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Review Article

Role of magnetic resonance imaging in sinonasal pathology: a review

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ABSTRACT

The last several years have seen a considerable advancement in the treatment of sinonasal diseases. The advent of minimally invasive functional endoscopic sinus surgery has led to an increased understanding of the anatomy and function of the sinonasal region, making previously inaccessible areas safe to operate in. The advancement in imaging of the sinonasal tract has been associated with the evolution of endoscopic sinus surgery. The imaging of sinonasal pathology has progressed from conventional radiographs (plain films) to computed tomography (CT) and magnetic resonance imaging (MRI). Technological advancements in CT and MRI have given a precise differential diagnosis and greater detail about the anatomical extent of sinonasal pathologies. Because the high water content of the inflammatory state causes a markedly enhanced signal on T2-weighted scans, MRI can currently distinguish between retained secretions and inflammatory responses from the mass of the tumor. The invasive lesions affecting the soft tissues outside of the sinonasal region are more easily distinguished by MRI. MRI largely took the position of CT scan for malignant sinonasal lesions due to its superior capacity to distinguish between inflammation and tumor and its increased sensitivity for intracranial extension. MRI can be more useful than a CT scan in demonstrating the degree of soft tissue abnormalities and in identifying lesions that have returned after surgery.

Keywords: Sinonasal pathology, MRI, Inverted papilloma, Sinonasal tumor

INTRODUCTION

The management of sinonasal pathologies has progressed significantly over many years. Sinonasal pathologies include sinusitis and benign and malignant lesions. There should be a proper understanding of the sinonasal function and anatomy, along with the functional endoscopic sinus surgery techniques to operate safely.[1] MRI is better imaging to evaluate the soft tissue extent than a CT scan and is particularly helpful for detecting recurrence following surgery.[2] MRI has been documented to be superior to CT scan for evaluation of soft tissue structures in the diseases of the nasal cavity.[3] The protein content of sinonasal secretions can affect the signal intensity on both T1 and T2 weighted images, resulting in various combinations of hypointense or hyperintense signals.[4] The signal intensity on T1-weighted images changes from hypointense to hyperintense as the concentration of protein in the sinonasal secretions increases.[4] Conversely, the signal intensity on T2 weighted images changes from hyperintense to hypointense once the protein concentration increases. If the protein concentration is more than 28%, the sinonasal secretions become inspissated and hypointense on both T1 and T2 weighted images.[4] Locally aggressive lesions in the nasal cavity or paranasal sinuses are better appreciated by MRI. Although CT scans usually depict bone erosion and differentiate it from expanded or remodelled bone, this differentiation is less important in the setting of aggressive lesions, when the bone is thought to have undergone invasion. This review aims to discuss the role of MRI in the management of sinonasal diseases.

LITERATURE SEARCH

Research articles regarding the role of MRI in sinonasal pathology were searched via multiple approaches. We began by doing an online search of the Scopus, Pub Med, Medline, and Google Scholar databases. PRISMA (Preferred reporting items for systematic reviews and meta-analysis) criteria were used to design a search strategy. While additional research publications were manually found from the citations, our search method recognized the abstracts of published works. The eligibility included randomized controlled trials, observational studies, comparative studies, case series, and case reports that assessed adequately. A total of 46 papers were included such as 16 case reports, 12 case series, and 18 research articles (Figure 1). The epidemiology, anatomy of sinonasal tract, and role of MRI in sinonasal pathology are covered in this article. This review paper provides a starting point from which future perspective trials can be developed, and it could catalyze more details about the role of MRI in sinonasal pathology, for which there are currently very few studies available.

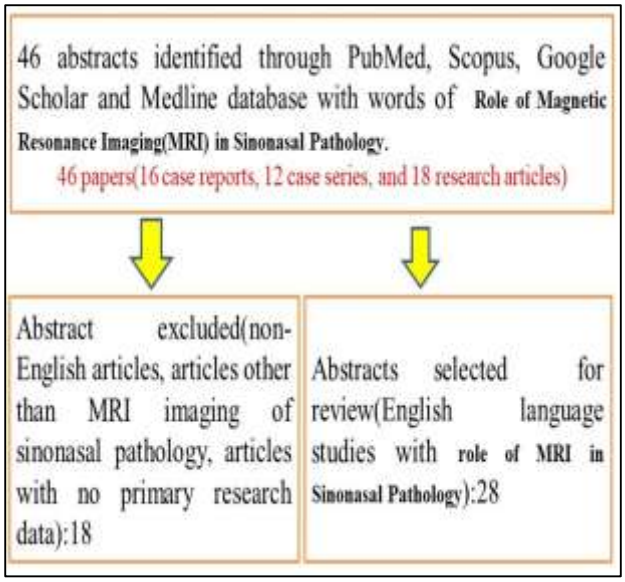

Figure 1: Methods of literature search.

PREVALENCE

The sinonasal tract plays host to a wide spectrum of pathological lesions which can be collectively called sinonasal disease.[5] The sinonasal diseases include a broad spectrum of clinical entities ranging from inflammatory lesions to tumors, both benign and malignant. Primary sinonasal tumors constitute only 3% of the head and neck malignancies and only 2% of all the malignancies.[6] Majority of the sinonasal masses are non-neoplastic. The nasal polyp is the most common non-neoplastic mass.[5] Common nasal polyps are ethmoidal and antrochoanal polyps. Rhinoscleroma and rhinosporidiosis are uncommon in the West and common in India, Sri Lanka, and Pakistan. Sinonasal polyps are a common cause of nasal obstruction in the adult age group with a prevalence of about in the general population.[7] The radiological assessment of sinonasal diseases is essential as the clinical features in these cases may not be specific. [8] The available imaging methods available include plain radiography, CT scan, MRI, and positron emission tomography (PET). MRI is needed in case of sinusitis with complications, extra-sinus extension of sinonasal malignancy and to evaluate the intracranial extension.[9] Congenital masses in the sinonasal tract are usually present in the midline and include dermoid, glioma, and encephaloceles.[10]

SURGICAL ANATOMY OF THE SINONASAL TRACT

The sinonasal tract includes the nasal cavity, maxillary sinuses, frontal sinuses, ethmoid sinuses, and sphenoid sinus.[11] These structures are lined by ciliated epithelium similar to the respiratory tract.[12] The complex anatomy of the craniofacial area may limit the routine visualization of the sinonasal tract in the diagnosis and also the ability of the surgeon to get a tumor-free margin. MRI is vital to establish the presence or absence of factors that decide the respectability such as invasion of the orbit, perineural invasion of the tumor, skull base invasion, intracranial invasion, and spread to the masticator and parapharyngeal space by the tumor.

CT SCAN VERSUS MRI FOR SINONASAL DISORDERS

A CT scan usually provides bony details and allows, a multi-planar assessment of the mucociliary drainage tract, making it an appropriate tool for preoperative planning of functional endoscopic sinus surgery.[13] However, CT has certain limitations like radiation burden.[14] It has also suboptimal soft tissue resolution. There are many clinical conditions where MRI can provide value over the conventional CT evaluation of the sinonasal areas. In comparison to a CT scan, MRI helps evaluate anosmia, fungal sinusitis and its complications, benign and malignant lesions, CSF leaks, and lesions extending into the sinonasal tract.[2] MRI can give a better depiction of the anatomy of certain important sinonasal subsites such as the olfactory structures. The absence of ionizing radiation and superior soft tissue resolution by MRI are attractive complements to CT scans. MRI is also very helpful in evaluating certain anatomical parts of sinonasal spaces, evaluation of anosmia, characterization of sinusitis complications, focal benign lesions, malignancy of the sinonasal tract, and extra-sinus pathology involving the sinonasal spaces.[2] An MRI protocol uses pre and post-contrast T1 weighted, T2-weighted and fat-suppressed sequences in different planes for optimal depiction and characterization of the sinonasal diseases. The post-contrast sequence is usually a spin echo T1 fat-saturated sequence, with a slice thickness of 3 mm.[15] MRI has few limitations such as cost, longer scan time,

inferior depiction of bony anatomy and artifacts (like dental amalgam).[13]

SINONASAL INFECTIONS

Diffuse weighted MRI is usually used for the characterization of benign and malignant lesions as well as for the detection of infections.[16] Low apparent diffusion coefficient values show restricted diffusion of water molecules in the sinonasal or surrounding tissues. So, infected lesions of the sinonasal tract may be differentiated from normal ones with this sequence. The T2 signal void should not be confused with a pneumatized paranasal sinus. Black turbinate sign (Figure 2) is a unique finding in the nasal cavity of MRI which is due to mucosal necrosis in patients with mucormycosis by angio-invasive nature.[17] The extra-sinus extension or bony erosion is highly suggestive of acute invasive fungal rhinosinusitis. [18] Obliteration of the fat at the peri-antral area is a subtle sign of invasion. The radiological findings in MRI such as peri-antral soft tissue infiltration suggest the possibility of invasive fungal rhinosinusitis with appropriate clinical settings.[19] Intraorbital invasion from ethmoidal sinus lesions is also a finding for features of acute invasive fungal sinusitis. The intraorbital and peri-antral invasion can happen without any evidence of bony erosion. In case of sinonasal lesions or infections crossing the cribriform plate, MRI is excellent for differentiating between the dural involvement from parenchymal involvement by assessing the parenchymal edema and the relationship of the lesions to the dura and gray and white matter. The contrast-enhanced coronal images of the cribriform plate and axial fluid attenuation invasion recovery (FLAIR) images are helpful in this assessment.

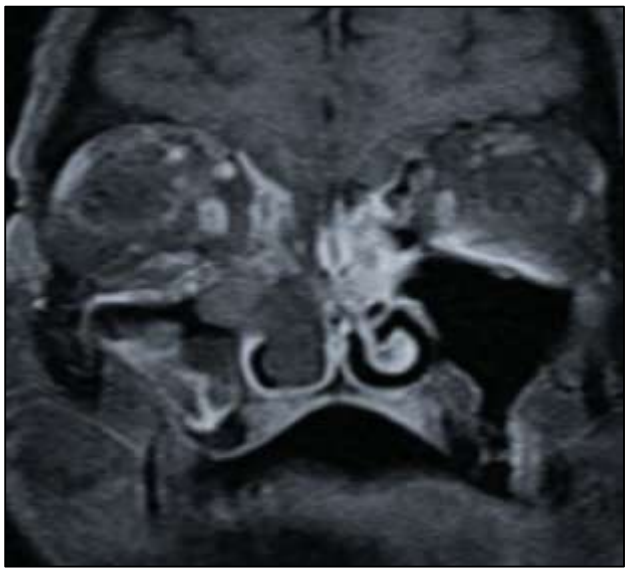

Figure 2: Contrast enhanced fat saturated T1 weighted MRI showing peripheral and central enhancement of enlarged right inferior turbinate (Black turbinate).

Sinusitis

There are two types of sinusitis: acute and chronic. Investigations beyond clinical examination are rarely necessary for acute sinusitis until complications arise.[20] The preferred imaging method for chronic sinusitis is a CT scan, which also helps to direct surgical planning by confirming the diagnosis.[21] An improved way to characterize pathology, including fluid buildup, irritated mucosa, and masses, is with an MRI. When it comes to determining the degree of sinonasal disease and identifying various secretions and masses, such as polyps and mucoceles, an MRI performs better than a CT scan.[22] Complex T1 and T2 signal intensities are present in fluid secretions based on the protein and/or fungal content. Lower protein concentrations result in the T2 hyperintensity.

Complications of sinusitis

Sinusitis may be classified into superficial, orbital, and intracranial. Orbital complications due to sinusitis are more common in the pediatric age group whereas intracranial complications are more common among young adults.[23] The use of MRI supersedes that of CT in depicting the orbital and intracranial complications.[24] Superficial complications of sinusitis include sub-galeal collections, osteomyelitis, and septic thrombophlebitis. The subgaleal collections osteomyelitis due to frontal sinusitis is usually called Pott's Puffy tumor. Contrast-enhanced MRI is very sensitive for osteomyelitis T1 hypointense replacement of marrow, with associated edema and enhancement. The intracranial complications of sinusitis are better depicted by contrast-enhanced MRI like meningitis, subdural abscess, encephalitis, intra-cerebral abscess, dural venous thrombosis, and infarction. Orbital complications often spread from ethmoidal sinusitis and include pre-septal cellulitis, orbital cellulitis, subperiosteal or orbital abscess.[25] CT scan is superior for orbital walls such as lamina papyracea and other walls. However, CT scan has lesser sensitivity of intraorbital soft tissue. The inflammations of the paranasal sinuses may spread into the orbit via small osseous vascular channels without any bony erosions.[26] Fluid-sensitive or post-contrast fat-suppressed MRI is helpful to depict early intra-orbital cellulitis seen as ill-defined edema or enhancement in intra-orbital fat. Orbital abscess shows rim enhancement and restricted diffusion, and are usually sub-periosteal.

SMELL DISORDERS

The olfactory bulb and tract, which terminate in the pyriform cortex and amygdala, are part of the intracranial component of the olfactory epithelium, which is located at the roof of the nasal cavity and receives the olfactory nerve that travels the cribriform plate.[27] The bony features surrounding the trans-ethmoidal and bulbar portions of the olfactory nerve are visible on a CT image. However, the CT scan does a poor job of defining the

olfactory nerve itself. The olfactory pathways from the olfactory bulb to the medial temporal lobe may be clearly seen on an MRI. Anosmia can develop over time or be inherited. Anosmia can be acquired due to many conditions such as rhinosinusitis, neurological illnesses, granulomatous diseases, sinonasal malignancies, and brain contusions.[28] When evaluating the complete olfactory pathway from the nasal cavity's roof to the olfactory cortex imaging is a great tool.[29] A CT scan can be used to show the basic sinonasal disease, such as rhinosinusitis, associated with anosmia; however, pathology arising from the olfactory bulbs and tracts is less well defined. When a CT scan fails to reveal congenital defects, tiny masses, or the inflammatory or infiltrative diseases, contrast-enhanced MRI becomes an invaluable diagnostic tool.

BENIGN SINONASAL PATHOLOGIES

In routine clinical practice dealing with sinonasal lesions, non-neoplastic lesions like inflammatory polyps contribute the most. The differentiation between benign and malignant lesions is often difficult in all imaging modalities and finally needs tissue biopsy for confirmation. However, in some instances, MR may play an important role in differentiating between benign and malignant lesions. CT scan's role in the differentiation of the lesions is limited, particularly if there are adjacent mucosal pathologies and secretions. Whereas, lesions on T2 weighted MRI are usually with lower signals than hyperintense mucosa and secretions and so can be depicted better. Inflammatory polyps usually display thin peripheral mucosal enhancement, whereas neoplastic polyps show internal enhancement. In the case of inverted papilloma, there is a convoluted cribriform pattern of enhancement with hyperostic origin from the lateral nasal wall.[30] Mucoceles show secretions in the paranasal sinuses due to blockage of the sinus ostia and are easily diagnosed with a CT scan, seen as an expansile paranasal sinus with soft tissue density material inside. However, these mucoceles may mimic a malignancy if associated with bone thinning and demineralization. These pathological changes can be clarified by MRI which shows nonenhancement and intact sinus wall periosteum.

Sinonasal tumors

Among sinonasal neoplastic lesions, benign and malignant tumors appear at almost the same frequencies.[31] (Tc) For diagnosis of sinonasal tumors, MRI has largely replaced CT scan because of its greater sensitivity towards intracranial extension and better ability to differentiate between neoplasm and inflammation.[32] The tumor margin is better seen in MRI due to its ability to differentiate between the tumor on one hand and retained inflammatory fluid in the paranasal sinuses and inflamed sinonasal mucosa on the other. MRI is helpful for the diagnosis of sinonasal tumors to differentiate inflammatory reactions and retained secretion from the tumor bulk because of the high water content of the inflammatory conditions leading to an increased signal on the T2 weighted scan.[33] The majority of the sinonasal tumors are highly cellular, and so, they have intermediate signal intensity on T2-weighted images.[34] Suspicious localized lesions with coexistent squamous cell carcinoma or the malignant transformation are better assessed on the MRI.[35]

MRI in inverted papilloma

Inverted papilloma usually arises from the central part of the middle meatus, so involving the osteomeatal complex. MRI has advantages over CT scans in defining the extent of the inverted papilloma rather than making the diagnosis. This is very important to determine the surgical approach in inverted papillomas.[36] MRI (T2 weighted) is accurate in differentiating papilloma (intermediate signal) from adjacent inflammatory changes (very high signal). The papilloma shows homogenous enhancement with intravenous gadolinium. One study concluded that there is no distinct signal intensity to enhancement features to differentiate foci of co-existent squamous cell carcinoma from inverted papilloma, however, it has been thought that malignant neoplasm enhances more homogenously than benign lesions. The frank destruction of the paranasal sinus walls due to malignant changes is less easy to identify by CT scan, but the invasion of the tumor into the nasopharynx and orbit is optimally shown by unenhanced T1 or enhanced T1 weighted sequences with fat suppression. Intracranial invasion by inverted papilloma is very rare but involvement with squamous cell carcinoma is more common and contrast-enhanced MRI is superior to a CT scan for demonstrating and differentiating the dural and pial infiltration when the anterior skull base is invaded. The signal intensity of the inverted papilloma is not as high as that of the benign inflamed mucosa or obstructed secretions. The solid-enhancing type of inverted papilloma may differentiate it from inflammatory mucosa and/or mucoceles, which have peripheral rims of enhancement.[37]

SINONASAL MALIGNANCY

Perineural neoplasms

Perineural invasion is an adverse prognostic indicator for staging the sinonasal malignancy. Contrast-enhanced MRI is the choice of imaging for the perineural spread of tumors. In the perineural spread of the tumor, MRI shows neural enhancement with thickening and irregular margins, obliteration of the fat in the pterygopalatine fossa and foramina of the skull base, enhancing soft tissue in the cavernous sinuses and Meckel caves. There is also denervation atrophy of the innervated muscles. The identification of the perineural spread by the MRI may upstage the lesion and alter the radiation treatment field.

Extrinsic pathology encroaching the sinonasal tract

Extrinsic pathologies may invade the sinonasal spaces. This may occur through the skull base, nasopharynx, oral cavity, or the masticatory space. Because of better soft tissue resolution, MRI helps assess the trans-spatial lesions and determine the site of the lesion. MRI is helpful to exclude the intracranial origin of the sinonasal mass. The intracranial tumors commonly spread to the sinonasal cavity are schwannomas, meningiomas, and pituitary adenomas.[38] Patients with intracranial tumors extending into the sinonasal area may manifest with headache, epistaxis, CSF leakage, and nasal blockage.

Mapping of the sinonasal malignancies

Generally, a CT scan needs enough cortical mineralization to depict the bone walls.[39] However, the important obstacle to inflammatory or neoplastic infiltration is the periosteum rather than the mineralized bony wall.[40,41] On a CT scan, a lack of mineralization might be mistaken for a breach and lead to incorrect staging. The periosteal lining can be seen on an MRI as a continuous hypointense line that reflects signals from the surrounding periosteal layers and cortical bones.[42] The Absence of a hypointense line is a feature of periosteal invasion and involves the adjacent anatomical regions such as orbits and the brain. Malignancies originating from the ethmoidal and frontal sinuses may spread to the anterior cranial fossa. Pathology inside the sphenoid sinus may spread superiorly into the central skull base, or superior-laterally to the middle cranial fossa. Contrast-enhanced MRI can show the dural invasion of the sinonasal malignancies, particularly when there is dural nodularity or dural thickening of more than 5mm whereas smooth thin linear enhancement supports the reactive changes.[43] Sinonasal tumors are advanced to the T4b stage by dural invasion, which has an impact on treatment and prognosis. The anterior cranial fossa may get infected with tumors that originate in the frontal and ethmoidal sinuses. Sphenoid sinus lesions can spread superiorly into the base of the central skull or superior-laterally to the middle cranial fossa.

Olfactory neuroblastoma

Olfactory neuroblastoma is a neoplasm originating from the olfactory neural crest epithelium. It is usually located at the superior nasal vault and may be advanced with invasion into the anterior skull base and brain. The Kadish staging is used for olfactory neuroblastoma where stage A includes a lesion confined to the nasal cavity, stage B involves the nasal cavity and one or more paranasal sinuses, whereas stage C tumors extend beyond the nasal cavity and paranasal sinuses. On MRI, the olfactory neuroblastoma is of intermediate signal intensity on T1-weighted imaging and intermediate to high signal intensity on T2-weighted imaging and enhanced heterogeneously with gadolinium. Tumor calcifications are not uncommon. The most important criteria for respectability is intracranial invasion. MRI helps in the distinction between the extradural tumor, dural invasion, or parenchymal brain invasion. The presence of peritumoral cysts capping the intracranial part of the tumor suggests a diagnosis of olfactory neuroblastoma.[44]

CEREBROSPINAL FLUID LEAK

Cerebrospinal fluid (CSF) leak may occur due to congenital causes and acquired causes. Cephalocele is one of the congenital causes; acquired causes include osseous dural defects and post-traumatic/surgical conditions. A positive beta 2 transferrin test on the nasal secretions indicates the presence of CSF. Imaging can be used to pinpoint the location of the CSF leak and direct surgical procedures. Gold standard imaging is CT cisternography but is an invasive study. Cephalocele is the herniation of intracranial contents via the skull base defects and varies its site and contents (meninges with or without neural elements). MRI often validates the diagnosis and provides information on the anatomy of the herniated tissues, preventing needless and perhaps disastrous samples and assisting with surgical treatment.[45]

Limitations

MRI has drawbacks of its own, including high cost, extended scan times, poor representation of skeletal structure and artifacts like amalgam fillings.[46] It's critical that radiologists and physicians are conversant with clinical situations in which MRI may be useful in addition to reducing necessity for pointless MRI examinations.[46]

CONCLUSION

Routine imaging does not allow to differentiate between various sinonasal pathologies. MRI is very useful imaging in selected conditions of sinonasal pathologies. The absence of ionizing radiation and superior soft tissue resolution are provided by MRI for evaluation of sinonasal pathology. MRI has a superior role in the staging of sinonasal tumors, assessment of anosmia, complications of sinusitis, and evaluation of certain niche anatomical regions like anterior skull bases, olfactory cleft, nasal vestibule, etc.

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