structure evaluated	Right	Left
• Superior turbinate		
12. Cavernous sinus		
• Size (normal/enlarged)		
• Enhancement (homogenous/filling defect)		
• Superior ophthalmic vein (normal/dilated)		
13. ICA (normal/thrombosis/narrowed)		
• Cavernous segment		
• Horizontal segment		
• Vertical segment		
• Cervical portion		
14. IJV and venous sinuses (normal/thrombosis)		
15. Dural enhancement/brain abscess (mention site)		
• Intra axial		
• Epidural/subdural		
• Cerebritis		
16. Visualized brain parenchyma (mention site)		
• Infarct		
• Intracerebral edema		
17. Osteomeatal complex		
18. Frontal nasal duct pathway		
19. Sphenoethmoidal recess		
20. Any variant anatomy		
Impression Mention as • Rhinosinusitis with no evidence of invasion • Rhinosinusitis with evidence of invasion (mention sites- orbit/PPF or periantral region/skull base/cavernous sinus/intracranial extension)		

fossa, skull base, and intracranial involvement in the form of abscess or infarcts. The extent of bone erosion could also be well delineated on the multiplanar reconstructions (MPRs) in the bone window. Further, a structured reporting format (Table 2) was employed to reflect the extent of disease.

As with other contrast-enhanced techniques, the limitation is that it cannot be employed in patients with impaired renal functions, in whom a combination of NCCT PNS and MRI is used. However, keeping in mind that all these patients will require amphotericin B (nephrotoxic), and some patients are diabetic and young, we have kept the dose 1 ml/kg and acquisition as single-phase scan to reduce radiation exposure.

In conclusion, we have described split-bolus single-phase CECT acquisition as a potentially useful first-line imaging modality for cases of suspected invasive fungal sinusitis. The structured reporting format can provide accurate delineation of extent of disease with considerable therapeutic implications.

Authors' contributions Dr. Ashu Seith Bhalla: conception and design of work
Dr. Smita Manchanda: manuscript preparation and design of work
Dr. Kavirajan Kabilan: acquisition of data
Dr. Alok Thakar: manuscript preparation and approval of manuscript
Dr. Kapil Sikka: drafting and review of literature
Dr. Hitesh Verma: review of literature

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Data availability Data available from the corresponding author.

Code availability NA.

Declarations

Research involving human participants and/or animals The CT technique involved human participants (Institute Ethical clearance was obtained).

Consent to participate Written, informed consent was obtained from all participants.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Expert Panel on Neurologic Imaging, CFE K, Bykowski J, Aulino JM, Berger KL, Choudhri AF, Conley DB, Luttrull MD, Nunez D Jr, Shah LM, Sharma A, Shetty VS, Subramaniam RM, Symko SC, Cornelius RS (2017) ACR Appropriateness Criteria® Sinonasal Disease. J Am Coll Radiol 14(11S):S550–S559. https://doi.org/10.1016/j.jacr.2017.08.041
2. Raut A, Huy NT (2021) Rising incidence of mucormycosis in patients with COVID-19: another challenge for India amidst the second wave? Lancet Respir Med S2213-2600(21):00265–00264. https://doi.org/10.1016/S2213-2600(21)00265-4
3. Sharma S, Grover M, Bhargava S, Samdani S, Kataria T (2021) Post coronavirus disease mucormycosis: a deadly addition to the pandemic spectrum. J Laryngol Otol 135(5):442–447. https://doi.org/10.1017/S0022215121000992
4. Desai EJ, Pandya A, Upadhya I Patel T, Banerjee S, Jain V (2021) Epidemiology, clinical features and management of rhino orbital mucormycosis in post COVID 19 patients. Indian J Otolaryngol Head Neck Surg 74(1):103–107. https://doi.org/10.1007/s12070-021-02807-2
5. Bang M, Choi SH, Park J, Kang BS, Kwon WJ, Lee TH, Nam JG (2016) Radiation dose reduction in paranasal sinus CT: with feasibility of iterative reconstruction technique. Otolaryngol Head Neck Surg 155(6):982–987