Covering Letter

++To,

The Editor

Sub: Submission of Manuscript for publication

Dear Sir,

We intend to publish an article '**Imaging pitfalls and diagnostic inhibitions in various advanced head and neck imaging modalities – Diagnostician's perspective**' in your esteemed journal

This paper will be presented in **"Holography Meets Advanced Manufacturing"**- an international conference on 22.01.2023 as an invited talk. I'm submitting this conference proceeding article with the intent of exploring and documenting the area of diagnostic radiology that has not been exposed much until now. In this paper, the diagnostic inhibitions and artifacts hindering the assessment of advanced imaging, with an attempt to search for new strategies to reduce the drawbacks and improve diagnostic and treatment planning.

I confirm that neither the manuscript nor any parts of its content are currently under consideration or published in another journal.

All authors have approved the manuscript and agree with its submission to (journal name).

On behalf of all the contributors, I will act as guarantor and will correspond with the journal from this point onward.

Thanking you,

Yours Sincerely,

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IMAGING PITFALLS AND DIAGNOSTIC INHIBITIONS IN VARIOUS ADVANCED HEAD AND NECK IMAGING MODALITIES - DIAGNOSTICIAN'S PERSPECTIVE

INTRODUCTION

The advent of advanced imaging modalities have marked a great impact and advantage in diagnosis and treatment planning in the head and neck region. Being the most complex region, two dimensional imaging can be used as a preliminary diagnostic order, but complex diagnosis and treatment planning needs advanced imaging.

In the various imaging modalities of the head and neck, we can divide them into –those indicated for - i) Odontogenic pathology / hard tissue imaging (predominantly Cone Beam Computed Tomography) and ii) Non – odontogenic: Trauma and malignancy (Computed Tomography, Magnetic Resonance Imaging and Contrast imaging, PET scans).

There has been an innumerable amount of research and reviews on the advantages of imaging modalities in the head and neck region. This review is intended to explore the other side – few disadvantages and diagnostic inhibitions. This paper attempts to bring up solutions and rectifications that can give significant increase in the quality of imaging.

Cone Beam Computed Tomography:

Imaging pitfalls:

Even though CBCT is used in the case of effective imaging and treatment planning for dental implants, maxillofacial trauma and assessment of odontogenic pathologies, random artifacts greatly decrease the diagnostic ability. There are many different types of CT artifacts including noise, beam hardening, scatter, pseudoenhancement, motion, cone beam, helical, ring, and metal artifacts. Manufacturers minimize beam hardening by using filtration, calibration correction, and beam hardening correction software. [1]

Consider this case where the patient presented with chronic left-sided sinusitis. There was a root canal-treated tooth in relation to the left maxillary molar. No clinical signs were evident in regard to teeth. On an intraoral periapical radiograph, obturation seemed to be normal but revealed well-defined periapical pathology. The extent of pathology was not assessable and suspected to be foci of sinusitis infection.

On CBCT, there was beam hardening streaking artifacts (black lines) present in the volume (figure 1). On assessing the axial section at the root end-maxillary sinus floor interface, the streaking artifact had mimicked the destruction of the sinus floor and communication between the sinus and periapical pathology (figure 2), indicating a radiodiagnosis of Odontogenic sinusitis, which on a surgical exploration of root end surgery proved to be a periapical scar and intact maxillary sinus floor.

The artifacts in CBCT are similar to CT but they are more pronounced in CBCT due to the fact that heterochromatic X-ray beam present in CBCT and lower mean kilovolt (peak) energy compared with conventional CT.

Diagnostic inhibitions:

CBCT has very low soft tissue resolution. It is still used for odontogenic/nonodontogenic cysts of jaws, trauma of the head and neck.

CBCT also doesn't give us a differential density value for soft tissues and fluid. The Hounsfield unit and CBCT gray values are highly correlated, which have been proven in multiple research studies [3,4]. Recent studies have attempted at diagnosing cysts and soft tissue pathologies through CBCT gray scale values. In a study by Meryem Etöz et al (2021)identifying radicular cysts or apical granulomas using CBCT, a 7 criteria method was used. The criteria included the relationship of lesions with dental roots, periphery of the lesion, shape, darker focus in the center, root resorption, displacement in related teeth, and cortical bone perforation. In addition, the minimum and maximum grayscale values of the lesions were measured and compared. They concluded that there was no relationship between the histopathological diagnosis of lesions and CBCT gray scale values [5].

This concept can be explained by a case of swelling in the lower jaw for the past 9 months. No associated pain, numbness, or paresthesis. Clinically, distal tipping of 32 and mesial tipping of 33 were evident. On vitality testing, 42, 41, 31, and 32 were found nonvital.A clinical provisional diagnosis of the radicular cyst was given. The aspiration of the lesion revealed a straw-colored fluid. On CBCT, the pathology in the anterior mandible was evident with buccal cortical bone destruction and internal structure revealed thin septae not extending throughout the lesion (Figure 3). This posed a diagnostic dilemma of tumor or a cystic lesion. The grayscale value did not give an insight of the internal structure. The histopathological diagnosis was plexiform ameloblastoma, an odontogenic tumor with centric cystic degeneration.

Computed Tomography (CT):

Computed tomography has been widely indicated in head and neck trauma, pan facial trauma and suspected head injuries. CT has been indicated in cases of soft tissue involvement (orbital trauma); pan facial trauma hindering soft tissue; muscular function and enophthalmos.

Due to the lack of immobilization of an acute trauma patient, artifacts could be more frequent and nerve canal involvement/muscle involvement is not assessed.

In a case of zygomatic complex fracture, orbital involvement revealed linear minimally displaced fracture noted involving the left zygomatic arch, lateral wall of the left orbit. A comminuted displaced fracture involving the lateral wall of the left maxillary sinus with fracture fragments lying inside associated with hemosinus (Figure 4,5). But the soft tissue window failed to reveal further details in regard to pterygoid muscles and orbital volume. Other than the displacement and type of fractures, the extent of orbital involvement will also determine surgical treatment in this case. The most common cause of posttraumatic enophthalmos is increased orbital volume [6]. All images were taken using 5th generation mono energy CT machines with standard exposure parameters of 140 kvp 200 mA slice thickness of 0.5-0.6 mm soft tissue and bony windows.

One more case of photon starvation artefact hindering the tongue pathology and extent assessment in a computed tomography image is presented in Figure 6.

In this photon starvation or quantum mottle has greatly hindered the diagnostic quality of the image. This results from insufficient X-ray photons reaching the sensor from the patients. Even though techniques such as Tube current modulation (TCM), vendor-specific and iterative reconstruction algorithms can reduce this effect, these types of artifacts still pose considerable hindrances in diagnosis and assessment.

Streak and windmill artifacts greatly affect the scan images in CT. Windmill artifacts occur due to under-sampling along the Z axis, which usually occurs in the clavicle region and base of the skull region where drastic anatomical changes and differential Hounsfield Unit is present. A black streak artifact of the beam hardening effect greatly disrupting the diagnostic quality can be seen in Figure 7.

Magnetic Resonance Imaging (MRI):

Magnetic resonance imaging is used in head and neck imaging predominantly for ruling out craniofacial neuralgias, soft tissue extension of pathologies and malignancies of head and neck, diagnosis and treatment planning.

The most common artifact present in MRI is motion blurriness (due to long scan time) and metal artifacts.

Motion blurriness happens due to patient motion, swallowing, even breathing in the case of the head and neck region. The degree of blurriness could be in a range of minimal to extensive blur. A pediatric MRI image that has severe motion blurs and distortion of the image is presented in the sagittal section (figure 7). This kind of artifact needs a re-scan.

Metal artifacts manifest in multiple forms -, a complete signal loss may be observed around the metallic object; a rim of high signal intensity may be present around the metallic devices. Metal-induced artifacts are still a challenging aspect of imaging.Many technical methods and minor alterations have been proposed to reduce the metal-induced artifacts in MRI such as View-angle tilting method, MAVRIC (Multi-acquisition variable resonance image combination) or SEMAC (Slice-Encoding for Metal Artifact Correction) can be used inthe plane and through-slice displacements but at a cost of increased scan time; further increasing the inconvenience [7, 8, 9]

A similar example is presented in T2 axial section (figure 8). The porcelain fused to metal placed in the mandibular anterior teeth has greatly caused a no signal artifact, present anterior and extending to the level of maxillary teeth. This particularly is an inconvenient problem since the MRI imaging was done to check for any malignant spread in a recurring cancer patient. Although different technical alterations gave us a clue about the region in one plane, it was not sufficient.

Positron emission tomography:

PET-CT is used to identify, locate and assess the anatomy and function of hypermetabolic tissue. It uses 18-FDG (fluorodeoxyglucose) as a medium. The signals are then read by the system. 18-FDG PET-CT is one of the most accurate methods for diagnosing the primary HNC lesion. The lesion cannot be accessed via visual inspection with or without concurrent vision-guided biopsy [10]. The specificity of PET-CT for identifying inspection-occult oropharyngeal SCC has been measured as being over 90%. According to the NCCN, PET-CT is indicated for initial diagnosis for the following types of physical-exam occult HNC: oral cavity, supraglottic larynx, ethmoid sinus, glottic larynx, oropharynx, and maxillary sinus [11, 12].

It is widely used as a recall–review imaging modality for post-treatment follow-up cases. The false positive of PET-CT poses a major diagnostic inhibition and a major pitfall. This is the reason why PET-CT has been avoided for post-radiation and therapy patients for atleast up to 8-12 weeks (to avoid post-inflammatory effects)[13].

Even then, PET-CT might show false positive results in a review patient which poses diagnostic confusion. One such case is presented here: A 58-year-old male patient who was previously diagnosed and treated for salivary gland ductal carcinoma by surgery and radiotherapy one year before. In the review CT, brain metastasis was evident. A PET-CT was advised immediately and PET-CT revealed lung nodules metastasis also.

In addition to the signals in the metastatic nodules, a well-defined positive signal was evident in the submental region (figure 8). On clinical correlation, there was no evidence of a sign of metastasis in the submental region. This might be confused with a metastatic involvement, thus a pitfall.

This briefly compiles the artifacts and diagnostic inhibitions/restrictions in head and neck imaging. Few software has been developed to reduce metal-induced artifacts but their usage is limited and not accessible. Metal artifact reduction software (MARs) have been tested in phantom with dental implants using mono-energy (MonoE) CT images and found that a combination of MonoE and MARs reconstruction was the best method for reducing metal artifacts. This study had some major limitations [14]

Conclusion:

The advanced imaging in the head and neck region has greatly lifted the quality and efficiency of diagnosis and treatment planning of pathologies. As new techniques and software are being introduced, their availability and accessibility are considerably less. Even after advancements in imaging, the modalities have their pitfalls and diagnostic inhibitions. This paper attempts at addressing those from the maxillofacial physician and radiodiagnosis point of view, which can be used by physicists for the development of more accessible software and technical alterations to reduce them.

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IMAGES:

FIGURE 1: Beam hardening streaking artifacts(black lines) in the axial section.

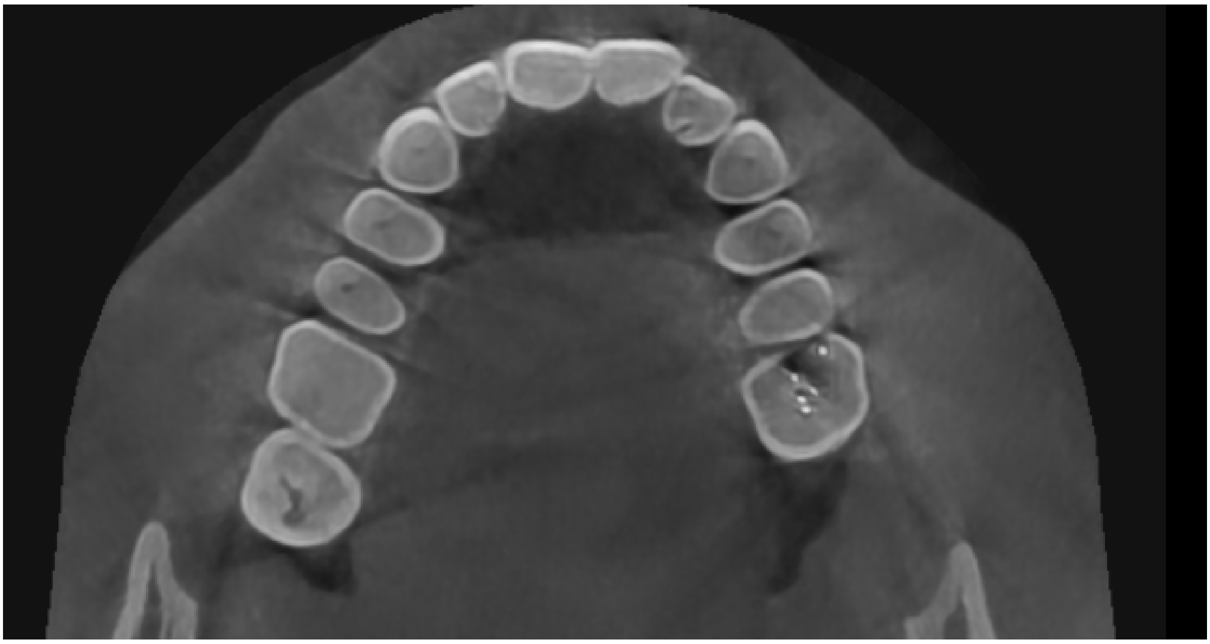


FIGURE 2: At the root end - maxillary sinus floor interface, the streaking artifact mimicked the destruction of the sinus floor and communication between the sinus and periapical pathology.

FIGURE 3: CBCT images of a clinically diagnosed cystic lesion reveals buccal and lingual cortical bone destruction and internal structure revealing thin septae that do not extend throughout the lesionwas evident. Gray scale value could not differentiate fluid/soft tissue in this case of plexiform ameloblastoma, thus posing a radiological diagnostic dilemma.

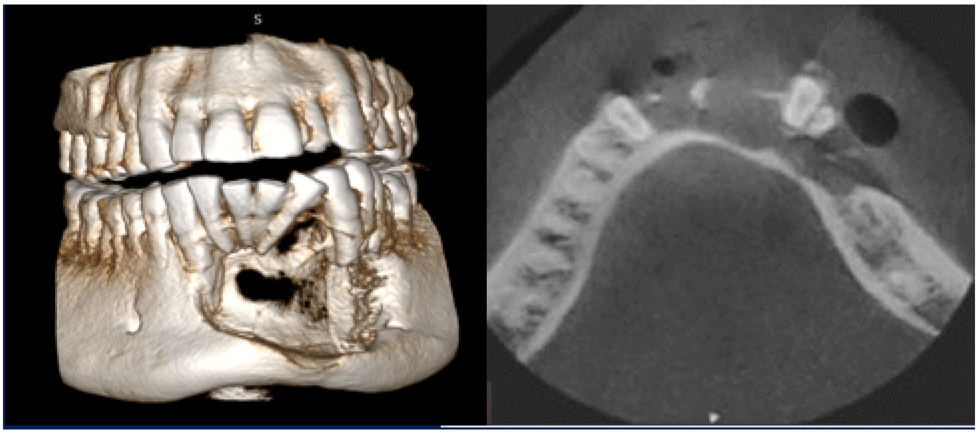


FIGURE 4: CT axial section of a pan facial trauma. A comminuted displaced fracture involving the lateral wall of the left maxillary sinus with fracture fragments lying inside associated with hemosinus

FIGURE 5: Comminuted displaced fracture involving the lateral wall of the left maxillary sinus with fracture fragments lying inside associated with hemosinus. The soft tissue window failed to reveal further details in regard to pterygoid muscles and orbital volume.

FIGURE 6: Photon starvation artifact hindering the tongue pathology and extent assessment in a computed tomography image.

FIGURE 7:

Black streak artifact of beam hardening effectevident in an axial section CT image. Present usually at the base of the skull region where drastic anatomical changes and differential Hounsfield Unit is present.

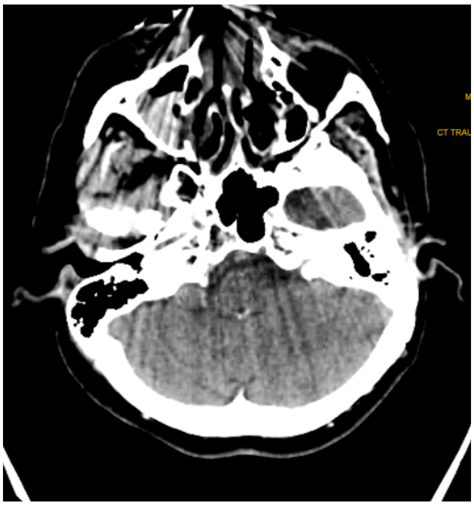


FIGURE 8:MRI image of a pediatric patient taken for the neuroimaging purpose. Severe motion blurs and distortion of the imageare evident.

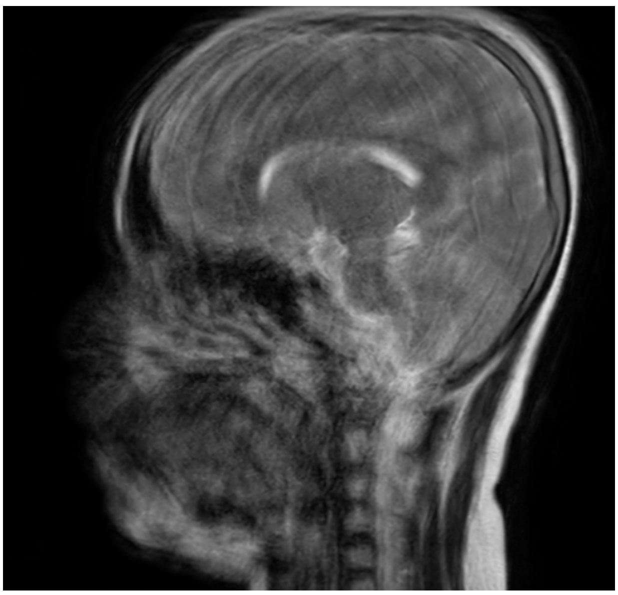


FIGURE 9: T2 weighted image – axial section showing loss of signal in anterior mandible and maxilla due to metal fused crown in mandibular anterior. This obscures the purpose of the MRI – done for identifying any malignant spread in a recurring cancer patient.

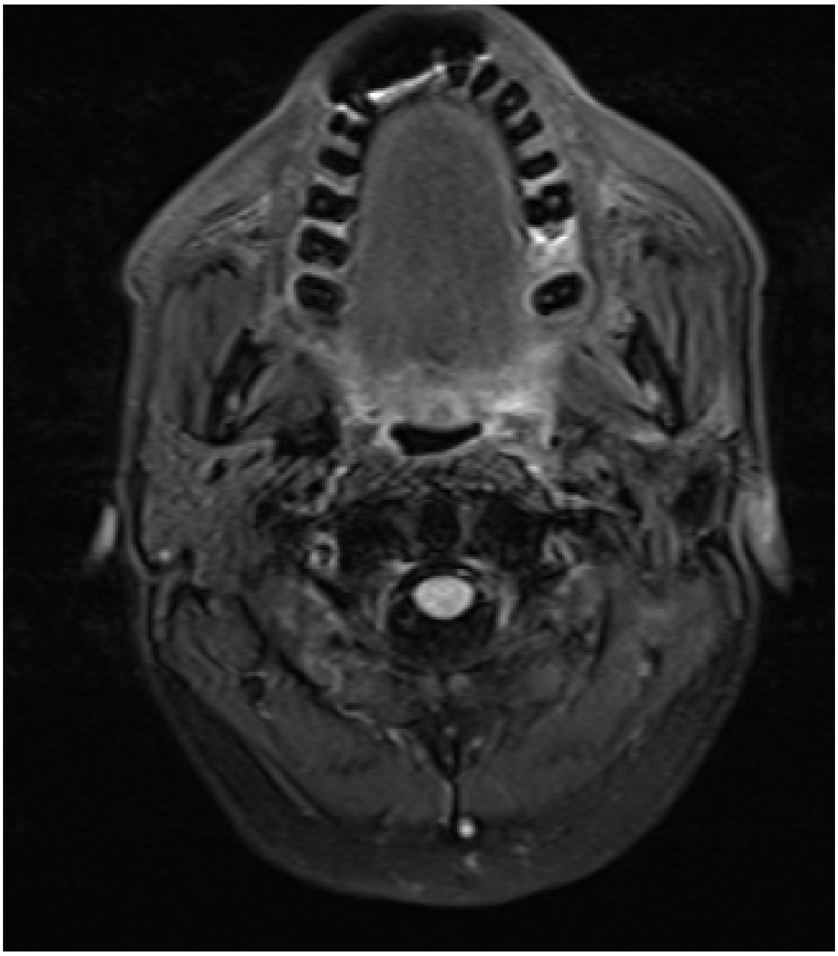
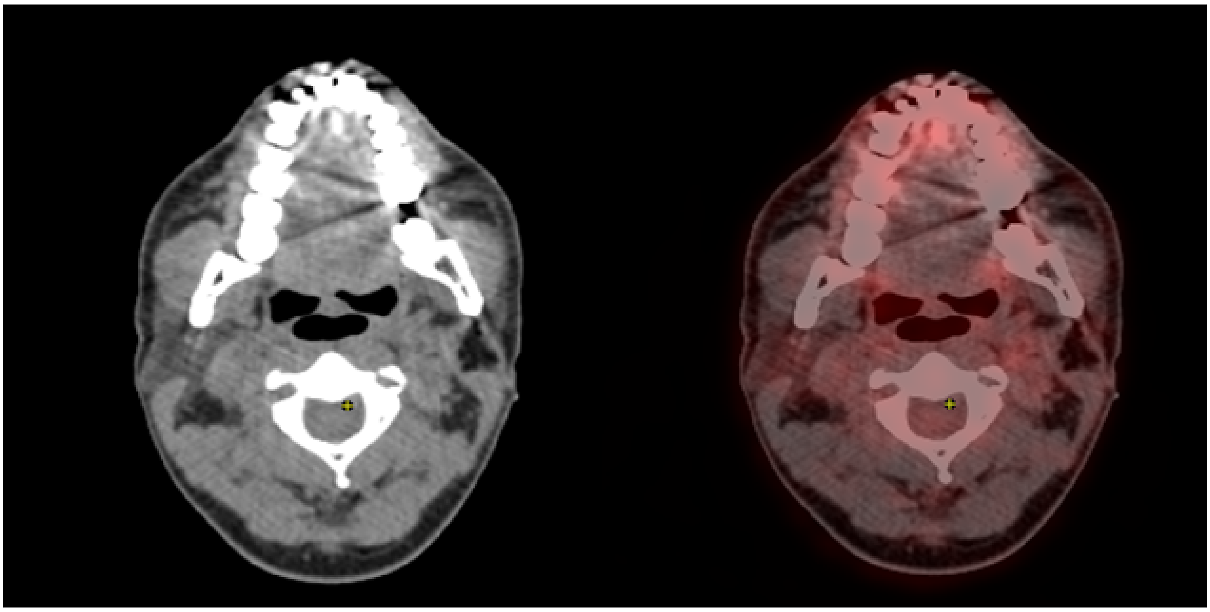


FIGURE 10: PET-CT of a 58-year-old male patient who was previously diagnosed and treated for salivary gland ductal carcinoma by surgery and radiotherapy one year before.In addition to the signals in the metastatic nodules in the lungs and brain, a well-defined positive signal was evident in the submental region which was a false positive finding.



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Conflicts of Interest: Nil.