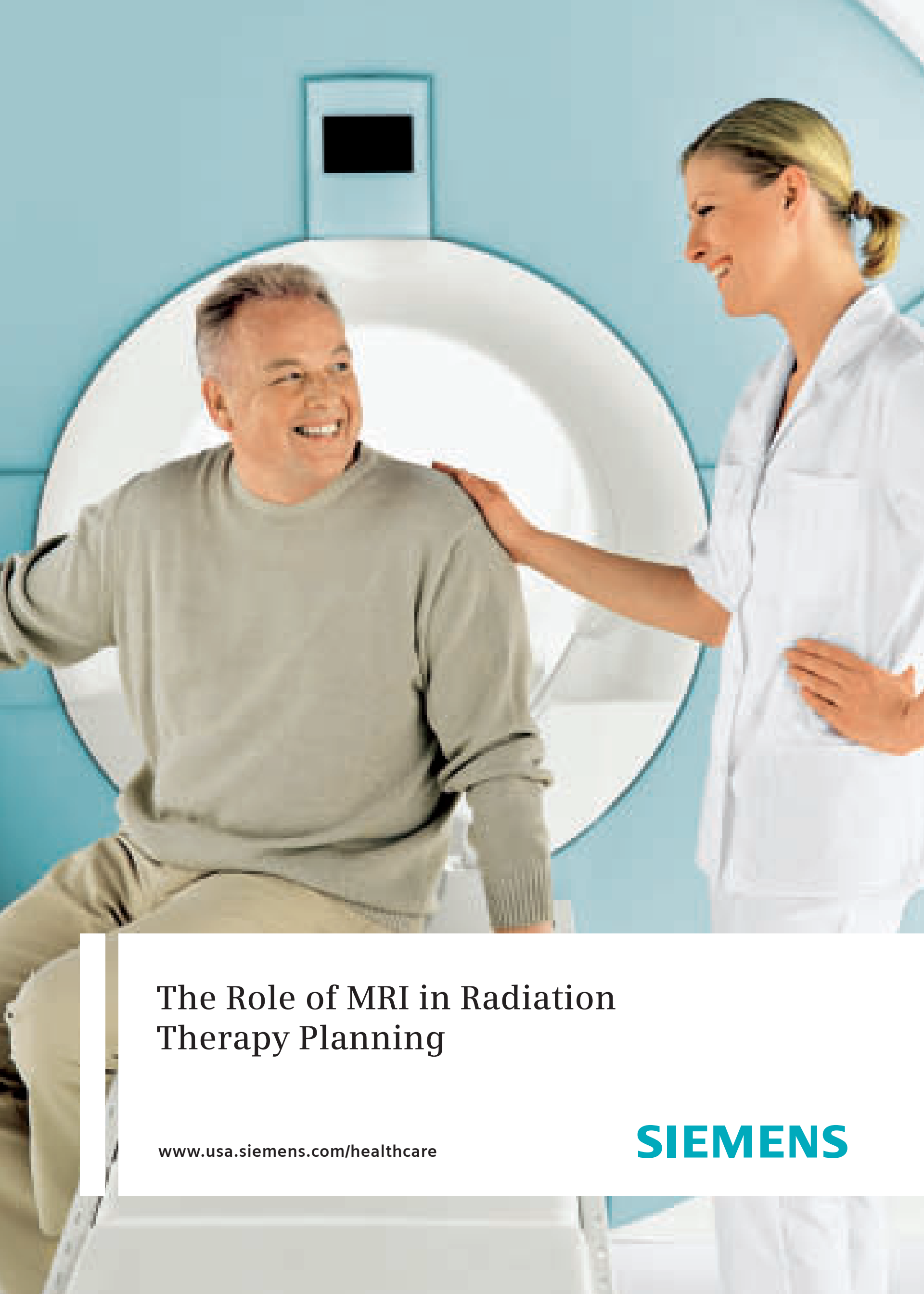

The Role of MRI in Radiation Therapy Planning

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Table of Contents

The information presented in this primer is for illustration only and is not intended to be relied upon by the reader for instruction as to the practice of medicine. Any health care practitioner reading this information is reminded that they must use their own learning, training and expertise in dealing with their individual patients. This material does not substitute for that duty and is not intended by Siemens Medical Systems to be used for any purpose in that regard.

The drugs and doses mentioned herein are consistent with the approval labeling for uses and/or indications of the drug. The treating physician bears the sole responsibility for the diagnosis and treatment of patients, including drugs and doses prescribed in connection with such use. The Operating Instructions must always be strictly followed when operating any MRI System. The source for the technical data is the corresponding data sheets.

1. Introduction

Shyam Paryani, Mary Koshy

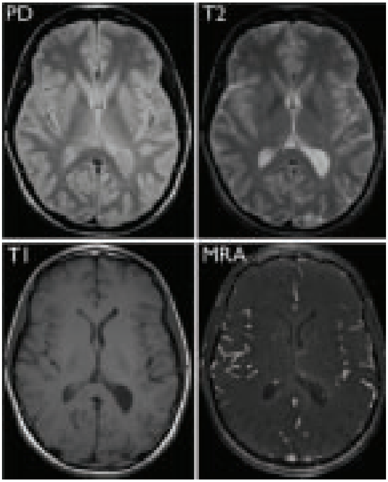
Magnetic resonance imaging (MRI) is a well established diagnostic and research tool that has numerous uses in multiple areas of medicine. Its popularity is based on its ability to provide excellent soft-tissue delineation and multi-planar imaging of different areas of interest.

MRI is based on the interaction of magnetic properties of hydrogen with both a large external magnetic field and radio waves, which results in the production of highly detailed images of the human body.

Purcell and Bloch first described the property of NMR (Nuclear Magnetic Resonance, the original name for MRI), for which they received the Nobel Prize in 1952.[1, 2]

Since its inception, NMR was widely used for the analysis of chemical composition and structure. In 1973, Lauterbur and Mansfield described its use for determining physical structure.[3, 4] Subsequently, MRI has been widely used for many biomedical, chemical, and engineering applications. Despite the change in name, MRI still uses the basic principles of NMR for image generation.

MRI has a vital role in radiologic imaging of different pathologic disorders, wherein the major aim is to develop radiologic imaging markers that can be used for noninvasive prediction of disease and response to treatment. MRI derives image contrast from hydrogen spin density in water and fat and from the MR relaxation parameters T1 and T2. Additionally, the use of an intravascular contrast agent (e.g., gadolinium) typically reveals many of the physiologic changes in tissue that are associated with the underlying disease processes.[5]



One of the major advantages offered by MRI is the ability to manipulate image contrast by using a variety of selectable parameters that have an impact on the type and quality of the information being obtained. Information about the vascular status of a lesion for example, can be combined with the intracellular environment of the tissue structures to assist a physician in making a diagnosis or monitoring a treatment regimen.[5]

In the field of oncology, MRI can help visualize both the presence and the extent of underlying pathology with outstanding anatomical details. The boundaries of the tumor can be clearly defined and target tissues can be clearly delineated from healthy surrounding tissue. We have decided to explore the use and limitations of MRI with respect to radiation oncology and treatment planning. What follows is a primer of what we have learned over the last year. We hope you find this information useful in the care of your patients.

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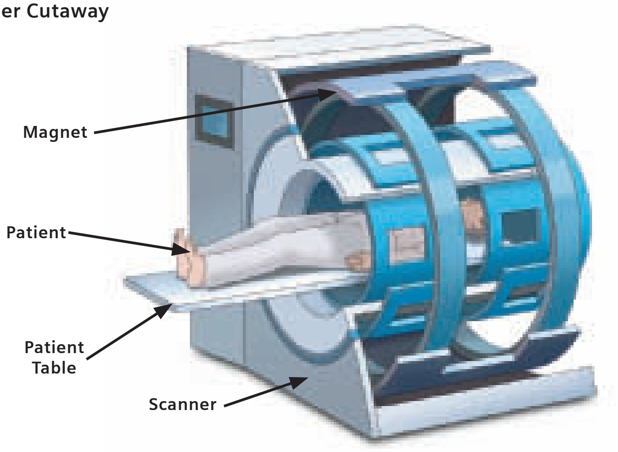
2. Basic Principles of MRI

Amar Patel, Michael Pentaleri, and Larry Wilf

MRI Scanner Cutaway



MR images are acquired from an application of nuclear magnetic resonance, also called NMR. The MR images are dependent upon the absorption of radiowaves by hydrogen nuclei, 1H (a single proton and no neutrons), wherein hydrogen has an intrinsic nuclear spin that is present in sufficient quantities to enable the production of a useful image of the human body. Many of the protons within the human body are found in the nuclei of water.

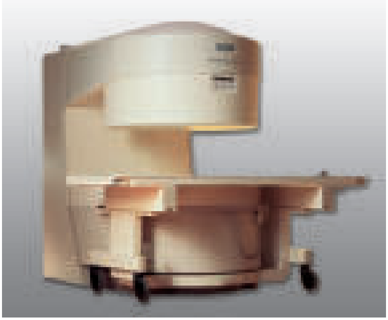
The generation of MR images is a result of the sophisticated interaction between the electronic components, radiofrequency (RF) generators, coils, and gradients that interface with a computer for communication between the different electronics. The magnet, gradient coils, and radiofrequency (RF) coils present in the MRI scanner are the basic parts that help form an image.[1]

Magnets

The magnet is used to form the “external” magnetic field in which the patient or object is placed. There are three types of magnets that can be used in MR imaging: permanent, resistive, and superconducting. Superconducting magnets are the most commonly used magnets in recent MRI scanners. Field strengths of 0.5–3 Tesla can be obtained for common clinical applications. The use of superconducting magnets in the 1.5 to 3.0 T range offer better image contrast due to the energy exchange between the protons (water) and their environments.[1]

Permanent magnets are based on the ferromagnetic properties of metals such as iron, nickel, etc. The configuration of the permanent magnets vary with that of the other two types of magnets wherein the main magnetic field (B_0) is perpendicular to the object or subject of interest. While the earlier magnets were quite heavy (weighing about 5-100 tons), the newer versions are much lighter. Permanent magnets do not require any cooling or power to run, which is considered advantageous in comparison to other magnets. However, these magnets cannot be switched off in case of any emergency. Additionally, they are also known to have less magnetic field homogeneity,[2] resulting in images of lower quality.

On the contrary, resistive magnets can be turned on and off and are based on the principle that a magnetic field is induced around a wire when electric current flows through the wire. However, these magnets require cooling and power supply. Other disadvantages include poor homogeneity and increased electrical costs. Field strengths of 0.1 to 0.3 T are generated with the use of resistive magnets.[2, 3]



The concept behind superconducting magnets is that when metal conductors are cooled down to near absolute zero, electric current can be used to generate high magnetic fields without the formation of excess heat. Most of the clinical systems being used in the field of MRI have superconducting magnets that are able to generate field strength of 1.5–3.0 T.[2, 3]

Gradient Coils

Gradient coils are used for localization of the MR signal in three dimensions (x, y, and z). In general, the gradient coils are electromagnets that can predictably perturb the main magnetic field along an axis when energized. The gradients are considered highly essential for maintenance of the imaging quality and image formation.

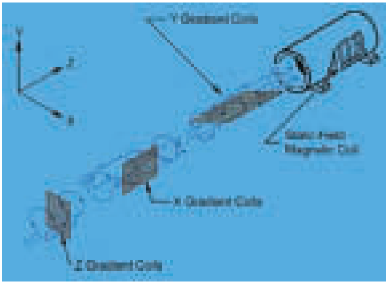


Figure 1. Typical gradient coil set used for localization of the MR signal. These coils are placed concentrically to each other within the magnet and are used sequentially for three-dimensional localization of the gradients to create images from the MR signal. Source: Jacobs MA, Ibrahim TS, Ouwerkerk R. MR Imaging: Brief Overview and Emerging Applications. Reprinted, with permission, from RadioGraphics. 2007; 27:1213–1229.

RF Coils

The radiofrequency (RF) coils serve two main purposes. Transmitting the RF energy to the tissues that need to be imaged is one of the purposes and the other is receiving the RF signal that is induced by the tissues in response to the transmitted energy. These coils are placed in a concentric manner. Several different types of RF coils are generally used in the MRI scanners. While some are used only to transmit or receive the RF energy, others may be used in combination to both transmit and receive the signals.

The configuration of the RF coils can be varied according to the needs. Surface, saddle, quadrature, or phased arrays (multiple elements) are some of the designs usually employed. The RF coils can be designed according to the purpose or to suit the organ being scanned.

The signal generated as a response to the RF transmitter coil is picked up by the RF receiver coil and is transmitted to an RF amplifier. The amplifier transfers the RF signal to the main computer for image reconstruction.[1]

Image Generation

MR images are produced by a complex interaction of the magnetic field and protons within the patient. The magnetic field causes the alignment of protons (i.e., hydrogen nuclei within the water and lipid molecules in tissues) along the main magnetic field. The application of an RF pulse (with the use of RF coils) at a specific frequency causes these protons to "flip" out of their alignment with the magnetic field. Subsequently, the protons begin to relax and align themselves back to the main magnetic field. The spinning protons during the process of relaxation produce a radiofrequency electromagnetic signal, which can be detected by the receiver coil and amplified. The end result is recorded as data by the computer attached to the magnet. This data is processed using mathematic algorithms (primarily Fourier transformations) and converted to an MR image.

There are several factors that determine the depth and quality of the image including the strength of the magnets, the frequency of the RF coils, hydrogen proton concentration in the tissues being examined, timing and strength of the radiofrequency pulses, and the algorithms used to process the data.[1, 4]

Contrast

The contrast of an MR image can be altered by varying the repetition time (TR) between radiofrequency cycles, and the time to sample the signal, the echo time (TE). Such a process is also referred to as weighing the image. Three of the basic types of weighing used in clinical practice are: T1, T2, and proton density weighting. T1 weighting is good for obtaining the anatomical detail while a T2 weighed images give a high signal for tissues with a higher content of free unbound water and are essential in imaging inflammation or neoplastic tissue. [4]

MR images can be obtained in any plane such as axial, coronal, parasagittal etc., depending on the clinical indication. MRI has become a critical diagnostic tool in imaging in oncology because of its multiplanar capability, lack of ionizing radiation, and advanced processing systems.[4]

More in-depth tumor localization and nodal staging are possible due to the inherently superior soft-tissue contrast resolution of MRI in comparison to CT. In urinary bladder carcinoma for example, MRI offers more accurate overall staging of the primary lesion because of its greater ability to detect perivesical spread and invasion of adjacent local structures. Additionally, it is also considered superior for the assessment of penetration of the lesion through the deep muscle layers of the bladder.[5, 6]

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3. Physics and Treatment Planning

Adam Elliot, Mary Koshy, Steven Lu, Scott Simmons, Tracey Simmons

There are several factors that contribute to MRI. Some of the major ones include the following:

- Quantum properties of nuclear spins
- Radio frequency (RF) excitation properties
- Tissue relaxation properties
- Magnetic field strength and gradients
- Timing of gradients, RF pulses, and signal detection

The hydrogen atom is the only major species that is MR sensitive and is also the most abundant atom in the body. Because of this, essentially all MRI is hydrogen (proton) imaging. In general, spinning charged particles such as hydrogen ions generate their own little magnetic fields. Such particles tend to line up according to the magnetic field lines when placed into an external magnetic field. These spinning particles have their own angular momentum, which resists attempts to change the spin orientation.[1]

Spin refers to a magnetic moment that results from or is associated with a "current loop" created by a spinning charged particle, where the charge resides on the outer surface of the particle. This current can be quantified as:

$$I = q * v/2\prod r$$

With q the charge on the particle, r the radius of the particle, and v the tangential velocity of a point on the surface of the particle.[2]

The energy difference between the two alignment states depends on the nucleus of the spinning particle or atom.

In magnetic resonance, the characteristic frequency depends upon the characteristics of the spin under investigation and the strength of the applied magnetic field as:

$$f = \gamma B_0$$

Where gamma (γ) is the gyromagnetic ratio, a fundamental constant for a given spin, and B_0 the field strength. This famous relationship is known as the Larmor equation.[2]

According to the Larmor equation, the precessional frequency is equal to the product of the strength of the external static magnetic field (B_0) and the gyromagnetic ratio (γ). Thereby, an increase in B_0 will subsequently increase the precessional frequency. Conversely, a decrease in the B_0 will decrease the precessional frequency.

When a subject or object is placed into a magnetic field, the protons align to the main field (B_0) in the z direction and the Larmor frequency is field dependent. Localization of the MR signal is obtained by applying a gradient that produces a controlled linear spatial variation of the B_0 magnetic field (z direction), which creates small perturbations to the field in three directions (x, y, and z).[1]

The linear dependence of the magnetic field B_i depends on the location within the magnet and is defined by the following equation:

$$B_i = B_O + G \cdot r_i$$

where, B_i = the magnetic field at r_i and G is the total gradient in the chosen direction. For example, the linear dependence in the x direction is as follows:

$$B_x = B_O + G \cdot r_x$$

The mechanism for contrast in an MR image is governed by the application of an RF pulse and, more important, the relaxation times of the tissue of interest, in particular T1 and T2. After the RF pulse, an MR signal is created. This MR signal is defined by a phenomenological equation called the Bloch equation. The Bloch equation can be solved for T1 and T2 for a spin-echo sequence:

$$M(t) = M_O \left(1 - e^{\left(-\frac{t}{T1}\right)}\right)$$

And

$$M_{xy}(t) = M_{xy} e^{\left(-\frac{t}{T1}\right)}$$

These equations show that MR pixel intensity is proportional to the number of protons within the tissue, T1, and T2.[1]

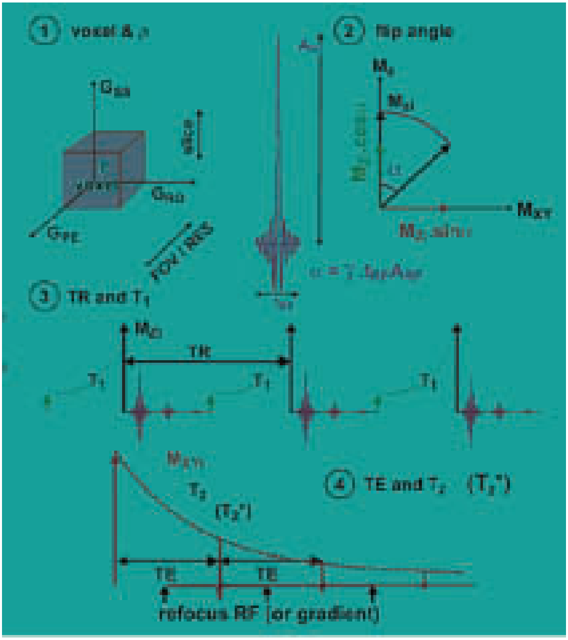

Figure 2. Four basic factors determining the pixel brightness of an MR image. 1, Application of each gradient for a voxel density (ρ) for localization of the MR signal. RES=resolution. 2, Use of the RF pulse to invert the magnetization signal within the voxel (ρ). Note that α=time of the RF pulse and area covered by the pulse (e.g., the strength of the pulse). M=magnetization. 3, Graphic representation of the relaxation parameter T1. TR=repetition time. 4, Graphic representation of the relaxation parameter T2. TE=echo time. Source: Jacobs MA, Ibrahim TS, Ouwerkerk R. MR Imaging: Brief Overview and Emerging Applications. Reprinted, with permission, from RadioGraphics. 2007; 27:1213–1229.

While T1 weighting of the image is dependent on the amount of TR in milliseconds between the slice selection and RF pulses and the field strength, T2-weighted images are dependent on the amount of TE in milliseconds. T1 is the longitudinal relaxation time. This occurs after application of a 180° RF pulse, where the magnetization vector is inverted. In contrast, T2 is called the transverse relaxation time and pertains to a decay process. The TE is defined as the time of the echo. This occurs after a short waiting period (TE/2), in which a 180° pulse in a spin echo is applied and an echo is formed.[1]

MR Use in Treatment Planning

MRI has been used for the diagnosis and monitoring of a wide range of conditions and treatments.

MRI offers several advantages over other imaging techniques with particular reference to computed tomography (CT). As known widely, the MRI is devoid of harmful radiation when compared to CT scanning. This is of particular use in malignant tumor cases where repeated imaging may be necessary to monitor the progress of the disorder. Additional advantage is offered by the ability to directly obtain images in planes other than axially, as with CT. The high contrast resolution noted with MRI over CT offers better clarity and easier diagnosis and demarcation of soft tissues or lesions in most situations.

Tumors tend to be more easily recognized because of their increased water content, which offers relatively long T1 and T2 when compared with normal soft tissue. Clear images can be obtained with T1 weighting, T2 weighting, or a combination of both. Tumors on T1 weighting appear dark due to low signal intensity while on T2 weighted images, they look bright as they have higher signal intensity.[1]

Currently, MRI is used for:
- delineation of soft tissues
- to determine extent and spread of disease
- staging of different tumors
- obtaining functional and metabolic information
- monitoring the response to treatment[2, 3]

Some of the newer applications of MRI have been discussed in the following pages.

MR imaging is generally combined with other imaging modalities such as ultrasonography for better diagnosis of different conditions associated with the breast, upper and lower extremities, liver, and uterus.[2]

Newer techniques of diffusion-weighted imaging (DWI) and perfusion-weighted imaging were initially used in neurologic applications, such as brain tumor imaging. DWI has additionally been used in other areas to diagnose metastatic disease, monitor the response to treatment, and/or for characterization of lesions in organs such as the liver, uterus, and breasts.[4, 5]

Proton spectroscopy is an offshoot of the original techniques of NMR where specific compounds with a tissue or solution can be delineated through their signal characteristics. The application of this technique, which was generally limited to identification of pathologies related to the brain is now being used in identifying conditions associated with other organs such as the liver, breast, prostate, and soft tissues. Information on intracellular metabolites, such as choline, creatine, citrate, N-Acetylaspartate, and lactate that are known to change in different pathologic conditions, can be obtained with the use of this modality. Some of the common examples where the estimation of these metabolites can be helpful include: brain tumors (N-Acetylaspartate levels decrease with a subsequent increase in choline), breast tumors (presence of a choline peak is considered to be suggestive of malignancy) and prostate (presence or absence of citrate and/or choline is generally determined to identify underlying lesions).[6, 7]

An increase in intracellular sodium concentration has been considered as a good indicator of compromised cellular membrane integrity or impaired energy metabolism. 23Na (Sodium) MRI has been used to identify lesions and conditions associated with the organs such as the brain, breast, heart, kidney, and the uterus.[8, 9]

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4. CNS/PEDS

Mike Olson, Sonja Schoeppel, Doug Johnson, Cynthia Anderson

The primary malignant central nervous system (CNS) tumors account for about 2% of all cancers with about 43,800 new cases of benign and malignant brain tumors being diagnosed in the U.S. every year. Malignant primary tumors of the brain have been considered as the leading cause of death from solid tumors in children. In the case of adolescents and adults aged 15 to 34 years, such tumors are reported as the third leading cause of death from cancer.[1]

The application of MRI for the diagnosis of primary and secondary tumors of the CNS has increased with emerging innovations in the imaging techniques and contrast media. The initial recognition of MRI as a useful modality was made with regards to the diagnosis of posterior fossa lesions, wherein CT images were frequently noted to be degraded by artifact from bone. An additional benefit offered was the ability to obtain images in the sagittal plane.[2]

MRI thereby plays an important role in diagnosing tumors related to the CNS in both adults and children wherein early diagnosis can have better outcomes. A need for clearer delineation of normal and diseased tissues is also required to offer better care.

In cases where the presence of brain tumor has to be confirmed, the use of MRI is considered to offer a more sensitive image in comparison to CT. Brain tumors in general appear as mass lesions on T1 weighted scans. These masses may or may not be enhanced when a contrast medium is used. In the case of T2-weighted images, a signal abnormality that is suggestive of tumor as well as the presence of vasogenic edema may be noted.

MRI perfusion scans are beneficial in identifying the increased blood flow in the tumor region while diffusion scans can reflect reduced water movement. However, it should be remembered that while MRI can provide vital clues about the tumor process, biopsy or histological studies are necessary for confirmation of the lesion.[1]

MRI is considered the imaging modality of choice for the evaluation of masses related to the spinal cord. In general, unenhanced T1- and T2-weighted images in the sagittal plane and contrast material enhanced T1-weighted images in the sagittal and axial planes are to be included while initially evaluating the lesions of the spinal cord. The solid portion of an intramedullary neoplasm can be effectively identified with the use of contrast-enhanced images. Additionally, such images are also useful in identifying other associated cysts or presence of other features that can modify the diagnosis. Such images can be beneficial even post-operatively wherein the use of a contrast agent can easily identify recurrent lesions.[3-5]

On detecting a tumor, importance must be given to determine its location, extension, size, and intrinsic signal characteristics and enhancement pattern. The findings can be correlated with the clinical characteristics to arrive at a differential or conclusive diagnosis. Most of the tumors appear either as hypointense regions on T1-weighted images and hyperintense regions on T2-weighted images. The use of a contrast agent is advised whenever the presence of a brain tumor is suspected. The contrast agents accumulate in the regions where the blood brain barrier has been disrupted by the tumor and make the tumor clearly visible on enhanced images.

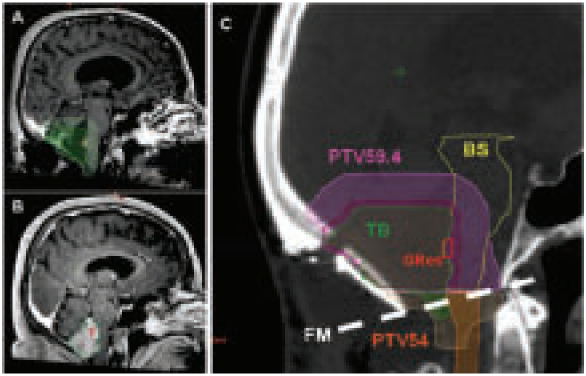

Figure 1: Patient with 4th ventricular Grade 2 ependymoma, near totally resected. Post-op (A), and pre-op (B) thin-cut volumetric T1 post-contrast sequences were fused to the treatment planning CT (C) obtained at simulation. Shown in (A) and (B) is the gross residual disease (red) and pre-op tumor volume (green). In (C): brainstem (BS, yellow) spinal cord (orange), gross residual disease (GRes, red), Tumor bed (TB, green) are shown, as are the PTV 59.4 (pink) and PTV54 (orange) divided by the foramen magnum (FM, white, dotted).

Some of the individual conditions related to the CNS and benefits of MRI in these conditions have been elaborated below.

Metastatic Tumors

The identification of intracranial metastasis has been more effective with the use of contrast media such as Gd-DTPA. MR images are more sensitive than CT in such cases (see Fig. 2). In general, the metastatic lesions have been usually noted to appear as areas of high signal on T2-weighted images. However, there are instances where such lesions may have a low signal (e.g., metastases from mucinous adenocarcinoma from the GI tract). The identification of multiple metastatic tumors becomes highly important if surgical resection or localized radiotherapy is the planned mode of therapy. The identification of such lesions is also vital while planning treatment in high-risk patients.[2, 6, 7]

Leptomeningeal Tumors

While CT can offer similarly sensitive images in conditions such as nodular leptomeningeal tumors, MRI offers an upper hand while diagnosing diffuse versions that are present at the inner table of the skull.[8]

Nodular or diffuse leptomeningeal carcinomatosis in the spinal canal can also be detected efficiently with the use of MRI. In the case of lesions related to the pituitary fossa, the soft tissue resolution and multiplanar capability of MRI makes it quite easy to evaluate the involvement or relation to optic chiasm and other important surrounding structures.[9]

Acoustic Neuromas

Contrast-enhanced MRIs are able to clearly detect acoustic neuromas and other extra-axial tumors.[10]

Cystic Tumors of the Spinal Cord

Astrocytomas are one of the spinal cord tumors commonly noted in the pediatric population. These lesions are frequently encountered in the cervicodorsal region of the spinal cord, which may be associated with swelling in several cases. Commonly noted as an eccentric lesion that is poorly defined, astrocytoma can be enhanced heterogeneously following gadolinium injection.[11, 12]

In the case of adults, ependymomas are the most common tumors of the spinal cord. These tumors present as intramedullary lesions with clear boundaries that are enhanced following the injection of contrast media such as gadolinium (see Fig. 1).[13]

Intramedullary hemangioblastomas can be noted as a well circumscribed lesion that can be enhanced extensively with the use of contrast agent. The feeding vessels can also be viewed due to the hypervascular nature of the lesion.[13, 14]

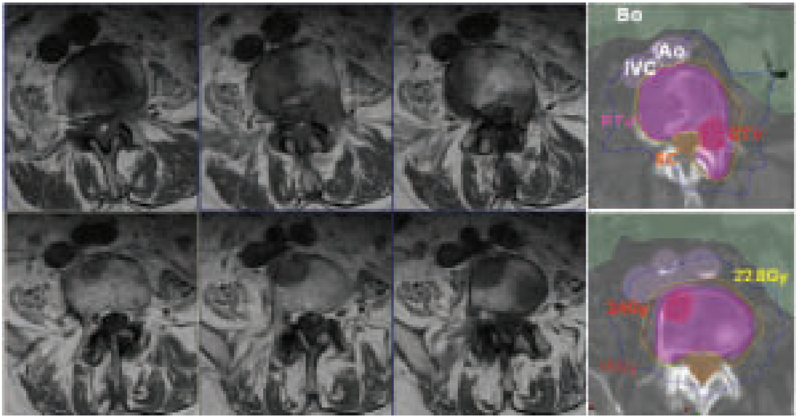

Figure 2: Patient with two discrete hypointense metastases within the L4 vertebral body (anterior/inferior and posterior/superior). Shown are sequential axial slices from a T1 volumetric series through the vertebral body. On the right are images from the dose plan with PTV (pink), GTV (red), great vessels (purple), small bowel (green), and spinal canal (orange) contoured. Three isodose lines from a 9 field IMRT plan are shown, with treatment delivered over three fractions. Typically, the whole vertebral body is treated, as allowed by dose to the spinal canal.

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5. Genitourinary

Riz Nurani, Jamie Cesaretti, Mitchell Terk

Significant advances have occurred in MRI procedures related to pelvic malignancies. The role of CT in staging some of the common malignancies of the bladder, cervix, and uterus has been challenged by MRI.

Bladder Carcinomas

In the staging of bladder carcinoma for example, MRI appeared to provide a more accurate overall staging of the primary lesion owing to its ability to detect perivesical spread and local invasion. Additionally, it can also be useful in the evaluation of the amount of penetration of the carcinomatous lesion through the deep muscle layers of the bladder. MRI is also considered the imaging modality of choice when cystectomy is considered. The multiplanar capability is useful in the detection of the perivesical spread of tumors prior to cystectomy.[1, 2]

Prostate Cancer

MRI can be used to assess the local and locoregional spread of a newly diagnosed prostate cancer. This can be aided by the detection of extracapsular extension (ECE), seminal vesicle invasion (SVI), and lymph node invasion in individuals diagnosed with prostate cancer. The assessment of local extension is considered possible with the use of phased array coils and a small field of view MRI or endorectal coils. Pelvic MRI with surface coils and the use of superparamagnetic particules have been noted to provide the sensitivity and the specificity that have never been obtained by the sole measurement of node size of the lymphatic chains draining the prostate gland.[3]

The use of MRI alone in the assessment of the prostate gland for radiotherapy has been questioned by many. CT is considered superior in certain aspects as MRI is associated with geometric distorsion and MRI can neither provide information about bone structure nor help assess the electron density of the body tissues. However, MRI is superior in certain aspects. These include better contrast than CT when demarcating the periprostatic soft tissues from the prostate gland, more precise delineation of normal critical structures, and more accurate definition of treatment volumes. The diagnostic information from MRI can be incorporated into that of CT, which is commonly referred to as “image fusion.”[4]

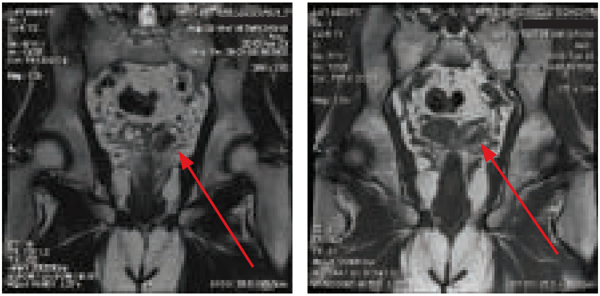

Figure 1. Coronal T2- and T1-weighted images show abnormal signal (arrow) in the left seminal vesicle, compatible with extension of disease to the gland.

Magnetic resonance (MR) and computed tomography (CT) image fusion with CT-based dose calculation is considered the gold standard for prostate cancer treatment planning. MRI is generally noted to be a useful tool for the simulation of radiotherapy in prostate cancer patients. When compared with CT, MRI-based treatment planning has been noted to meet the accuracy in terms of dose calculation and also provides consistent treatment plans for prostate IMRT.[5]

T2 MRI is useful in visualizing the three major prostate zones (inner, outer, and anterior fibromuscular). Additionally, structures such as the external “lower” sphincter, internal pudendal artery, corpus cavernosum, and neurovascular bundle are visible with MRI. Ejaculatory ducts within the prostate can also be viewed on sagittal MRI. Further, the prostate-rectum interface is clarified by MRI.[6]

At 1.5T MRI is noted to provide excellent imaging of the whole prostate gland. Currently, the focus of MRI is on the intraprostatic prostate cancer identification. The use of dynamic contrast-enhanced and diffusion-weighted MRI sequences has significantly improved the accuracy for cancer detection and volume estimation. At present, high-resolution MRI with pelvic coil appears to offer the most readily available and useful imaging for the diagnosis, staging, and prognosis of prostate cancer. MRI and MR spectroscopic imaging has been considered useful in the evaluation of patients with prostate cancer being considered for focal therapy by providing additional evidence of an otherwise undetected high-risk, aggressive cancer.[7, 8]

The diagnostic performance of MRI has been said to be improved with the use of functional imaging techniques such as diffusion-weighted imaging (DWI), dynamic contrast-enhanced (DCE) MRI, and MR spectroscopy (MRS) for cancer detection, staging, monitoring of treatment effect, and guidance from prostate biopsy.

Single shot echo planar imaging (EPI) has been most widely used for DWI wherein fat suppression is mandatory to reduce distortion and artifacts. A gradient-echo sequence has been considered adequate for image acquisition in the case of DCE-MRI. In case of MRS, chemical shift imaging with point-resolved spectroscopy (PRESS) voxel excitation and band selective inversion with gradient dephasing for water and lipid suppression is the most widely accepted technique for prostate imaging.[9]

MRI of the Kidneys

In the adult population, the renal cell carcinomas account for 3% of all the malignancies among which almost about 50% of such tumors are discovered incidentally. Studies have suggested that in almost about 85% of the cases, suspicious renal lesions turn out to be malignant ones. The size of the lesion, the thickness of the walls of the lesions, presence of calcifications and wide extension of the lesion are often suggestive of a malignancy.[10]

While CT scanning has been preferred in most of the cases of renal involvement, the use of MRI is growing and is advocated in certain specific situations. These include cases where the renal function is compromised, or the individual has an allergy to iodinated contrast material being used for CT or if radiation exposure is contraindicated (such as in children and pregnant women).

MRI of the kidneys can be difficult because of respiratory motion of the kidneys. This requires one to follow the fast imaging techniques to overcome this problem. If possible, particular sequences should be completed within one breath-hold. Preferably, these should be performed during the expiration as the position of the kidney seems to be more constant at this period. Respiratory triggering or respiratory gating can be considered if the sequence to be followed is too long.[11]

There are several image sequences that can be used during MRI procedure. Each sequence may offer specific benefits in different situations. A fat suppressed T2-weighted fast spin echo sequence provides detailed T2-weighted information. This sequence is considered to be helpful in evaluating the cysts and intraparenchymal abscesses. Additionally, solid lesions present in the kidneys can also be detected with the use of T2-weighted images.

FSE T1-weighted and gradient echo sequences can be useful in evaluating solid renal lesions. Many of such lesions are hypointense in comparison to the renal parenchyma. On the contrary, lesions with hemorrhage, macroscopic fat, or melanin and cysts that have high protein content may show hyperintense signals.

T1-weighted sequences with the addition of intravenous gadolinium contrast provides enhanced images that can help in the detection and characterization of the renal lesions. Coronal 3D gradient echo sequences with fat suppression can be performed immediately following a contrast-enhanced sequence and can be useful for analyzing the venous anatomy and presence of tumor and also evaluating the extent of a tumor.[11, 12]

Enhancement of the lesion following the administration of the contrast can be suggestive of a malignant renal lesion. The enhancement also helps in differentiating the tumor from a simple cyst. In some cases, MRI has been used to differentiate or identify the sub-types of renal carcinoma.[12]

Extranodal spread of lymphoma often affects the genitourinary system wherein the kidneys are the most frequently affected organs. Although reported in a few studies, MRI was noted to be as equally effective as contrast-enhanced CT images. Additionally, the MRI has been said to offer better efficacy in identifying the involvement of the bone marrow. As with other tumors, lymphoma lesions exhibit a hypointense signal on T1-weighted MR images, although lymphoma may not be enhanced following the administration of the contrast medium.[13]

Other Conditions

Primary penile cancers that are known to manifest as solitary, ill-defined infiltrating tumors are generally noted to appear as hypointense areas on both T1- and T2-weighted MR images. Delineation of the tumor margin and evidence of extension of the lesion can be evaluated with T2-weighted imaging. Use of contrast agent enhances the tumor to a greater extent on T1-weighted images.[14]

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6. GI

Allison Grow and April Mendoza

Tumors of the gastrointestinal tract have been diagnosed with the help of both MRI and CT scanning. While MRI is preferred owing to the lack of exposure to radiation as compared with CT scanning, its use may be limited in the intestinal regions. This has been attributed to the long acquisition times and high risk of motion artifacts. However, with the advances in technology and introduction of techniques such as parallel imaging, much faster and higher quality image acquisition has been made possible.

Rectal Cancers and Small Bowel Malignancies

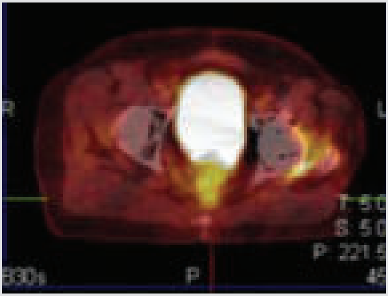
MRI is considered to be the gold standard for staging of rectal cancers. Exact visualization of infiltration of the rectal wall and perirectal fat is possible with the use of pelvic MRI allowing for reliable TNM staging. MRI also offers multi-planar images that allow for the visualization of the complete small intestine. This helps detect the presence of any other abdominal pathology that may or may not be directly related to the small intestine.[1]

Endorectal coils were originally touted as the standard for MRI of the pelvis in rectal cancer. However, we have found the use of endorectal coils tends to be limited by the amount of near-field artifact created by the coils direct contact with the rectal wall. The insertion of endorectal coils can also be quite painful in certain instances and their use is also limited by their high costs. The introduction of high-resolution phased-array surface coil systems has brought a breakthrough in the staging of rectal cancer. The use of these phased-array surface coils, which combine a very high spatial resolution with the ability to enlarge the FOV, permits detailed evaluation of the intestinal wall and depiction of the surrounding anatomy.

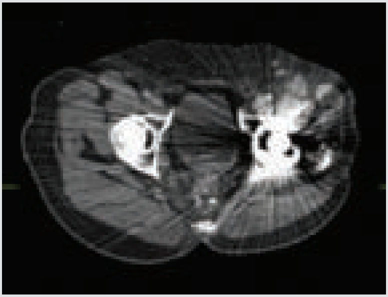
Evaluation of the small intestine is generally performed with the use of very fast breath-hold sequences. Several studies have validated the use of single-shot sequences such as the half-Fourier single-shot turbo spin-echo (HASTE) and single-shot fast spin-echo in T2-weighted images.

Case Study 1: Locally Recurrent Rectal Carcinoma

PET·CT for Staging

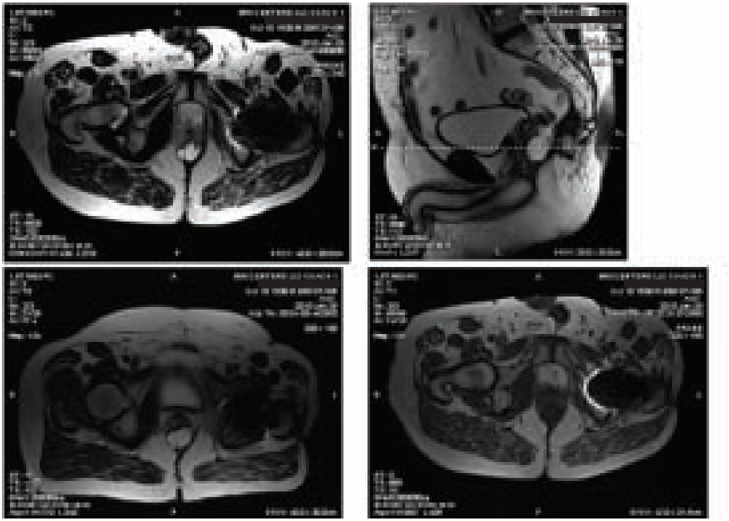


CT for Treatment Planning



Patient FG, whose PET·CT and CT treatment planning images are seen above, is a 71-year-old man diagnosed in 1992 with Dukes' stage B2 adenocarcinoma of the rectosigmoid junction, treated with surgical resection and postoperative chemoradiotherapy on RTOG 9014, with a radiation dose of 45 Gy to the pelvis and a total tumor dose of 54 Gy. He then did well until late 2009, when he developed progressive coccygeal pain.
PET·CT imaging showed possible mild heterogeneous soft tissue infiltration in the surgical bed with a hypodense fluid-density mass in the precoccygeal space abutting the posterior rectal wall, with mild heterogeneous FDG uptake, but the study did not definitively localize the recurrent lesion. Biopsy returned metastatic adenocarcinoma of colorectal origin. Due to the very deep and inferior location of the recurrent lesion, he was felt to be clearly unresectable and thus underwent salvage CyberKnife® radiosurgery. Precise targeting, essential for treatment of a lesion in intimate contact with previously radiated pelvic viscera, was not possible based on PET·CT. A high-resolution treatment planning MRI (seen below), done with an immobilization device, clearly showed a fluid-signal cystic mass with contrast-enhancing mural nodularity along the right lateral wall. This study enabled precise targeting of the complex lesion and the adjacent critical organs and provided a basis for following the radiographic response (complete obliteration of the contrast enhancement in the nodular portion of the lesion). The patient also had an excellent clinical response with resolution of his coccygeal pain.

MR for Therapy Planning



Rectal tumors generally have a low signal intensity on T1-weighted sequences, which makes it easy to differentiate them from the perirectal fat that demonstrates high signal intensity on T1. T2-weighted images are useful in detecting pelvic sidewall invasion.

While benign lesions, such as adenomas, leiomyomas, and lipomas, are the most common neoplasms of the small intestine, adenocarcinomas account for about 50% of all small bowel malignancies. Tumors of the small intestine show enhancement with contrast, making them distinguishable from the adjacent bowel tissues. Precontrast breath-hold T1-weighted spoiled gradient-echo images and gadolinium-enhanced fat suppressed images have been shown to provide reliable images for determining the extent of the tumors.[2]

Hepatocellular Carcinoma (HCC)

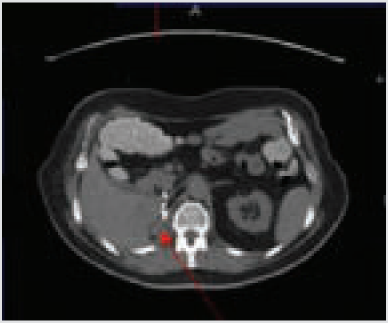
MRI has been considered to be extremely useful for the detection and characterization of regenerating and dysplastic nodules in the liver; it is also beneficial in diagnosing hepatocellular carcinoma (HCC). MRI has also been shown to be superior to CT for the detection and characterization of focal hepatic lesions.

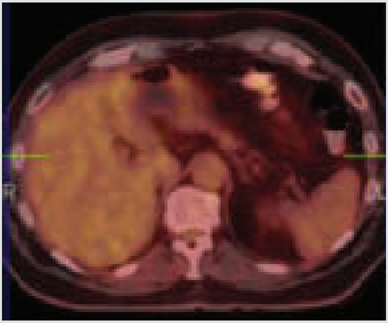
Several imaging techniques have been advised for the evaluation of HCC and other nodular lesions of the liver. We have found that T1-and T2-weighted fast spin echo sequences, in and out of phase gradient echo T1 images, and fat suppressed T2 FSE sequences are some of the most useful non-contrast image sequences.

T1-weighted imaging is generally performed with the breath-hold gradient echo technique. Spin echo techniques are considered effective in patients who cannot hold back the breath but have regular breathing. If the breathing is irregular, breathing independent techniques such as turbo FLASH can be utilized. In case of T2-weighted images, fast spin echo sequences are generally used.

Contrast-enhanced T1 W images are known to improve the detection and characterization of lesions, particularly small HCC.[3]

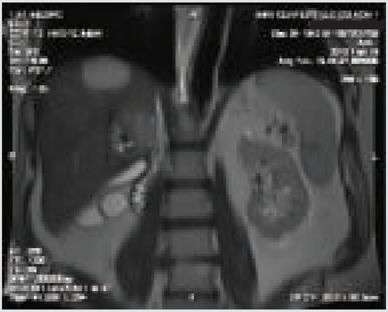
Case Study 2: Renal Cell Carcinoma Metastatic to Liver: CT and PET images





Patient JH, whose images are seen above, is a 67-year-old man with stage IIIB right renal cell carcinoma, treated with nephrectomy followed by adjuvant Sutent. A routine follow-up PET·CT in January 2010 was suggestive of recurrence in the nephrectomy bed, with biopsy at the time of fiducial placement providing histologic confirmation. The immediately adjacent inferoposterior portion of the right hepatic lobe showed changes, including increased FDG uptake, suggestive of metastasis via possible direct extension. This had been noted on previous imaging and a prior liver biopsy had returned negative. The suspicious area had progressed on the new imaging and was confirmed with a liver MRI, which also provided much more precise delineation of the extent of involvement.

The patient was treated with CyberKnife radiosurgery and this area of hepatic involvement was included in the treatment volume with excellent radiographic results.



Abdominal Cancers

Diffusion weighted magnetic resonance imaging (DWI) has been noted to be of great benefit while evaluating abdominal cancers. DWI has multiple applications in the field of abdominal oncology wherein it has been found useful in tumor detection, characterization of the tumor, prediction of tumor response to therapy, monitoring tumor response, and detecting tumor recurrence.

Tumors of the abdominal regions generally show high signal intensity in DWI images. Studies have reported that DWI is superior to SPIO-enhanced MRI in the detection of liver metastases. Similarly, DWI has been shown to have a high level of specificity and sensitivity in the detection of colorectal cancers.[4, 5]

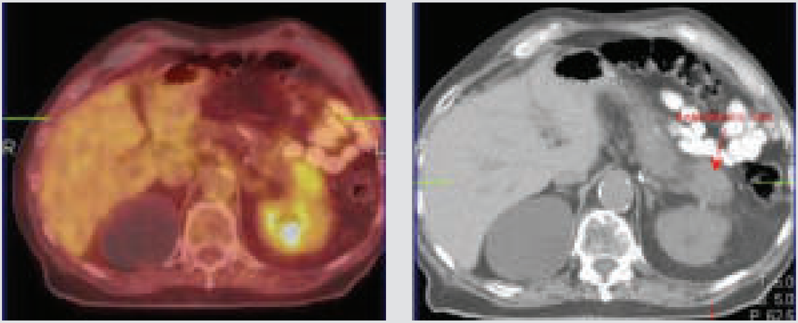
Pancreatic Cancer

Early diagnosis can significantly improve the survival rates in individuals suffering from pancreatic cancer. Abdominal US, helical CT, MRI, endoscopic US, and endoscopic retrograde cholangiopancreatography (ERCP) are some of the common imaging modalities used to detect pancreatic cancers.

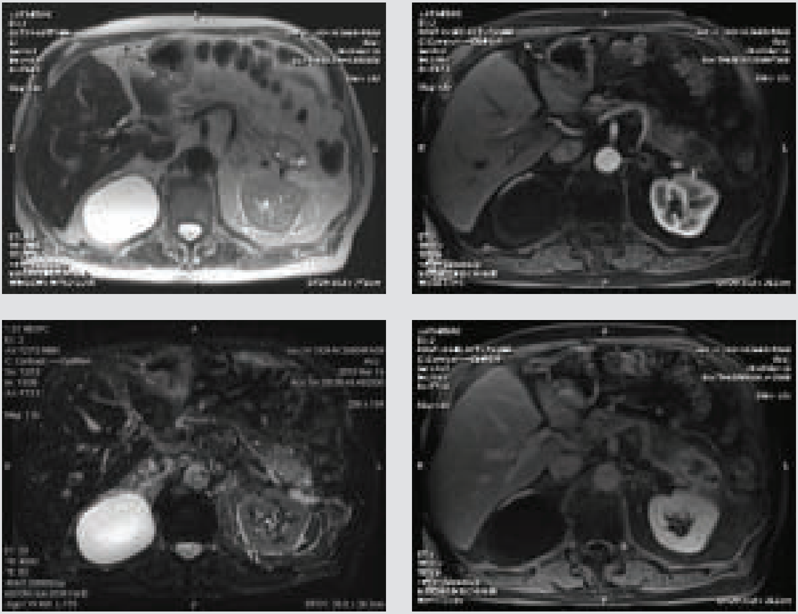
MRI offers the benefit of non-ionizing imaging methods and soft tissue delineation. Conventional spin-echo sequences using contrast enhancement have been noted to be beneficial. T1-weighted spin-echo sequences with fat suppression produce high signal-to-noise ratios, reduce motion artifacts, and are considered to be best for differentiating normal regions from the cancerous areas. Breath-hold contrast-enhanced images are considered to be beneficial for detecting small tumors of the pancreas and liver metastasis.

In detecting and staging pancreatic adenocarcinoma, MRI has an accuracy rate of 90–100% according to certain studies and is hence projected to be better than CT.[6, 7]

Case 3: Non-small cell lung carcinoma metastatic to the pancreas: PET·CT and CT images



Patient EA, whose images are seen above, is an 85-year-old man with stage III non-small cell lung carcinoma, initially treated with chemoradiotherapy. He later developed a single brain metastasis treated with CyberKnife® radiosurgery followed by whole brain radiotherapy. A routine follow-up PET·CT showed an area of hypermetabolic uptake in the pancreatic tail, with associated focal prominence but no clearly delineated lesion on CT. Biopsy returned metastatic carcinoma consistent with lung primary, and CyberKnife radiosurgery was offered due to the small volume of disease and poor tolerance to chemotherapy. A treatment planning MRI (next page) provided excellent delineation of the extent of the hypoenhancing lesion for precise targeting.



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7. GYN

Abhijit Deshmukh, Janelle Park, and Dwelvin Simmons

MR is an imaging modality that can help in staging as well as providing prognostic information in many gynecological cancers. MRI can be used to accurately detect myometrial invasion in cases of uterine carcinoma, the depth of which can define the prognosis for the patient. Such information can help in deciding on therapy choices or the extent of surgical procedures. Similarly, MRI is considered to be superior to transrectal ultrasound or CT while determining the parametrial extension and local invasion in cases of cervical carcinoma.[1, 2]

Ovarian Masses

MRI can assist in characterization of ovarian tumors as benign or malignant. The morphological characteristics and signal characteristics on T1- and T2-weighted images need to be considered while evaluating ovarian masses with MR. Cystic ovarian masses can be either benign or malignant tumors; the presence of solid masses should raise the suspicion of malignancy. T1-weighted images can be useful in evaluation of hemorrhagic adnexal masses such as endometriosis and cystic teratomas wherein blood products within these masses have high signal intensity. If significantly low signal intensity is noted in solid masses in T2-weighted images, it can be suggestive of fibrous tumors such as fibrothecomas and Brenner tumors.[3]

Intravenous gadolinium contrast material is essential in differentiating malignant tumors with the use of MRI. While contrast-enhanced MRI is generally not advised for endometriosis, the use of contrast medium may be necessary to identify the presence of malignant changes if such a change is suspected in these cysts.[3]

Endometrial and Cervical Cancers

Endometrial and cervical carcinomas are common carcinomas of the female genital tract. The peak age for the presentation of endometrial carcinoma is about 60 years old; cervical carcinomas tend to affect women between the ages of 35–50 years. Accurate staging is necessary to initiate the appropriate surgical, medical, and radiation therapy treatment. Some prognostic factors that can be identified with the help of MRI include grade of the tumor, depth of myometrial invasion, cervical invasion, or presence of lymph node metastasis.[4]

Endometrial carcinomas are best evaluated using high-resolution sagittal and axial T2-weighted fast spin echo. These sequences are excellent at depicting the uterine zonal anatomy. Axial T1-weighted spoiled gradient-echo images are noted to be helpful for the detection of enlarged pelvic lymph nodes. Sagittal T1-weighted spoiled gradient-echo sequences (with or without fat suppression) may be performed following IV injection of contrast material when there is a need to improve tumor detection, distinguish tumor from debris in the endometrial cavity, or facilitate the evaluation of myometrial invasion. This is helpful because gadolinium increases the contrast between the tumor and the normal myometrium.[5-7]

It has been reported that MRI is able to detect variable abnormal endometrial findings in about 81–84% of patients with endometrial carcinoma. The endometrium may appear focally thickened, diffusely thickened, widened by polypoid tumor, or entirely normal in certain circumstances. The signal intensity of the tumor may vary on T1- and T2-weighted noncontrast images appearing isointense in the majority of cases or high intensity in some cases. The accuracy of MRI in staging endometrial carcinoma is noted to be as high as 85–92%. Contrast enhancement has been reported to improve detection of the tumor and also improve differentiation between tumor and unenhanced blood clots or fluid in the endometrial cavity.[8]

MRI is highly useful in treatment planning for endometrial carcinomas due to its excellent soft tissue contrast and multiplanar capability. It has been considered superior to US and CT in helping assess the depth of myometrial invasion, cervical invasion, and early parametrial invasion. For the detection of enlarged lymph nodes, MRI is approximately equivalent to CT.[8]

Some authors have reported MRI to be 79% sensitive, 85% specific, and 80% accurate for staging endometrial carcinoma. MRI has been recommended as a safe, accurate non-invasive imaging modality in staging of endometrial carcinoma and can be used as a first-line radiological investigation in patients with endometrial carcinoma for treatment planning.[9, 10]

Accurate assessment of the myometrial involvement can be performed preoperatively in order to select patients requiring pelvic lymphadenectomy. However, the presence of conditions such as large polypoid tumors, leiomyomata, adenomyosis, congenital anomalies, or a small uterus may affect the specificity of MRI. The accuracy of detection of cervical invasion is good when there is stromal invasion.[11]

MRI has been noted to have an accuracy rate of 67–94% for the evaluation of parametrial involvement in women diagnosed with cervical cancer. However, the presence of edema in the cervical stroma or the parametrial tissues can result in false positives.[11]

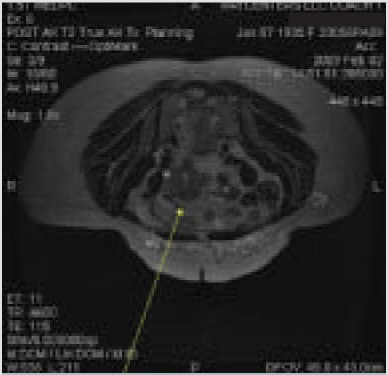
MR is also considered a reliable imaging modality in endometrial and cervical cancer cases wherein it helps in accurate staging and formulating the treatment plan.[11]

Case Study 1: Stage IV Cervical Cancer

EM is an 80-year-old female who presented with vaginal bleeding. Exam under anesthesia revealed a large ulcerative cervical mass, involving the vaginal apex. Induration was noted to extend into the anterior surface of the vagina and peri-vaginal tissues including the urethra. Bilateral parametrial nodularity was noted. Cystoscopy demonstrated extensive tumor infiltration of the bladder and proximal urethra. Proctoscopy showed no direct involvement of the rectal mucosa. She was staged IVA and was recommended to undergo external beam irradiation with concurrent cisplatin chemotherapy, followed by brachytherapy and radiosurgical boost.

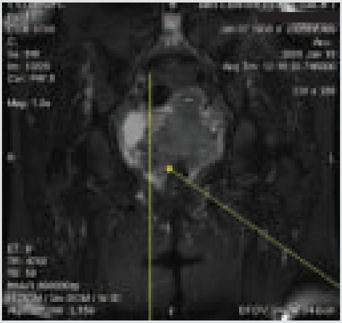
MRI was obtained in the treatment planning position, allowing more accurate design of target volumes to encompass lower uterine segment involvement. MRI also confirmed direct invasion of the bladder and lack of rectal invasion, as seen during her clinical staging procedures. She was counseled as to the risk of developing a vesico-vaginal fistula following treatment.

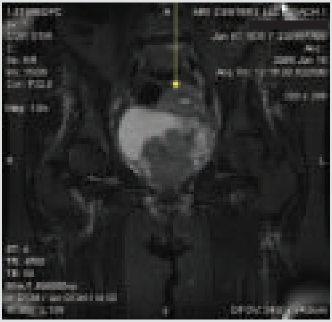
She tolerated her combined modality treatment well, and at last follow-up was free of recurrent disease.



Top of uterus

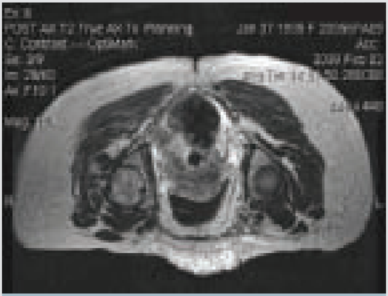
Top of tumor in lower uterus segment





Tumor in LUS +Cx

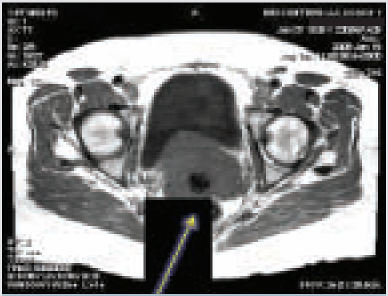
Corresponding coronal images show tumor below anteverted uteral body.



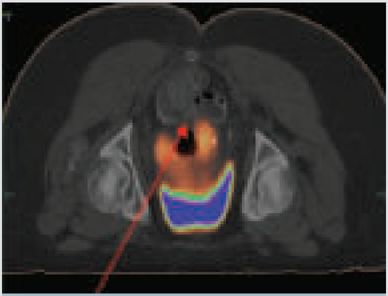
MRI = clear bladder involvement on left side, with loss of fat plane

PET = difficult to distinguish if bladder involved

CT = even more difficult to distinguish tumor and whether surrounding structures involved

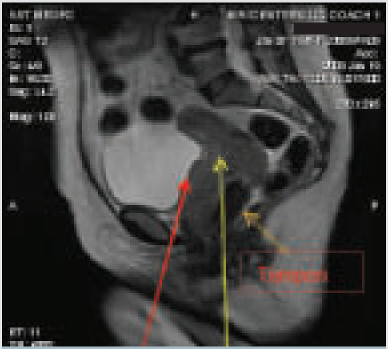


MRI T1 axia: Fat plane is preserved = rectum not involved
Confirmation = Rectal involvement not seen on proctoscopy

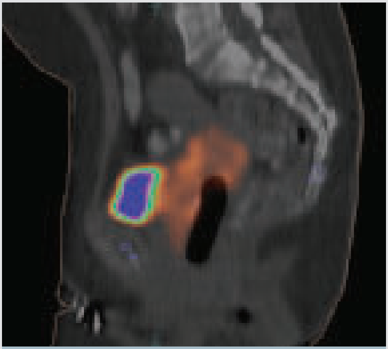


PET = difficult to distinguish if rectum involved

CT = even more difficult to distinguish tumor and whether it is involving surrounding structures



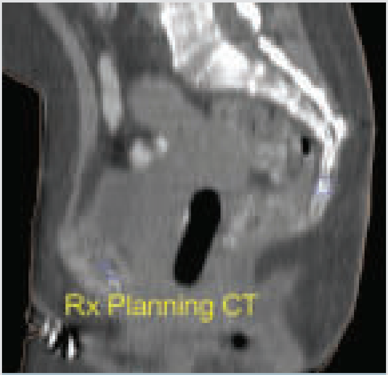
Cystoscopy showed tumor in trigone and proximal rethra = stage IVA tumor in LUS



On PET, cervix tumor was ill-defined and it was difficult to delineate LUS involvement

MRI was very helpful in clearly delineating bladder involvement, allowing generous bladder coverage during treatment planning, and it was the only modality that clearly showed the extent of lower uterine segment involvement. In addition, visualizing posterior extension of the tumor toward the rectum improved GTV delineation. These three important radiologic findings facilitated treatment planning and complemented PET·CT.

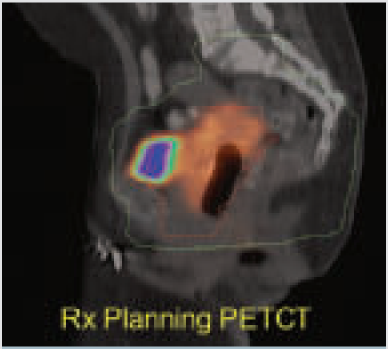
Rx Planning MRI



Rx Planning CT

Rx planning CT sub-optimal as bladder not distended and consequently small bowel lower in pelvis.

Note: Superior tumor extension into LUS clearly well defined in T2 Rx planning MRI (red arrow above).



Rx Planning PET·CT

4500 cGy color wash is based on MRI tumor volume. CT tumor volume would not have adequately covered superior extension into LUS. Patient was treated with full bladder to displace small bowel superiorly.

Vaginal Carcinomas

Primary vaginal carcinomas are a rare entity, accounting for only about 1–2% of all gynecological malignancies. However, a metastatic spread can commonly affect the vaginal region causing malignant changes in the vagina. Direct local invasion from the urogenital tract is one of the most common causes for vaginal carcinomas. Determining the extent of such cancers and staging is essential to form a plan for treatment. While clinical examination can help in determining the extent of the cancer, the use of MRI may be necessary in cases where the involved regions are not easily accessible.

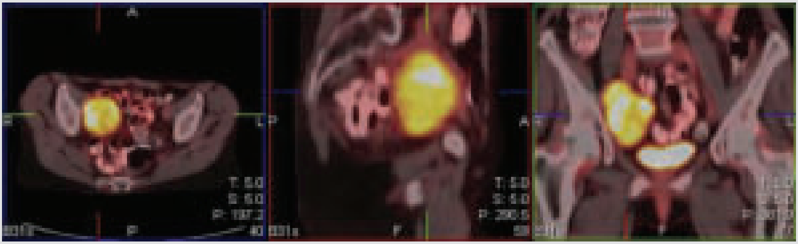
MRI's crucial role is in demonstrating the location of the tumor and evaluating the parametrial extension. Additionally, the involvement of the pelvic walls can be evaluated. MRIs also help determine the spread to genital and nearby structures such as bladder or urethra, rectum, and lymph nodes. Information obtained about the pelvic anatomy during the imaging procedure may be useful while planning for surgical and radiation therapies.

MR offers several advantages over CT in the imaging of vaginal carcinomas. MRI offers higher soft-tissue contrast when compared to CT and the ability to perform multiplanar exams. This helps in better evaluation of the size, location, and extent of vaginal tumors and determining the degree of lymph node involvement for preoperative planning.[12-13] In comparison to MRI, CT is not able to distinguish the normal areas from tumor, which causes difficulties in planning the surgical excision. MRI allows the visualization of intact mucosa and intact cervical and endometrial epithelium, which can help in distinguishing lymphoma of the upper vagina from cervical or uterine carcinoma.[14]

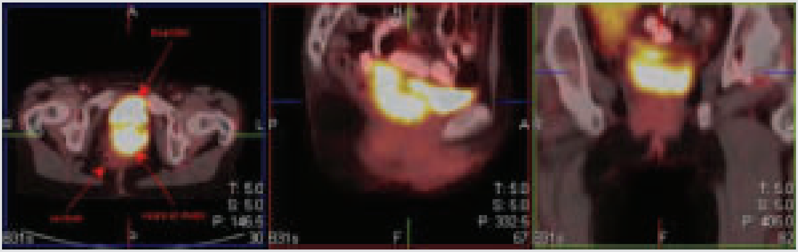
MRI was able to identify over 95% of the primary vaginal tumors enabling radiological staging, which was noted to correlate with outcome, and provided information of use in treatment planning.[15] This can guide treatment choice, surgery, and radiotherapy versus chemo and radiotherapy.

Case Study 2:
72-Year-Old with T2N1M0 Squamous Cell Carcinoma of the Vagina

RW is a 72-year-old with a diagnosis of T2N1M0 squamous cell carcinoma of the vagina with a history of a prior total abdominal hysterectomy. Further complicating this clinical case was the fact that the patient had reported hematuria on occasion. Results of an intraoperative cystoscopy were inconclusive. Also at the time of diagnosis, there was the presence of a large obturator node, which was excised to aid in the staging of the patient.

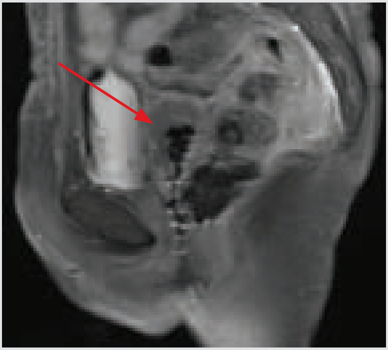


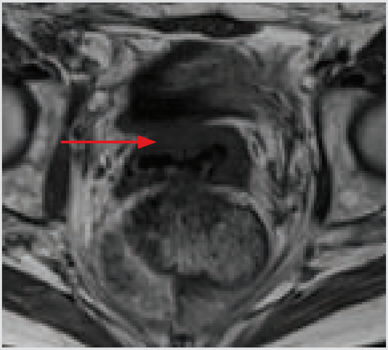
PET·CT (above and below) performed prior to surgery was useful in the assessment of the pelvis for additional adenopathy, of which there was none. Unfortunately, the PET·CT was of little benefit in determining the size or the extent of the primary lesion.



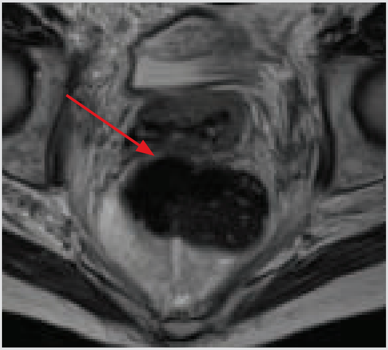
As primary vaginal carcinoma is treated definitively with radiation consisting of external beam as well as implantation of radiation to the vagina and the parametrial tissues, it is extremely important to appreciate the overall extent of the lesion to adequately treat the tumor. The extent of the tumor is often difficult to appreciate on exam as it was in this case. MRI was used and proved to be quite beneficial.

Note that the node seen on PET·CT has been excised. There is noted thickening of the vaginal walls appreciated on MRI (white arrow below).





The presence of intact fat planes between the vagina and the rectum, as well as between the vagina and the bladder, demonstrates that there is no involvement of these structures (red arrows). This information was imperative to ascertain that all disease would be encompassed within the radiation portals as well as in the implant. The patient completed chemotherapy and radiation and has remained disease free.



One of the basic imaging protocols followed during the evaluation of vaginal carcinomas consists of axial T1-weighted and T2-weighted fast spin-echo imaging through the pelvis from the aortic bifurcation to below the vulva. Such a process provides an overview of the whole pelvis while allowing the evaluation of the pelvic and inguinal lymphadenopathy. Sagittal T2-weighted fast spin-echo imaging from pelvic sidewall to sidewall is useful in determining the extension of the vaginal tumor into the nearby regions. High-resolution oblique axial T2-weighted fast spin-echo imaging can be followed as supplementary sequences.[11, 13] Coronal T2-weighted images can be utilized to assess the pelvic walls. Routine use of contrast media is not necessary as the paravaginal structures often enhance avidly providing little demarcation from the other structures.[14]

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8. Head and Neck

Anand Kuruvilla and Mary Koshy

While evaluating the head and neck carcinoma cases, the multiplanar ability of the MRI is considered highly useful. The use of pre- and post-contrast enhanced fat suppressed T1 images have also been noted to be of significant value while confirming the local infiltration associated with nasopharyngeal carcinomas. Intracranial extension of disease, if suspected, can also be confirmed with the use of coronal and sagittal imaging sequences. However, MRI is not considered to be superior to CT in the case of tumors of the larynx and hypopharynx, where the degree of motion artifact created by swallowing can affect the image quality.

Extracranial Head and Neck Tumors

MRI is considered quite superior to CT when imaging the extracranial head and neck. It has been noted to offer higher image quality and better recognition of tumor masses present in the paranasal sinuses, nasopharynx, and parapharyngeal spaces. Because of its superior sensitivity in detecting small lesions, MRI is considered the method of choice for the detection and staging of skull base lesions. Furthermore, it offers superior accuracy while staging head and neck tumors and helps narrow down the diagnostic possibilities.[1]

Nasopharyngeal Carcinomas

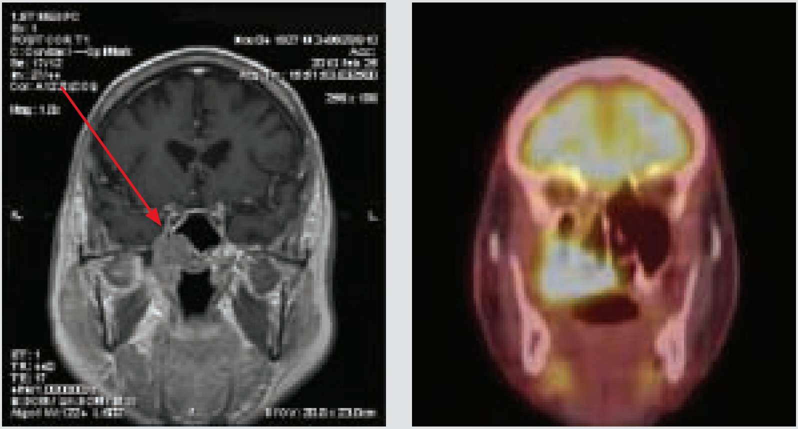
CT and MRI have largely replaced the conventional plain radiography techniques for staging of nasopharyngeal carcinomas and also to determine the extent of skull-base involvement. While CT scans can offer some good results, it is considered deficient in certain areas such as evaluation of the symmetry of the nasopharynx, detection of skull-base invasion, or distinguishing compression when the tumor is still confined within the mucosal space. MRI is considered extremely helpful in the detection of primary tumor in these areas because of its multiplanar capabilities and its ability to depict soft tissue details in a superior manner.[2]

T2-weighted and contrast-enhanced MRIs are useful in differentiating the mucosa (high signal intensity) from the torus tubarius and intrapharyngeal portion of the levator palatini muscle (low signal intensity).

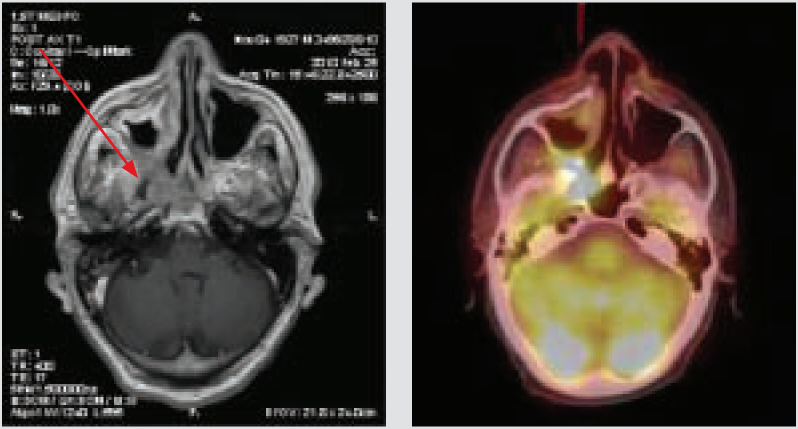
Primary tumors in these regions are slightly hypertintense in comparison to the adjacent muscles on T2-weighted MRIs. In the case of T1-weighted images, these areas appear isointense.[3-5] Tumors tend to enhance following the administration of gadolinium contrast medium, but it may not be more than that of the normal mucosa. T2-weighted images and short-tau inversion recovery (STIR) images are helpful in distinguishing primary tumors and the metastasis. Abnormal areas are hyperintense and appear conspicuous in iso or hypointense signal background.[3-5]

Multiplanar MRIs can clearly demonstrate the nasal extension of carcinoma, and are also useful in evaluating retropharyngeal extension into the lymph nodes in the oropharyngeal region.[3-5]

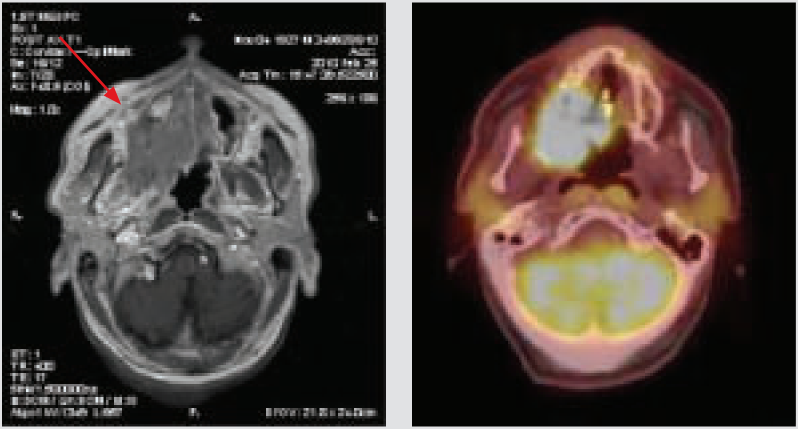
Case Study 1: Nasopharyngeal 82-Year-Old with T4N2cM0 Maxillary Sinus Carcinoma



MRI reveals lack of temporal lobe involvement, whereas PET·CT image of the same is unclear, allowing for potential sparing of temporal lobe in PTV.



The right pterygopalentine fossa is noted to be involved on the MRI, not well seen on the PET, and therefore included in the GTV.



MRI shows the mass extending into the nasopharynx and prevertebral space, allowing these areas to be included in the GTV.

MRI is superior to CT in the evaluation of the involvement of the skull base, as it better depicts infiltration of the bone marrow. Similarly, it is also beneficial while evaluating the intracranial extension of the pathology as MRI offers better contrast, which makes it easier to distinguish the tumor from the brain tissues.[3-5]

CT scan appears to have an upper hand in diagnosing nodal metastases in the neck as fat around the nodes decreases the conspicuity of lesions on the MR images. Acquisition time for MRI is also significantly longer when compared to CT.[3-5]

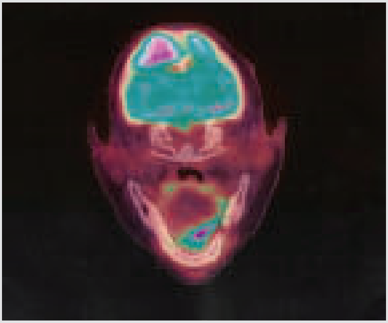
Oral and Oropharyngeal Carcinomas

Local or regional relapse of tumor is one of the most common problems associated with treatment of cancers of the tongue. Tumor thickness has been noted to be a significant factor that determines the outcome of the treatment for such cancers. While there are different methods available to measure the thickness of the tongue tumors, MRI appears to offer superior results. Tumors of the tongue display higher signal intensity than normal tissues, which makes it easier to identify the cancerous regions of the tongue. The use of a contrast media further improves this differentiation. MR can easily distinguish between the tumor, mucosal epithelium, lamina propria, and tongue musculature. T1- and T2-weighted images had a strong positive correlation with the histologically determined thickness. Along with assessing the thickness and extent of the tumor, MRI can also be used to evaluate whether elective postoperative radiotherapy to improve local and nodal control is necessary.[6]

Other studies have also supported the use of MRI in the diagnosis and treatment planning of tumors of the tongue. MRI is better suited to the evaluation of tongue carcinoma as it provides valuable information both within and around the tongue. The extent of soft tissue infiltration through the floor of the mouth or posteriorly into the tongue base can be better assessed with MRI.[7]

Several studies have also evaluated the role of MRI in detection and staging of oral and oropharyngeal carcinomas and also its superiority over CT. MRI was superior to CT in delineating the tumor margins in 78% of patients. T1-weighted and gradient echo sequences after intravenous gadolinium injection were particularly useful. MRI is especially useful in T1 tumors and in cancer of the base of the tongue. MRI should also be used instead of CT where dental fillings obscure the region of interest on CT.[8]

Case Study 2: Oral Tongue Carcinoma
71-Year-Old Female with T2N1M0 Tongue Carcinoma



MRI clearly shows deep muscular invasion not noted on either CT or PET. This influenced contouring of GTV.

Treatment Planning in Head and Neck Cancers

For display of soft tissues and tumor, MRI, being a multiplanar technique, is superior to CT. MRI is significantly better than CT in the treatment planning of head and neck cancers for several reasons. The greater soft tissue contrast permits better definition of disease extent and identifies organs at risk. While T1-weighted images can give a good anatomical detail, T2-weighted images are better able to differentiate between normal and pathological tissues. Nonenhanced T1-weighted MRI is better for defining the exact extent of medullary bone invasion, which appears as a low-signal-intensity area within hyperintense medullary fat.[9] Image contrast can be enhanced with the use of contrast medium such as intravenous gadolinium. Artifacts arising from dental amalgam can be made significantly less conspicuous on MRI than CT. Further, MRI is considered the modality of choice for imaging tumors at the base of the tongue and other suspicious lesions arising at the skull base. Additionally, visualization of important organs at risk such as the orbit, optic nerves and chiasm, and central nervous system is also possible with MRI.[10-12]

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Conclusion

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Several new imaging techniques, both anatomical and functional, are currently being evaluated for diagnosis and treatment planning of cancers in different regions of the body. Introduction of newer methods of MRI, which offer better imaging options, have increased the popularity of MRI. MR imaging is now able to offer better options in terms of tumor delineation and identifying the extent, spread, and involvement of neighboring structures when compared to other modalities. While image distorsion was one of the problems that commonly restricted the use of MRI, options such as phased array and faster sequences have reduced the disadvantages of MRI. Newer concepts such as diffusion-weighted and perfusion-weighted imaging and proton spectroscopy have changed the scenario of soft tissue imaging to a major extent. Further studies and further improvements in the field of imaging technology can enhance the use of MRI, making it the imaging modality of choice in almost all cancers in the body.

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