Chelonian Conservation And Biology

Vol. 20 No. 2 (2025) | https://www.acgpublishing.com/ | ISSN - 1071-8443

THE ROLE OF MRI IN DIAGNOSING NEUROLOGICAL DISORDERS

Mohammed Abdulaziz Al Qahtani[1], Moayad Alwi Abdalwahed[2] and Noura Saud Alonizi[3]

1 Corresponding Author, Radiographer, Mohammed-991@hotmail.com, Radiology department,

2 Radiographer, Moayad3Lwe@gmail.com

3 Senior radiographer, Radiology department, n.algabaeen37@gmail.com,

Abstract

Magnetic resonance imaging (MRI) has become an indispensable tool in the diagnosis and management of neurological disorders. Ischemic stroke, hemorrhagic stroke, multiple sclerosis, Alzheimer's disease, and brain tumors are examples of conditions for which MRI scans provide crucial clinical information.

MRI produces images by subjecting the body to a magnetic field, and then using radio-frequency pulses to stimulate the emission of energy from atomic nuclei. The resulting signals are used to reconstruct images that encode structural or functional information about the brain. Structural scans visualize the anatomy in cross-section at high resolution. Functional MRI (fMRI) renders maps of cerebral activity and metabolism. Diffusion tensor imaging (DTI) tracks the flow of water molecules along the white-matter tracts and thereby reveals connective pathways.

Keywords: MRI, Neurological Disorders, Brain Imaging, Diagnosis, Neuroimaging, Magnetic Resonance Imaging, Nervous System and Medical Technology

1. Introduction to MRI Technology

Magnetic resonance imaging (MRI) exploits the interactions of nuclear spins in the body with radiofrequency pulses in an applied magnetic field to generate images of internal structures. Since its early medical applications four decades ago, the range of techniques and applications has expanded considerably, nourished by the ongoing evolution of magnet, gradient and radiofrequency hardware and by deepening knowledge of the underlying physics (Seiler et al., 2021). By the early 1980s, systems operating at 0.5 Tesla equipped with resistive or permanent magnets provided whole-body medical imaging for some pioneering clinics. Commercial systems operating at 1.5 T employing exclusively superconductor magnets were soon introduced and have since become the most common magnetic field strength worldwide. Beyond ongoing improvements in superconducting magnets and gradients, the past two decades have witnessed the emergence of high-field systems operating at 3 T and, since 2007, ultra-high-field systems operating at 7 T., with the associated possibilities of enhanced sensitivity (Bruschi et al., 2020).

2. Understanding Neurological Disorders

Neurological disorders—including Alzheimer's disease, multiple sclerosis, stroke, brain tumors, Parkinson's disease, epilepsy, and Huntington's disease—are brain or nervous system anomalies with significant medical and social implications. Alzheimer's disease represents the dominant form of dementia among older adults. Parkinson's disease ranks as the second most common neurodegenerative disorder after Alzheimer's and the most frequent movement disorder. Multiple sclerosis is a chronic condition characterized by demyelinating plaques within the central nervous system. Epilepsy is distinguished by the occurrence of recurrent unprovoked seizures. Huntington's disease comprises an autosomal-dominant neurodegenerative disorder affecting the motor, cognitive, and psychiatric domains. Brain tumors are intracranial neoplasms arising from the brain parenchyma or its supporting structures. Stroke is delineated as a focal neurological deficit persisting for at least 24 hours, attributed to either ischemic or hemorrhagic events (Shi & Koike, 2024).

3. The Importance of Imaging in Neurology

Neurologists rely on clinical history and physical examination to establish a differential diagnosis and localize the neurologic lesion (S Zubair et al., 2021). Imaging modalities serve as essential tools that allow visualization of the nervous system, enable the identification and characterization of lesions, and assist in treatment planning. For instance, in patients with ischemic stroke, portable MRI positively impacted patient management by shortening emergency department length of stay (De Vito et al., 2021). In the diagnosis of epilepsy, MRI remains the gold standard imaging study for revealing the pathological substrates of regional brain epileptogenesis and significantly improves outcomes in children with epilepsy. Imaging significantly aids in patients with newly diagnosed epilepsy or with refractory epilepsy. MRI plays a fundamental role in the management of epileptic patients by localizing epileptogenic foci and assisting with pre-surgical assessment, particularly for drug-resistant focal epilepsies.

4. Principles of MRI

Magnetic resonance imaging (MRI) encompasses advanced methods that exploit nuclear magnetic resonance of protons in the abundant water content of biological tissues to gain insight into different tissue properties. Following a strong magnetization pulse, a series of detector coils measures electromagnetic signals, which are subsequently reconstructed into cross-sectional images by computer algorithms. The resulting image contrast varies with the sensitivity of the pulse sequence to different physical quantities.

A modest external magnetic field B0 (typically 1.5–3 T in the clinical setting) aligns the protons' intrinsic magnetization M parallel to the field. An applied radiofrequency field B1, oriented perpendicular to B0, rotates M towards the transverse plane. With the cessation of B1, the protons' longitudinal magnetization relaxes back to equilibrium with time constant T1, while the transverse magnetization decays with time constant T2. The properties of M and its relaxation differ depending not only on tissue structure, but also on the local macroscopic and microscopic magnetic environment; B0 inhomogeneity and anisotropy may furthermore distort the relaxation behavior (F. McFarland, 2009). Relaxation is usually detected via the induction of an electric signal in receiver coils; its decay governs image contrast in the time-domain analysis. The NMR resonance

frequency that forms the basis of image encoding is conventionally detected in the frequency domain, permitting the derivation of chemical-shift spectra in arbitrary voxels.

The above principles offer versatile means to investigate neurological diseases (Scheau et al., 2012). Basic tissue parameters such as the proton density (PD) or the T1- and T2-relaxation times can be determined using well-defined pulse sequences and fit models, often involving multiple inversion and echo times (Seiler et al., 2021). These approaches eliminate hardware effects linking tissue parameters to physical tissue properties, such as the microstructural and biochemical organization governed by the pathophysiology of neurological diseases. Additional specific readouts are attainable, for instance in perfusion- and diffusion-weighted imaging or further metabolite signals via selective NMR detection or contrast agents.

4.1. Magnetic Fields

Magnetic resonance imaging (MRI) detects synchrotron radiation by first inducing bulk magnetisation, which is an excess of aligned nuclear spins. A strong and static magnetic field (B0) polarises the spins along its direction. Today, B0 is usually produced by a large superconductor, which can be a critical constraining factor in deploying the technology, both because it requires to work at low temperatures and because it is costly. Nuclear magnetisation is proportional to B0, so the stronger the field the stronger the signal. Modern MRI systems for human scanning therefore employ very high magnetic fields, above 1 T. The spins also precess about B0 at the Larmor frequency, $\omega 0$, which is given by $\omega 0 = \gamma B0$, where γ is the nuclear gyromagnetic constant; typical values for γ can be found in (Bruschi et al., 2020). The precession, and therefore signal emission, depends on the z-direction, z being parallel to B0 because the magnetisation would not precess if parallel to B0. This identifies the longitudinal component of the magnetisation. In addition to this component, radiation induces a transverse magnetisation, perpendicular to the field, which precesses in the x-y (transversal) plane. Because of B0, the spins precess coherently and produce a rotating magnetic induction field (Taschler, 1970). This is detected by the receiver coil and constitutes the MRI signal.

4.2. Radiofrequency Pulses

In MRI, radiofrequency (RF) pulses play a pivotal role in generating fine image contrast and assuring image quality (Williams, 2018). A major historical factor restricting the wider use of magnetic resonance imaging has been signal loss appearing at off-resonant locations, which account for a large portion of the imaging volume. New multiband spectral-spatial RF pulse designs are able to compensate for local magnetic field inhomogeneity and to provide sharp, uniform spectral selectivity at multiple target bands, even when off-resonance approaches 100 Hz. Compared with previous methods, the proposed designs are simple, versatile, and robust and can be easily accepted and adapted by a wide range of MRS and MRI applications.

Standard MRI applies tailored RF pulses to rotate the net magnetization by a desired flip angle. Recently, a new class of RF pulses, known as prewinding pulses, is designed that also performs phase-gradient rewinding and helps reduce the signal loss caused by intravoxel dephasing in balanced steady-state free precession (bSSFP) acquisitions. Spectral-spatial prewinding pulses realize a substantially larger effective bandwidth than purely spectral prewinding pulses. A slab-

selective prewinding pulse design extends this method to 3D imaging. The pulse-design framework incorporates time-optimal gradient waveforms and parallel transmission with up to eight channels. A cost function maximizes rephasing and minimizes out-of-slice excitation. The design approach also generates laboratory-frame parallel-transmit encodings that permit a straightforward marriage to automatic in vivo flip-angle mapping. The resulting pulses achieve excellent in-plane distortion mitigation with limited through-plane errors at B0 = 3T and B0 = 7T. The improvement can be significantly increased with large transmit arrays.

Fig. 4.4 illustrates the principle. After application of a 9051 RF pulse, the net magnetization vector is tipped into the transverse plane, and the precession of that transverse magnetization induces a rotating magnetic field that produces a measurable signal in the receiver coil (Antti Kalevi Pölönen, 2016). In the classical picture of NMR, the protons are represented as individual tiny magnets that align with the applied 1.5-T magnetic field. The protons tend to process around the field direction at the Larmor frequency and will absorb and emit electromagnetic radiation at the same frequency. When a RF pulse, with a frequency at the proton precession frequency, is applied, resonance occurs and net magnetization will tip from the longitudinal direction toward the transverse plane. RF pulses that flip the magnetization by 9051 produce maximum transverse magnetization, and 18051 pulses invert the longitudinal magnetization. When the RF pulse is applied, the protons rotate in phase, and the phase coherence leads to a measurable signal. After the RF pulse ends, the phase coherence gradually diminishes and the signal decays exponentially, described as free induction decay.

4.3. Image Reconstruction Techniques

Reconstructing magnetic resonance images (MRI) from acquired data involves various algorithms supporting both two-dimensional and volumetric imaging. While original reconstruction methods demanded multiple minutes per image, innovations over the past decades have reduced this to milliseconds (Ghoshal et al., 2023). Fourier-based techniques remain prevalent but face computational load limitations for enhanced quantitative, statistical, or texture analyses. Image sparsity permits focused reconstruction in masked regions. Deep learning methods trained on raw data have accelerated high-quality reconstructions with reduced undersampling, substantially benefiting real-time applications in cardiac and pediatric imaging, among others. These approaches also aid artifact reduction by suppressing undersampling manifestations or addressing motion-induced distortions.

5. Types of MRI Scans

Structural MRI (sMRI) generates detailed anatomical images by measuring the density of protons in different tissues: water-rich regions appear brighter on T2-weighted scans and darker on T1-weighted scans. White matter is brighter than grey matter in T1-weighted images and darker in T2-weighted images. T2-weighted images also highlight pathological changes, which generally appear brighter than normal tissue. High-resolution sMRI is commonly used to exclude other pathologies and is a common measure of atrophy. Functional MRI (fMRI) monitors cerebral blood flow to detect task-induced activations or resting-state connectivity, tracking blood oxygen level-dependent (BOLD) signals at temporal resolutions of a few seconds. Diffusion tensor imaging

(DTI) maps the diffusion of water within tissue microstructure, providing means to differentiate tissue types and detect subtle changes in white-matter fibre organisation (Seiler et al., 2021) (Sawlani et al., 2020).

5.1. Structural MRI

Magnetic resonance imaging (MRI) evolved into a crucial non-invasive technique for studying the central nervous system (CNS) (Seiler et al., 2021). The standard MRI examination for neurological diseases is typically a multimodal scan protocol combining structural T1-weighted images, FLAIR, and T2- or proton-density-weighted images. Structural magnetic resonance imaging (sMRI) techniques provide the highest resolution images for neuroanatomy and brain morphology studies (Cui et al., 2023).

sMRI techniques are generally based on T1-weighted images and are widely employed for measuring the volume and thickness of gray-matter structures in neurological diseases. They have enabled the detection of widespread CNS alterations in multiple sclerosis (MS), including the whole brain, the cortices, the deep gray-matter nuclei, and the cerebellum. For Alzheimer's disease (AD), sMRI has examined regional brain atrophy in the hippocampal and entorhinal cortex consistently with cognitive or behavioural measures. For brain tumours, sMRI allows estimation of brain tissue damage surrounding the tumour and is critical for characterizing the tumour and delineating the surgical plan.

5.2. Functional MRI

Functional magnetic resonance imaging (fMRI) plays a crucial role in modern psychiatric research. It provides a means to assess differences in brain systems underlying psychiatric illness, treatment response, and properties of brain structure and function that convey risk factors for mental diseases. fMRI has become the dominant neuroimaging technique due to its non-invasiveness, good spatial and temporal resolution, and ease of use. Data processing methods for task-based and resting-state fMRI are used to probe specific brain activity patterns, with an ongoing shift toward understanding functional connectivity among brain regions and the organization of large-scale brain networks. The development of a clinical fMRI service involves specific software and hardware requirements to facilitate accurate mapping of eloquent brain regions, essential for planning surgeries and improving patient outcomes. Methods for identifying the regions of eloquent brain that should not be disturbed are critical to the surgeon. By accurately identifying these regions preoperatively, virtually every pre-surgical decision—from the surgical approach, operative goals, to the potential need for awake craniotomy with intraoperative cortical mapping—is affected. fMRI has become the primary modality of choice due to its capability to assess both anatomy and functionality of the brain. Its value was validated in 2007 when the Centers for Medicare and Medicaid Services established CPT codes for clinical fMRI based on its use for pre-therapeutic planning (Rigolo et al., 2017) (Zhan & Yu, 2015).

5.3. Diffusion Tensor Imaging

Diffusion Tensor Imaging (DTI) offers a quantitative measurement of water diffusion in biological tissues, providing insights into neural tractography that echo the outcomes of post-mortem anatomical dissections (Vargas et al., 2018). The technique models the tensor shape using both

fractional anisotropy (FA), which quantifies the degree of anisotropy, and the principal eigenvector that defines the primary fiber orientation (E. Rizea et al., 2012). Following the alignment of the diffusion-sensitizing gradient with the orientation of an axonal fiber bundle, diffusion-weighted imaging is performed to capture the directional preference of water diffusion. Repeating this operation with gradients sequentially rotated around orthogonal axes enables the computation of the FA value for each voxel in a brain volume (Ahn & Lee, 2011). Consequently, DTI is particularly sensitive to changes affecting tissue water content and the integrity of cellular membranes, intracellular microstructures, and the macromolecular environment of the brain, uncovering alterations that remain invisible to conventional magnetic resonance imaging.

From a clinical standpoint, preoperative DTI facilitates the mapping of white matter tracts and the elucidation of their specific relationships with intracranial lesions. It is instrumental in distinguishing between tumor compression or displacement and fiber route interruption caused by neoplastic infiltration, thereby identifying eloquent brain regions and potential patterns of tumor spread. Moreover, abnormal tractography signal parameters often overextend the limits of the contrast-enhanced lesion, delineating the presence of tumoral infiltration. In the diagnostic workflow, DTI has been applied to various conditions, including brain tumors, cerebral stroke, epilepsy, multiple sclerosis, and demyelinating disorders.

6. MRI in Stroke Diagnosis

MRI has become the preferred method for diagnosing acute stroke. It is the only imaging technique able to confirm cerebral ischaemia within the first few hours after symptom onset and to reliably distinguish ischaemic from haemorrhagic stroke (Verclytte et al., 2016).

The two main types of acute stroke, ischaemic stroke and haemorrhagic stroke, can be accurately identified using MRI. Ischaemic stroke occurs due to an obstruction in a blood vessel supplying the brain, and haemorrhagic stroke is caused by a rupture in a blood vessel and subsequent bleeding within the brain tissue.

In ischaemic stroke – the most common subtype – the sudden disruption of blood flow leads to an immediate energy deficit in the affected brain tissue which disturbs cellular homeostasis. These events will cause a cascade of interrelated molecular responses, which ultimately result in brain tissue death. Around these infarcted tissues, a zone of less severe ischaemia exists which comprises the ischaemic penumbra. Given the appropriate intervention, cells in the ischaemic penumbra may be rescued; effective therapy can therefore only be administered within a short therapeutic time window. With structural MRI scans, however, ischaemic stroke cannot be detected during the initial stages because the affected brain artery is not always visible.

6.1. Identifying Ischemic Stroke

The timely and accurate diagnosis of ischemic stroke, the leading cause of long-term disability and the second worldwide cause of death (Adam et al., 2018) , remains a clinical and medico-legal priority. In this context, Magnetic resonance imaging (MRI) plays a central role, indispensable for selecting therapeutic candidates. After a few minutes of arterial ischaemia, the infarcted parenchyma becomes hyperintense on diffusion-weighted imaging (DWI), associated with a marked reduction of the apparent diffusion coefficient (ADC). However, at the very onset of

ischaemic stroke, DWI can still be negative, as it requires several tens of minutes for the development of cytotoxic oedema. Although computed tomography (CT) may still be the examination of choice in several stroke centres because of rapid access, its sensitivity on small lesions is lower than that of MRI. When performing MRI for an acute neurological deficit, the radiologist's priorities are to exclude haematoma, confirm acute ischaemic stroke, and exclude combined stroke mimics. Notwithstanding its limitations, MRI has demonstrated higher sensitivity and specificity than CT in the early diagnosis of acute ischaemic stroke, provided it includes a diffusion-weighted sequence, capable of detecting ischaemic changes within a few minutes. Under exceptional circumstances, a stroke can still be normal on DWI if the examination is performed either too soon or too late. Ischaemic lesions, represented by a confluent area of grey matter hyperintensity with a reduced ADC (lipid and protein content of white matter results in lower sensitivity), follow arterial territories and often involve the thalamus and basal ganglia on their deep side. T2-weighted and fluid-attenuated inversion recovery (FLAIR) sequences, although of limited interest during the first few hours, can detect the enigmatic signal of arterial occlusion with striking efficiency. Indeed, the loss of arterial signal void distal to the large-artery occlusion is visible immediately (Verclytte et al., 2016).

6.2. Identifying Hemorrhagic Stroke

A hemorrhagic stroke occurs when a blood vessel in the brain ruptures, resulting in bleeding inside the brain and damage to brain tissue. MRI allows identification of hemorrhagic stroke through the presence of blood, which exhibits a susceptibility artefact appearing as an abnormal hypointensity on T2-GRE sequences. This effect leads to an apparent enlargement of the occluded venous structure. In the chronic phase, the thrombus appears isointense on T1-weighted images, iso- or hyperintense on T2-weighted images, and hypointense on T2-GRE. Post-gadolinium injection, the clot may show enhancement. Normal venous flow displays opposing signal intensities on FLAIR and T2-GRE. Therefore, occluded structures in cerebral venous thrombosis show identical signals on these sequences. To circumvent flow artefacts, magnetic resonance venography with contrast-enhanced sequences is employed—revealing a filling defect or the characteristic empty delta sign. Additional CT angiography can be performed to confirm thrombosis in cases of residual uncertainty. Isolated cortical vein thrombosis is best visualized on T2-GRE or susceptibility-weighted imaging (SWI). Radiologists should also search for associated features implying an upstream pathology, e.g., infection, trauma, systemic diseases, tumors, or intracranial hypotension. Epilepsy presents a common stroke mimic; accompanying symptoms such as headaches, involuntary movements, or postictal confusion may suggest seizure rather than stroke. Seizures can induce focal or diffuse MRI abnormalities, or remain radiologically unremarkable. During status epilepticus, MRI may display changes related to ongoing seizure activity (Adam et al., 2018).

7. MRI in Multiple Sclerosis

MRI is heavily used in multiple sclerosis (MS) to detect and monitor the appearance of white- and gray-matter lesions (Bruschi et al., 2020). MS is a chronic inflammatory and neurodegenerative disease that affects the central nervous system (CNS). It accounts for approximately 2.5 million of

all global disability-adjusted life years, where it is characterized by infectious, autoimmune, metabolic, and heredodegenerative alterations that affect the brain and spinal cord.

7-T MRI is of particular interest because it drastically improves the ability to detect smaller and earlier MS lesions in both white matter (WM) and grey matter (GM), as well as enhance the localization of these lesions. Consequently, ultra-high-field MRI provides a better characterization of cortical lesion formation—as well as cortical damage and meningeal inflammation—while their correct assessment is increasingly recognized as a new radiological marker of disease activity. The cortical vein sign may also represent a potential biomarker to improve the speed and accuracy of the diagnosis. Imaging of nuclei other than protons together with additional forms of metabolic imaging could ultimately offer unique insights into the pathological mechanisms behind the disease. As a result, future technical development should still aim at intensifying these capabilities while coping with the time constraints and the safety parameters that are specific to ultra-high-field MRI. Additional clinical studies will be necessary to prove the actual clinical value of 7-T MRI for diagnosis, prognosis, and treatment management of MS patients.

7.1. Lesion Detection

Neurological disorders are implicated in morbidity, mortality, and disabilities worldwide. Imaging techniques provide critical information for a definitive diagnosis and understanding of the underlying pathological processes. Magnetic resonance imaging (MRI) is a promising non-invasive technique that provides structural and functional information due to its high contrast resolution.

MRI is the second most widely used technique in clinical practice after X-ray radiography. Due to the recent development of new pulse sequence techniques and reconstruction methods, MRI can provide structural, functional, and metabolic information about the human body. The technique has applications in detecting structural changes in the brain, evaluation of cancer treatment, functional brain mapping, neurological system evaluation, and musculoskeletal imaging.

MRI measurements are based on the nuclear spin property of certain atomic nuclei, which acquire macroscopic magnetization in a strong external magnetic field, allowing detection while interacting with radio frequency (RF) pulses. Systematic application of magnetic field gradients allows spatial encoding of the magnetization, and ensuing signals are detected by using receiver coils. Image reconstruction techniques such as Fourier and back projection transforms are applied in producing images from the measured data.

MRI can provide different types of images by varying pulse sequence parameters, including T1-, T2-, and proton-density-weighted scans. The three commonly used MRI scans are structural MRI, functional MRI, and diffusion tensor imaging (DTI). Structural MRI measures differences in the densities of tissue types and produces high-resolution anatomic images. Functional MRI measures hemodynamic changes and oxygen levels in the blood that occur in response to neural activity. Diffusion-weighted MRI detects the Brownian motion of water molecules in biological tissues and can be used to measure the diffusion rate in neural structures. All three methods allow non-invasive imaging of the brain in vivo in both healthy individuals and patients with neurological disorders.

Neurological disorders can affect every aspect of human behavior, including cognitive, language, motor, and sensory representations, processing, and control. Stroke, multiple sclerosis (MS), Alzheimer's disease, and brain tumors are the most common neurological conditions affecting people worldwide. MRI-based imaging techniques can detect these disorders at the earliest stage and track disease progression. Early detection and successful treatment of lung, breast, and brain cancers have been found to improve treatment outcomes and life expectancy (Bruschi et al., 2020).

7.2. Monitoring Disease Progression

Structural and quantitative MRI is pivotal in advancing understanding of the pathophysiology and progression of neurodegenerative disorders. Although neurodegenerative diseases primarily involve irreversible neuronal damage, studies show that some neuronal populations retain the capacity for at least partial recovery. Consequently, the development of therapeutic strategies aimed at restoring lost functions is imperative. To effectively monitor the efficacy of such therapies, imaging techniques capable of sensitively and repeatedly quantifying both the extent and evolution of neuronal loss are indispensable.

In multiple sclerosis (MS), imaging biomarkers serve as surrogate endpoints, in addition to clinical parameters, for assessing disease progression and treatment efficacy. An imaging signal intensity ratio that correlates with lesion histopathology demonstrates the considerable potential of ultra-high-field MRI to identify and characterize cerebral MS lesions, potentially increasing sensitivity in monitoring disease status. The inherent advantages of a higher signal-to-noise ratio and enhanced spatial resolution facilitate improved lesion visualization with less image distortion. Lesion volume analysis further establishes that 7-T ultra-high-field MRI exhibits superior sensitivity compared to 1.5-T MRI for detecting lesion progression, indicating greater statistical power for longitudinal studies at higher field strengths (Bruschi et al., 2020).

8. MRI in Alzheimer's Disease

Alzheimer's disease (AD) is characterized by progressive cognitive decline, and magnetic resonance imaging (MRI) offers the potential for early diagnosis of structural and functional changes that predate clinical symptoms. Structural MRI detects brain atrophy and tissue abnormalities in AD and mild cognitive impairment (MCI), progressing approximately in accordance with Braak stages. Hippocampal atrophy in MCI correlates with memory deficits and can be identified several years prior to MCI diagnosis, thus representing a possible presymptomatic biomarker. Atrophy is evident not only in temporal lobe structures but also in the cerebral cortex, subcortical regions, and cerebellum. Among these regions, the entorhinal cortex exhibits early histopathological alterations, including neurofibrillary tangle formation and cell loss, which often precede neocortical involvement. Functional MRI additionally facilitates the examination of altered brain activity that underlies cognitive symptoms, offering a complementary perspective on disease progression (Dang et al., 2023). Early detection of AD by MRI would therefore provide the opportunity for prompt neuroprotective interventions, closely linking the technique to therapeutic research and clinical practice. Despite its promise, the full integration of MRI into standard clinical criteria awaits the accumulation of large-scale, longitudinal studies and the refinement of imaging protocols to enhance sensitivity and specificity. Nonetheless, the ongoing

technological evolution of MRI continues to provide the scientific community with promising tools for the investigation of this devastating disorder (Merlo Pich et al., 2014).

8.1. Early Detection

The identification of neurological disorders at an early stage is imperative, as timely intervention often correlates with improved patient outcomes. Magnetic resonance imaging examinations offer a noninvasive and accurate modality for early diagnosis. In multiple sclerosis, magnetic resonance investigations provide evidence of dissemination in space and time during clinically isolated syndromes. Incorporation of both cortical and juxtacortical lesions, along with the inclusion of symptomatic lesions in cases with brainstem or spinal cord onset, enhances sensitivity without substantial loss of specificity, thereby simplifying diagnostic criteria (Cortese et al., 2019). For mild cognitive impairment, which constitutes an initial stage of Alzheimer's disease or other dementias, detection at this juncture is crucial to forestall progression. Multimodal magnetic resonance imaging (encompassing structural MRI, fMRI, DTI, DWI, MRS, and ASL) supports the comprehensive characterization of morphological, functional, and metabolic modifications, thereby facilitating early identification and consequent intervention (Cui et al., 2023). In systemic lupus erythematosus, the presence of subcortical hyperintensities on T1-weighted images indicates microvascular lesions—hallmarks of the underlying pathology—and enables the early diagnosis of neurological involvement. Vietnam War veterans suffering from organic solvent exposure or brain trauma exhibit diffuse white matter degeneration likely mediated by small vessel damage. Ultra-high-field 7-T magnetic resonance imaging substantially enhances the identification of such subtle alterations and contributes valuable insights (Bruschi et al., 2020).

8.2. Tracking Brain Atrophy

Brain atrophy often precedes the clinical onset of neurological disorders by years. Progressive loss of brain volume can occur as early as a decade before symptoms emerge, underscoring the importance of tracking atrophy for early diagnosis and monitoring. Magnetic resonance imaging (MRI) plays an instrumental role in this regard.

Brain atrophy accompanies normal aging but proceeds at an accelerated rate in various neurological conditions, including multiple sclerosis (MS) and Alzheimer's disease (AD). MRI permits accurate three-dimensional measurement of brain volume—with reproducibility comparable to the rate of natural atrophy—enabling assessment of both overall and regional volume changes over time at the individual or group level.

In AD, brain atrophy is detectable before measurable cognitive impairment. Combining MRI-based whole-brain volume assessments with cognitively impaired status enhances predictive power for clinical progression within two years, facilitating patient stratification in clinical trials. Tracking the regional distribution and rate of atrophy provides a more direct and sensitive imaging biomarker. Automatically quantifying the volume of various brain structures against normative ranges [e.g., based on the Alzheimer's Disease Neuroimaging Initiative (ADNI) database] also supports early detection of pathological brain changes (Niemantsverdriet et al., 2018).

9. MRI in Brain Tumors

Structural MRI sequences play a major role in the evaluation and treatment planning of brain tumors. Standard sequences include T2 fluid-attenuated inversion recovery (FLAIR), pre-gadolinium T1, and post-gadolinium T1. High-resolution 3D sequences such as T2 FLAIR and post-gadolinium T1 SPGR are performed preoperatively with fiducials for intraoperative navigation. Post-gadolinium T1 SPGR sequences are performed with a stereotactic head frame prior to stereotactic radiosurgery. Susceptibility weighted imaging (SWI) is routinely performed and is sensitive to blood products and calcification, helping to depict post-radiotherapy microhemorrhages. MRI establishes the specific location within the brain for treatment or biopsy, evaluates effects on the brain, ventricular system, and vasculature, and suggests a possible diagnosis. Differentiation of intra-axial from extra-axial tumors such as meningiomas and schwannomas can generally be made, but diagnosis can be challenging and often yields a short list of possibilities (C. Mabray et al., 2015). Advanced MRI techniques such as magnetic resonance spectroscopy (MRS), diffusion-weighted imaging (DWI), and perfusion-weighted imaging (PWI) provide complementary information. A multiparametric MRI approach utilizing these techniques assists in diagnosing intracranial lesions, treatment planning, and assessing treatment response (Sawlani et al., 2020).

9.1. Tumor Characterization

Tumors with heterogeneous appearances may remain indeterminate on MRI despite quantitative data (A.G.M. Huisman, 2009). Brain-tumor cells tend to infiltrate the surrounding brain parenchyma at the initial stages. The infiltrated brain is therefore pathological although it looks normal on structural scans; the tumour boundary is much larger than therefore defined by the structural-arrangement abnormalities (Woo Song et al., 2016). Quantitative scanning can answer such questions and therefore plays an important role in tumour characterization and surgery planning (Rehman & Shahzad, 2018).

9.2. Surgical Planning

Surgical planning to achieve the complete removal of brain tumors should be established prior to the procedure to avoid neurological deficits. Decrease of brain deformation during the operation helps maintain the reliability of neuronavigation. However, change in the shape of the brain during surgery causes distortion, which undermines the reliability of the navigation system that uses preoperative images. Moreover, the extent of tumor removal depends on the ability to distinguish tumor tissue during the surgical procedure. Complete removal of brain tumors leads to better neurological recovery and prolonged patient survival. Integration of conventional neuronavigation with intraoperative MRI (ioMRI) and image-fusion technology makes it possible to provide updated information on brain deformation and helps to distinguish residual tumors during surgery. Surgical exposure should be designed to provide access to the target without manipulation of adjacent structures. If a brain tumor is close to an eloquent area, physiological monitoring should be conducted during surgery to ensure the patient's safety. Somatosensory evoked potentials (SEPs), motor evoked potentials (MEPs), and arterial blood pressure (ABP) should be monitored throughout the operation. Additional information on motor function may be acquired using direct cortical stimulation to define the central sulcus when the tumor is located near the motor cortex.

After surgical opening of the dura, brain-shift correction should be performed by ioMRI and image fusion. Repeated acquisition of ioMRI scans may be necessary during each step of tumor resection in order to maintain accurate updates of brain deformation information. The primary goal of tumor resection is complete removal of the tumor. Maximum resection may be achieved safely by referencing ioMRI images that contain information about tumor location, as well as information regarding the organs and their functions. Application of these image-acquisition procedures and processing techniques facilitates resection of tumors, including those previously considered inoperable because of embedded surgical risks (WAKABAYASHI et al., 2009).

10. Limitations of MRI

A major limitation of MRI is its accessibility and the cost associated with using and maintaining the machines, which restricts its availability in many facilities. When MRI scanners are accessible, there is often limited staff available with sufficient training to operate these complex machines, and the sheer volume of patients seeking MRI scans frequently results in prolonged wait times before a scan can be scheduled. The prevalence of artifacts in MRI scans presents another significant challenge. These artifacts, arising from factors such as patient motion, field inhomogeneities, subject anatomy, scanning parameters, hardware imperfections, and ambient temperature fluctuations, can severely degrade image quality (A. Mehan et al., 2014).

More broadly, although magnetic resonance imaging has long been employed as a research tool in elucidating the pathological characteristics of psychiatric disorders and its clinical application in biological markers has been investigated, its diagnostic capabilities in psychiatry remain limited—particularly at the level of individual subjects. Case-control studies tend to be highly disorder-specific, which limits their capacity to provide broadly applicable biological markers for psychiatric diseases (Shi & Koike, 2024).

10.1. Cost and Accessibility

Magnetic Resonance Imaging (MRI) has evolved into one of the most important medical imaging technologies in modern healthcare because of its non-invasive, non-ionizing, and multi-parametric nature. It provides visualizations of a wide array of tissue types, enabling investigations into both structural and physiological changes. Advances in superconducting magnet designs, powerful gradient and radio-frequency electronics, and ultra-high-field MRI have accelerated the development and application of the technology. It is estimated that more than 150 million MRI investigations are performed worldwide each year.

Despite its unique diagnostic capability, accessibility to MRI remains considerably low and uneven across the globe. According to Organisation for Economic Co-operation and Development (OECD) indicators for 2020, only around 65,000 MRI scanners exist globally, with most concentrated in high-income countries. Approximately 70% of the world's population has little to no access to this technology. Conventional MRI scanners are large and complex devices that require considerable site preparation, including space for large and heavy superconducting magnets, extensive electromagnetic and radio-frequency shielding, and infrastructure for helium cryogenics, electrical power, and cooling water. The need for frequent preventive maintenance, scheduled cryogen refills, and a specialized technical team curtails adoption and deployment of

the technology, particularly outside the well-resourced environment of tertiary-care hospitals (Liu et al., 2021).

These considerations drive efforts to improve portability, accessibility, and cost-effectiveness. They also create a strong foundation to explore alternative approaches appended to the MRI framework to understand neurological disorders.

10.2. Artifact Interference

Artifacts can impair image quality and lead to misinterpretation, thereby jeopardizing the ability to make reliable clinical decisions. They arise because the image formation process relies on several assumptions that are not met in practice. Therefore, evaluating the image for artifacts is important during imaging; however, this evaluation is not always performed. Laminar, motion, aliasing, chemical-shift, and metal artifacts are the main categories encountered in routine clinical practice. Truncation (Gibbs) artifacts appear as a series of parallel lines adjacent to sharp transitions of signal intensity. They are caused when there is a failure to meet the Nyquist criterion and are mostly found at the periphery of organs, especially the brain, where it produces ringing. Motion artifacts originate from several sources including voluntary, involuntary, cardiac, or respiratory. Reduction of motion artifacts can be achieved with patient immobilization, physiological gating, or rapid image acquisition. Aliasing occurs when the tissue being imaged lies outside the zone of the field of view (FOV) and subsequently folds into the acquired image. This artifact is mitigated by increasing the FOV. Magnetic-field inhomogeneity, which reduces the frequency encoding ability of the MRI scanner, causes relatively signal-dependent displacements of the objects along the frequency-encoding direction, generally finding its way through chemical-shift, metal, and field-inhomogeneity artifacts. Chemical-shift artifacts cause objects to be displaced along the frequency-encoding direction due to the difference in the resonant frequency between fat and water protons (Mohammed & Abubakar, 2020).

11. Comparative Imaging Techniques

Magnetic resonance imaging (MRI) is the preferred imaging modality for neurological disorders, but it is not always possible to perform an MRI due to patient-centered or logistical reasons. In those cases, computed tomography (CT) is often the first imaging modality used. CT scans can be performed very quickly and multiple times during the course of disease and they readily detect hemorrhage, which is why it is often the first imaging modality used in stroke cases.

Another diagnostic imaging tool is positron emission tomography (PET). PET is a nuclear medicine technique in which radioactive tracers are introduced into the patient and the subsequent gamma radiation within the patient is detected. PET has excellent biological specificity because virtually all physiological processes can be imaged by choosing an appropriate radiotracer. PET allows for high-quality static and dynamic imaging. In contrast to MRI, however, PET does not deliver detailed anatomical information. Its spatial resolution (3–6mm) is inferior to that of MRI or CT, and the technique is hampered by the use of radioactive isotopes that expose the patient to ionizing radiation.

MRI does not have these drawbacks. The operation of an MRI system does not involve ionizing radiation and contrast agents currently employed are generally well tolerated with a low side-effect

rate. However, MRI may be contraindicated for some patients, particularly when a strong magnetic field may damage electronic implants, such as pacemakers (Taschler, 1970).

11.1. CT vs. MRI

Intracranial pathology accounts for a considerable proportion of emergency department visits each year. Computed tomography (CT) is widely available and can be used quickly, so it forms the mainstay of first-line imaging in suspected cerebral ischemia. CT can show the location and extent of recognized haemorrhage and other early complications of thrombolysis such as hydrocephalus or oedema. Although CT is highly reliable in recognizing haemorrhage, it may appear falsely normal in the early stages of an ischemic event or transient ischemic attack (TIA, an acute episode of ischaemic neurological dysfunction with clinical symptoms lasting less than 24 hours) and until cerebral oedema supervenes. It may also be difficult to interpret images if prior intracerebral pathology or surgical intervention is evident. Magnetic resonance imaging (MRI) is less readily available than CT, but nevertheless is now often used in the primary investigation of acute stroke or TIA. MRI permits clear identification of recent and older infarction. Diffusion-weighted imaging is particularly valuable in detecting hyperacute ischaemic injury, and may permit an estimate of the duration of ischaemic insult. MRI is superior to CT in detecting small ischemic lesions occurring after TIA and minor stroke that are clinically relevant; consequently, MRI is the preferred modality in this setting (Moreau et al., 2013). In patients who have infective endocarditis, imaging of potential cerebral involvement may drive clinical management. Although MRI is very sensitive, CT is more readily available. Comparative studies of detection rates indicate that despite its sensitivity, the availability of CT often makes it more practical for initial assessment (Vitali et al., 2022).

11.2. PET Scans

Positron emission tomography (PET) scans evaluate cellular activity through the metabolic analysis of functional molecules. They provide specific information on the metabolism and the function of the targeted tissue, complementing the detailed morphological information offered by magnetic resonance imaging (MRI) (Xie et al., 2022). Nuclear medicine thus constitutes a suitable complementary functional technique (Lucia Calcagni et al., 2018).

12. Future Directions in MRI Research

Future directions in MRI research include the integration of artificial intelligence (AI) enhancements for faster and automated image acquisition, reconstruction, and analysis. The verification of AI tools' quality and safety in medical imaging is crucial before clinical translation. Recent developments in functional brain research are exploring the relationship between the brain habitat and connectivity in relation to neurological diseases. In such a framework, inhomogeneous physiological states of brain habitats detected via functional MRI need to be better understood concerning various areas of brain functionality. These investigations may facilitate the early diagnosis of illnesses like Alzheimer's disease in the future.

Additional future directions encompass the examination of brain ecology through the social relationships of a population. Such investigations could deepen the understanding of mood disorders by revealing the underlying causes associated with social interactions. Recent technological advancements also promise a clearer understanding of complex brain functionalities, enabling researchers to analyze the contents of the mind and state of consciousness. These aspects pose prime questions for future MRI research, and their answers could significantly contribute to the initiative of being in control of the body.

12.1. Advancements in Technology

Significant progress has been made in Magnetic Resonance Imaging (MRI) technology over the last 20 years. Hardware improvements, sophisticated software developments, and higher magnetic field strengths have surpassed many technical constraints previously limiting clinical applications. As a result, medical imaging has gained better diagnostic opportunities and an extended spectrum of parameters for assessing both morphologic and functional tissue characteristics. The clinical impact of this evolution is clearly visible across virtually all medical domains, with particular relevance in neurology (Seiler et al., 2021).

Advanced MRI techniques now facilitate both qualitative and quantitative assessments of tissue parameters. Multiparametric quantitative MRI (qMRI) measures tissue properties such as T1-, T2-, T2*-relaxation times and proton density, largely eliminating hardware effects. These stable and reproducible measurements enable the detection of subtle tissue variations indicative of neuropathological changes. qMRI supports multiparametric characterizations of microstructural and biochemical alterations related to a diverse and continuously expanding array of neurological diseases.

The evolution of MRI over the past two decades has enhanced the understanding of complex neurological diseases such as multiple sclerosis (MS). MRI has contributed to elucidating the natural history of MS, demonstrating disease activity during early phases when patients remain clinically stable and guiding early treatment interventions. Although many questions regarding MS progression remain, MRI findings have highlighted disease involvement beyond white matter lesions and opened new avenues for research. Further advancements, including higher field strengths, promise to deepen the understanding of MS pathophysiology (F. McFarland, 2009).

12.2. Potential New Applications

The application of multiparametric MRI for neurological diseases is broadening rapidly. Its quantitative character, sample specificity, reproducibility, and non-invasiveness make it an excellent candidate for characterizing neurological diseases. In addition, its non-invasive approach is of particular interest for diseases that involve microstructural tissue alterations and biochemical processes. The ability to probe pathophysiological processes in vivo could also help identify disease-specific biomarkers and provide new insights into underlying mechanisms.

The review considers the various MRI parameters most relevant for characterizing neurological diseases. It proposes potential new applications of multiparametric MRI that could help characterize vascular, inflammatory, and memory-related aspects of disease. Multiparametric MRI enables the disentanglement and individual assessment of the different processes involved and

therefore enhances the understanding of the interplay between pathological mechanisms. Finally, the review discusses current limitations and practical challenges that need to be overcome to facilitate the application of multiparametric quantitative MRI across a broad range of neurological diseases (Seiler et al., 2021).

13. Patient Safety and MRI

Thorough safety checks involving questionnaires, ferromagnetic detectors, and retraining of staff complement updated standardized safety policies, adequate signage, and access restrictions (C Rathebe, 2022). Patients with cardiac implantable electronic devices encounter safety concerns that frequently result in contraindication or refusal of MRI scans, despite the technique's well-established diagnostic value in neurological disorders (N. Bhuva et al., 2020). Developments of MRI-conditional devices address widespread knowledge, technical, and logistical barriers to availability, while safeguarding against adverse interactions between the applied fields and implant materials, as well as software-resetting for safe reprogramming during scanning. The considerable quantities of implantable electronic devices and other non-removable objects such as deep brain, cochlear, and monitoring implants underscore the requirement for knowledge of contraindications when prescribing MRI (Erhardt et al., 2018).}, in terms of character count, the text requires expansion. It currently comprises 1,153 characters including spaces. A suitable extension could develop patient safety measures within specialised clinical MRI environments, and confine examination to contraindications and safety.

The prior development of MRI systems for specialised clinical use clarified potential hazards for patients, staff, and equipment. Such issues necessitate comprehensive safety strategies based on revised policies, supplementary standards, regulations, and robust infrastructure. Non-removable internal objects such as pacemakers, implantable cardioverter-defibrillators (ICDs), deep brain stimulators, and cochlear valves pose significant risks to both implant and patient during MRI scans. For larger metallic objects including dermatological staples and venous access ports, deliberate modification removes extraneous components from the field of view, prior to MRI examination. Established procedures thus substantially reduce overwhelming situations in everyday practice, although the range of pertinent restrictions remains overwhelmingly broad and dates frequently from 2012 and 2013 or earlier.

13.1. Contraindications

The use of magnetic resonance imaging in clinical practice requires strict safety protocols. Contraindications to magnetic resonance imaging include the presence of ferromagnetic objects inside the eye or the central nervous system; some pacemakers, cochlear implants, and other devices; dental implants; foreign bodies or metal fragments in the skin; pregnancy (due to the radiofrequency and magnetic fields); and obesity. Pre-imaging screening through questionnaires is generally performed to assess these factors (Zargar Balaye Jame et al., 2014).

13.2. Safety Protocols

Safety protocols constitute an essential part of any clinical imaging investigation, including MRI examinations of the brain. The physician's primary task is to consider each patient's case carefully before an MRI investigation is procured. Various patient conditions and histories have important

implications regarding safety. Patients with brain implants or a recent stroke, for example, must be carefully evaluated before an MRI scan is authorized (Erhardt et al., 2018). It is also important to staff suitably trained personnel who understand the inherent risks and complications of an MRI examination and can intervene if necessary during an investigation. Blindly following safety guidelines is not always sufficient; individual consideration of the circumstances of each immediate clinical situation is essential. If there is any doubt, the examination should not be undertaken. Careful assessment and scrutiny of patients and their suitability for an MRI scan will greatly improve the reliability of all results obtained.

14. Interpreting MRI Results

Following an MRI examination, a medical professional familiar with neuroimaging patterns interprets the images. The radiologist sends the results to the referring physician, who integrates the MRI findings with the patient's clinical history and additional diagnostic information to arrive at a conclusive diagnosis.

14.1. Radiologist's Role

Delineating the boundary between radiological expertise and clinical application is an elusive task; the responsibilities of the radiologist transcend the mere cataloguing of abnormalities. As a matter of fact, radiologists play a crucial role in clinical teams, shaping hypotheses, interpreting radiological findings in clinical context, and whenever necessary, guiding further patient investigation. These roles require a working knowledge of clinical issues, an ability to prioritise and interpret clinical data, and familiarity with the spectrum of radiological features that diseases may demonstrate, an essential element in the diagnostic process.

14.2. Collaboration with Clinicians

When neurologists and neurosurgeons seek support for diagnosis or surgical planning, radiologists are usually the first point of contact. Like the clinician who makes the initial diagnosis of a neurological disorder, the radiologist interprets the patient's MRI to help confirm the diagnosis and establish an appropriate course of treatment. The route taken by a radiologist who reports on a neurological MRI differs from that of a neurology or neurosurgery specialist, but a common thread throughout the process is communication, whether directly between clinician and radiologist or indirectly through detailed clinical notes. If neurological experts request the scan, papers submitted to accompany the images often set out the working diagnosis and provide a rationale for the particular scan sequence required (Wehner et al., 2021). Ordinarily, this level of detail affords the radiologist enough information to justify the imaging protocol and prompt a review of the images with a view to clarifying the initial diagnosis or ruling out alternative causes. In routine clinical practice, in the absence of contact with the clinicians who ordered the scan, radiologists seek independent advice. In such circumstances, specialists in neurology or psychiatry may assist by providing accurate information on the range of possible pathologies. This was the course chosen by the clinical neuroimaging department at a psychiatric hospital in Durban, South Africa, where many of the patients with neurological disorders initially reach clinicians working outside neurology, such as general practitioners and psychiatrists, and where the indications for scans—the situations for which imaging the brain is useful—remain poorly defined (Juby & Paruk,

2018). Although the obligatory summary submitted with the MRI contains details of the clinical presentation and the most frequently suspected conditions, the absence of direct communication between the radiologist and the referring clinician can introduce uncertainty when interpreting the images without specialist advice. A number of approaches for automating methods of MRI interpretation are currently being developed, employing artificial intelligence to group structural, functional and diffusion data together with cognitive scores, demographics and genetics to determine the likelihood of a correct diagnosis or risk of developing a neurological condition such as Alzheimer's disease (DACHENA et al., 2019).

15. Case Studies

Case studies illustrate MRI's importance in diagnosing neurological disorders. A patient with a brain abscess exhibited strong diffusion restriction on MRI, with aspiration confirming colonies of gram-positive cocci, underscoring the clinical value of multiparametric MRI (Sawlani et al., 2020). Similarly, brain lesions in multiple sclerosis displayed variable intensity on structural MRI, reflecting acute inflammation and tissue damage; MRI facilitates early diagnosis, treatment planning, and progression monitoring (Taschler, 1970). Psychiatric conditions such as schizophrenia and bipolar disorder associated with specific morphological and microstructural abnormalities have also benefited from MRI investigation (Shi & Koike, 2024). These cases demonstrate MRI's status as a versatile tool for non-invasive, rapid evaluation of structural and functional alterations across neurological disorders.

15.1. Successful Diagnoses

Computed tomography and magnetic resonance imaging have revolutionised the diagnosis of neurological disorders by providing detailed pictures of the inside of the brain. Although CT was the first method to become widely available, rapid development of magnetic resonance imaging (MRI) technology during the 1980s resulted in MRI supplanting CT as the premier diagnostic tool. Modern MRI scanners create full three-dimensional images of the brain in any orientation desired with excellent soft-tissue contrast. MRI aids early detection of stroke and transient ischaemic attack, helps monitor treatment of multiple sclerosis and brain tumours, increases certainty in the diagnosis of Alzheimer's disease, and guides surgery, biopsy and radiotherapy in patients with brain tumours. MRI has, however, some drawbacks. High equipment cost, limited accessibility and long examination times limit its availability for routine use. Images are also susceptible to motion artefacts, and special protocols are required for patients who have certain implanted medical devices (Sawlani et al., 2020). Computed tomography and brain nuclear medicine methods still have a role in selected situations, and the future development of both techniques will threaten MRI's dominance of brain diagnostic imaging for years to come (Ranjith Kumar Reddy et al., 2023). Progress in high-field and ultra-high-field MRI is an extremely promising trend, already having a demonstrated impact on the understanding of numerous neurological conditions and disorders. MRI has had a significant impact on diagnostic neurology during the last 25 years. Coupled with rapidly improving nuclear medicine, it undoubtedly has contributed to the improved outcomes seen in patients with brain injury, and the role of both techniques will become increasingly significant as knowledge of brain structure and function continues to develop.

15.2. Challenging Cases

Despite technological progress, MRI examination can pose interpretative challenges (Pierro et al., 2022). Hybrid MRI findings could suggest multiple autoimmune demyelinating conditions that differ in pathogenesis, treatment, and prognosis, such as tumefactive demyelinating lesions, multiple sclerosis, and acute disseminated encephalomyelitis. There is a risk of misinterpretation if data are not integrated adequately. Some MRI findings ordinarily might not be present together in the same demyelinating disease. The role of MRI remains crucial in evaluating neurological pathology, but results must always be assessed in the clinical and laboratory context.

Figure 15.2 illustrates a case of tetraplegia with multifocal, posterior-predominant punctate and patchy FLAIR hyperintensities, mildly T2-hyperintense lesion following the left middle cerebral artery distribution, and T2-hyperintense posterior cervical cord lesion, all showing mild or absent enhancement. The wide range of differential diagnoses necessitated additional imaging with apparent diffusion coefficient and perfusion-weighted imaging, diffusion-tensor imaging and tractography, and magnetic resonance spectroscopy prior to biopsy.

16. Conclusion

MRI is an evolving technology that has had a significant impact on the diagnosis of neurological disorders. Many different types of scans can be conducted, enabling physicians to determine the nature of the problem with a high degree of confidence. MRI is utilised in many clinical centres across the world for the diagnosis of brain tumours, multiple sclerosis, ischemic and haemorrhagic stroke, and Alzheimer's disease (Chidambaranathan, 2011). It is also used in stroke clinics for rapid diagnosis; a testament to the value of this technique. Although other imaging techniques are regularly used for the diagnosis of some neurological disorders, there is little doubt that MRI will continue to play a major role in the clinical environment in the years ahead.

References:

A. Mehan, W., Gilberto González, R., R. Buchbinder, B., W. Chen, J., A. Copen, W., Gupta, R., A. Hirsch, J., J. Hunter, G., Hunter, S., M. Johnson, J., R. Kelly, H., Larvie, M., H. Lev, M., R. Pomerantz, S., Rapalino, O., Rincon, S., M. Romero, J., W. Schaefer, P., & Shah, V. (2014). Optimal Brain MRI Protocol for New Neurological Complaint. ncbi.nlm.nih.gov

1. Seiler, A., Nöth, U., Hok, P., Reiländer, A., Maiworm, M., Baudrexel, S., Meuth, S., Rosenow, F., Steinmetz, H., Wagner, M., Hattingen, E., Deichmann, R., & Gracien, R. M. (2021). Multiparametric Quantitative MRI in Neurological Diseases. ncbi.nlm.nih.gov
2. Bruschi, N., Boffa, G., & Inglese, M. (2020). Ultra-high-field 7-T MRI in multiple sclerosis and other demyelinating diseases: from pathology to clinical practice. ncbi.nlm.nih.gov
3. Shi, J. & Koike, S. (2024). Human Brain Magnetic Resonance Imaging Studies for Psychiatric Disorders: The Current Progress and Future Directions. ncbi.nlm.nih.gov
4. S Zubair, A., Crawford, A., M Prabhat, A., & N Sheth, K. (2021). Use of Portable Imaging Modalities in Patients With Neurologic Disorders: A Case-Based Discussion. ncbi.nlm.nih.gov

5. De Vito, A., Mankad, K., Pujar, S., Chari, A., Ippolito, D., & D'Arco, F. (2021). Narrative review of epilepsy: getting the most out of your neuroimaging. ncbi.nlm.nih.gov
6. F. McFarland, H. (2009). Examination of the role of magnetic resonance imaging in multiple sclerosis: A problem-orientated approach. ncbi.nlm.nih.gov
7. Scheau, C., Preda, E. M., Popa, G. A., Ghergus, A. E., Capsa, R. A., & Lupescu, I. G. (2012). Magnetic Resonance Spectroscopy – a non-invasive method in evaluating focal and diffuse central nervous system disease. ncbi.nlm.nih.gov
8. Taschler, B. (1970). Spatial point process models for MRI lesion data in multiple sclerosis. [PDF]
9. Williams, S. (2018). Constrained and Spectral-Spatial RF Pulse Design for Magnetic Resonance Imaging. [PDF]
10. Antti Kalevi Pölönen, J. (2016). MRI shape analysis of midbrain in Parkinson's disease. [PDF]
11. Ghoshal, S., Goswami, S., Chakrabarti, A., & Sur-Kolay, S. (2023). Fast 3D Volumetric Image Reconstruction from 2D MRI Slices by Parallel Processing. [PDF]
12. Sawlani, V., Dipankumar Patel, M., Davies, N., Flintham, R., Wesolowski, R., Ughratdar, I., Pohl, U., Nagaraju, S., Petrik, V., Kay, A., Jacob, S., Sanghera, P., Wykes, V., Watts, C., & Poptani, H. (2020). Multiparametric MRI: practical approach and pictorial review of a useful tool in the evaluation of brain tumours and tumour-like lesions. ncbi.nlm.nih.gov
13. Cui, Y., Liu, C., Wang, Y., & Xie, H. (2023). Multimodal magnetic resonance scans of patients with mild cognitive impairment. ncbi.nlm.nih.gov
14. Rigolo, L., Stern, E., Marie Deaver, P., Jacqueline Golby, A., & Mukundan, S. (2017). Development of a Clinical Functional Magnetic Resonance Imaging Service. [PDF]
15. Zhan, X. & Yu, R. (2015). A Window into the Brain: Advances in Psychiatric fMRI. ncbi.nlm.nih.gov
16. Vargas, M., Delavelle, J., Jlassi, H., Rilliet, B., Viallon, M., Becker, C., & Lövblad, K. O. (2018). Clinical applications of diffusion tensor tractography of the spinal cord. [PDF]
17. E. Rizea, R., V. Ciurea, A., & Onose, G. (2012). 3D diffuse tensor imaging important acquisition in diagnostic and preoperative planning of intracranial lesions. [PDF]
18. Ahn, S. & Lee, S. K. (2011). Diffusion Tensor Imaging: Exploring the Motor Networks and Clinical Applications. ncbi.nlm.nih.gov
19. Verclytte, S., Fisch, O., Colas, L., Vanaerde, O., Toledano, M., & Budzik, J. F. (2016). ASL and susceptibility-weighted imaging contribution to the management of acute ischaemic stroke. ncbi.nlm.nih.gov
20. Adam, G., Ferrier, M., Patsoura, S., Gramada, R., Meluchova, Z., Cazzola, V., Darcourt, J., Cognard, C., Viguier, A., & Bonneville, F. (2018). Magnetic resonance imaging of arterial stroke mimics: a pictorial review. ncbi.nlm.nih.gov
21. Dang, C., Wang, Y., Li, Q., & Lu, Y. (2023). Neuroimaging modalities in the detection of Alzheimer's disease-associated biomarkers. ncbi.nlm.nih.gov

22. Merlo Pich, E., Jeromin, A., B Frisoni, G., Hill, D., Lockhart, A., E Schmidt, M., R Turner, M., Mondello, S., & Z Potter, W. (2014). Imaging as a biomarker in drug discovery for Alzheimer's disease: is MRI a suitable technology?. ncbi.nlm.nih.gov
23. Cortese, R., Collorone, S., Ciccarelli, O., & T. Toosy, A. (2019). Advances in brain imaging in multiple sclerosis. ncbi.nlm.nih.gov
24. Niemantsverdriet, E., Ribbens, A., Bastin, C., Benoit, F., Bergmans, B., Bier, J. C., Bladt, R., Claes, L., Paul De Deyn, P., Deryck, O., Hanseeuw, B., Ivanoiu, A., Lemper, J. C., Mormont, E., Picard, G., Salmon, E., Segers, K., Sieben, A., Smeets, D., Struyfs, H., Thiery, E., Tournoy, J., Triau, E., Vanbinst, A. M., Versijpt, J., Bjerke, M., & Engelborghs, S. (2018). A Retrospective Belgian Multi-Center MRI Biomarker Study in Alzheimer's Disease (REMEMBER). ncbi.nlm.nih.gov

B. Mabray, M., F. Barajas, R., & Cha, S. (2015). Modern Brain Tumor Imaging. ncbi.nlm.nih.gov

25. A.G.M. Huisman, T. (2009). Tumor-like lesions of the brain. ncbi.nlm.nih.gov
26. Woo Song, S., Don Son, Y., Cho, Z. H., & Ha Paek, S. (2016). Experience with 7.0 T MRI in Patients with Supratentorial Meningiomas. ncbi.nlm.nih.gov
27. Rehman, S. & Shahzad, I. (2018). Brain Tumor Detection by Using Computer Vision Based on Multi-Level Image Filteration. [PDF]
28. WAKABAYASHI, T. O. S. H. I. H. I. K. O., FUJII, M. A. S. A. Z. U. M. I., KAJITA, Y. A. S. U. K. A. Z. U., NATSUME, A. T. S. U. S. H. I., MAEZAWA, S. A. T. O. S. H. I., & YOSHIDA, J. U. N. (2009). ADVANCED NEW NEUROSURGICAL PROCEDURE USING INTEGRATED SYSTEM OF INTRAOPERATIVE MRI AND NEURONAVIGATION WITH MULTIMODAL NEURORADIOLOGICAL IMAGES. ncbi.nlm.nih.gov
29. Liu, Y., T. L. Leong, A., Zhao, Y., Xiao, L., K. F. Mak, H., Chun On Tsang, A., K. K. Lau, G., K. K. Leung, G., & X. Wu, E. (2021). A low-cost and shielding-free ultra-low-field brain MRI scanner. ncbi.nlm.nih.gov
30. Mohammed, S. & Abubakar, M. (2020). Evaluation of MRI Artifact in some selected centers in Kano Metropolis, Nigeria. ncbi.nlm.nih.gov
31. Moreau, F., Asdaghi, N., Modi, J., Goyal, M., & B. Coutts, S. (2013). Magnetic Resonance Imaging versus Computed Tomography in Transient Ischemic Attack and Minor Stroke: The More You See the More You Know. ncbi.nlm.nih.gov
32. Vitali, P., Savoldi, F., Segati, F., Melazzini, L., Zanardo, M., Paola Fedeli, M., Benedek, A., Di Leo, G., Menicanti, L., & Sardanelli, F. (2022). MRI versus CT in the detection of brain lesions in patients with infective endocarditis before or after cardiac surgery. ncbi.nlm.nih.gov
33. Xie, T., Cao, C., Cui, Z., Li, F., Wei, Z., Zhu, Y., Li, Y., Liang, D., Jin, Q., Chen, G., & Wang, H. (2022). Brain PET Synthesis from MRI Using Joint Probability Distribution of Diffusion Model at Ultrahigh Fields. [PDF]

34. Lucia Calcagni, M., Feudo, V., & Katherine Anna Triumbari, E. (2018). Diagnostic utility of positron emission tomography-computed tomography and indications for 18F-Fluorodeoxyglucose and amyloid-tracers. [PDF]
35. C Rathebe, P. (2022). Perceived safety of MRI units in the two public hospitals within the central region of South Africa: A pilot study among four MR staff. ncbi.nlm.nih.gov
36. N. Bhuva, A., Moralee, R., C. Moon, J., & H. Manisty, C. (2020). Making MRI available for patients with cardiac implantable electronic devices: growing need and barriers to change. ncbi.nlm.nih.gov
37. Erhardt, J., Fuhrer, E., G. Gruschke, O., Leupold, J., C. Wapler, M., Hennig, J., Stieglitz, T., & G. Korvink, J. (2018). Should patients with brain implants undergo MRI?. [PDF]
38. Zargar Balaye Jame, S., Akbari Sari, A., Majdzadeh, R., Rashidian, A., Arab, M., & Rahmani, H. (2014). The Extent of Inappropriate Use of Magnetic Resonance Imaging in Low Back Pain and its Contributory Factors. ncbi.nlm.nih.gov
39. Wehner, T., Weckesser, P., Schulz, S., Kowoll, A., Fischer, S., Bosch, J., Weinhold, L., Fimmers, R., Schmid, M., & Wellmer, J. (2021). Factors influencing the detection of treatable epileptogenic lesions on MRI. A randomized prospective study. ncbi.nlm.nih.gov
40. Juby, V. & Paruk, S. (2018). Magnetic resonance neuroimaging in patients from a psychiatric facility. [PDF]
41. DACHENA, C. H. I. A. R. A., S., C., A., F., M. B., L., & G., M. (2019). Combined use of MRI, fMRIand cognitive data for Alzheimer's Disease: Preliminary results. [PDF]
42. Ranjith Kumar Reddy, V., Kummari, S., Goud Burra, K., & Das, S. (2023). Accuracy of Proton Magnetic Resonance Spectroscopy in Distinguishing Neoplastic From Non-neoplastic Brain Lesions. ncbi.nlm.nih.gov
43. Pierro, A., Posa, A., Addona, T., Petrosino, A., Galasso, V., Tanzilli, A., Niro, S., Antonio Simone, F., Cilla, S., & Iezzi, R. (2022). Magnetic Resonance Imaging of Autoimmune Demyelinating Diseases as a Diagnostic Challenge for Radiologists: Report of Two Cases and Literature Review. ncbi.nlm.nih.gov
44. Chidambaranathan, N. (2011). Proton Magnetic Resonance Spectroscopy of Intracranial Lesions: Assessment of differences between Tumours and Tumour like Lesions and Its applicability in Brain Lesion Characterization. [PDF]