

Review Article

A Review Article on the Advancements in Abdominal MRI

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Abstract

Magnetic Resonance Imaging (MRI) is now a key tool for looking at the abdomen. It offers better soft-tissue contrast, works in multiple planes, and does not use ionizing radiation. However, traditional abdominal MRI faces challenges. It often takes a long time to get images, and motion artifacts from breathing, digestion, and patient movement can reduce diagnostic accuracy. Recent improvements in MRI hardware, pulse sequences, and reconstruction methods have changed abdominal imaging. These advancements focus on speed, correcting motion, and assessing tissue function.

Motion reduction strategies like respiratory gating, PROPELLER/BLADE sampling, golden-angle radial acquisition, and deep learning-based image reconstruction have greatly improved image quality in uncooperative or moving patients. Accelerated imaging techniques, including parallel imaging (SENSE, GRAPPA), compressed sensing, and simultaneous multi-slice acquisition, significantly cut down scan times while keeping diagnostic quality. Functional and multiparametric techniques such as Diffusion-Weighted Imaging (DWI), Magnetic Resonance Elastography (MRE), Dynamic Contrast-Enhanced (DCE) MRI, and MR Spectroscopy (MRS) offer quantitative biomarkers for tissue issues, including fibrosis, tumor vascularity, and metabolic makeup.

Clinically, these innovations broaden MRI applications in describing lesions, monitoring therapy, staging liver fibrosis, evaluating organ stiffness, and quantifying fat and metabolites. Together, they allow for earlier disease detection, better diagnostic precision, and personalized treatment planning. In the future, combining these technologies with artificial intelligence and machine learning may bring additional improvements in motion correction, reconstruction speed, and automated tissue characterization. This will establish advanced abdominal MRI as an essential tool for precision medicine in hepatobiliary, pancreatic, and renal diseases.

Keywords: Advancement, Abdomen, Motion, Artifacts, Breath hold issues, Parallel Imaging, Simultaneous Multi-Slice Acquisition, Diffusion Imaging, Perfusion Imaging etc

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Introduction

A key component of contemporary diagnostic radiology, magnetic resonance imaging (MRI) is distinguished by its remarkable soft-tissue contrast, multiplanar capabilities, and non-ionizing properties. It is especially helpful in assessing the intricate abdominal architecture and in identifying and characterizing diseases of organs such as the kidneys, pancreas, and liver. Conventional abdominal MRI has extensive scan periods and has previously been limited by motion artifacts from respiration, intestinal peristalsis, and patient movement, despite its many benefits. These difficulties may limit the examination's diagnostic potential, require more scans, and degrade image quality.

In recent years, there has been a significant shift in abdominal MRI technology, fuelled by advancements in hardware, pulse sequences, and image reconstruction methods.⁽¹⁾ In recent years, there has been a significant shift in abdominal MRI technology, fuelled by advancements in hardware, pulse sequences, and image reconstruction methods. This new wave of MRI techniques is specifically aimed at addressing these persistent challenges, resulting in quicker, more reliable, and informative scans. This review article examines the groundbreaking

progress in abdominal MRI, emphasizing crucial technological advancements that have greatly improved diagnostic capabilities and broadened clinical uses. We will explore how these innovations—from speedier imaging methods to sophisticated functional sequences—are transforming the field and enhancing patient care.

1. We Need the Speed (Overcoming Motion Artifact): Motion artifacts are a significant challenge in abdominal MRI, primarily caused by involuntary movements like breathing and bowel peristalsis. To overcome these, modern MRI scanners employ various strategies that prioritize speed and motion-compensation.

Motion Compensation and Correction: These techniques don't necessarily make the scan faster but are designed to handle and correct for motion during the acquisition itself.

- **Respiratory Gating and Triggering:**

This technique monitors the patient's breathing using a bellows or navigator echoes and collects data only during a specific, consistent phase of the respiratory cycle (such as end-expiration). This approach ensures that all data is gathered from the same position, minimizing motion-related ghosting. Although this may prolong the overall scan duration,

it greatly enhances image quality in challenging imaging regions.

- **Golden-angle Radial Sampling:**

This method gathers data in a continuous and non-linear manner. The distinctive radial path guarantees that, despite constant movement, k-space is filled in a manner that supports motion-resistant image reconstruction.

- **The PROPELLER/BLADE**

It is very helpful for patients who are not cooperative. Sampling approach uses rotating strips or "blades" to collect data in k-space. The images are easier to comprehend since the motion is spread across several blades, creating artifacts that resemble a general blurring rather than discrete ghosts.

- **Deep Learning (DL) Reconstruction**

It is a new and effective method. High-quality images can be recovered from extremely little, under sampled, or motion-corrupted data using AI models trained on enormous MRI scan datasets. DL is an effective approach for motion artifact reduction since it may drastically cut scan times without sacrificing image quality.⁽²⁾

1. Fast Images (Faster Imaging Techniques)

Accelerated imaging techniques in MRI are methods designed to significantly reduce scan time. Intentionally gathering less data than is customarily needed and employing sophisticated algorithms to create a high-quality image from that scant data are how this is accomplished

a) **Parallel Imaging**

This fundamental technique speeds up data collecting by utilizing the spatial sensitivity of many receive coils. "undersamples" kspace, or the raw data space of an MRI scan, rather than gathering all the information required for a complete image. Every coil has a different perspective on the anatomy, the undersampled data from all of the coils combined contains sufficient information to rebuild an image devoid of artifacts. Using precalculated coil sensitivity maps,

- **SENSE (Sensitivity Encoding)** reconstructs the image by "unfolding" aliased (or folded) signals.

- **Generalized Autocalibrating Partially Parallel Acquisitions, or GRAPPA**, uses a tiny, centrally acquired calibration area to immediately fill in the missing k-space data.⁽³⁾

b) **CS or Compressed Sensing**

In contrast to other undersampling techniques, CS gathers data in a random, nonuniform fashion, avoiding the structured artifacts.

The most believable, sparse image that matches the collected data is then found using a sophisticated iterative reconstruction process. Very high acceleration factors are made possible by this, frequently allowing freebreathing scans that would otherwise necessitate lengthy breath-holds.⁽³⁾

c) **Simultaneous Multi-Slice (SMS) Acquisition**

Simultaneous Multislice (SMS) acquisition significantly cuts down on scan duration.

Because it uses a single multiband radiofrequency (RF) pulse to excite many slices simultaneously—which are typically excited sequentially—it is frequently referred to as Multiband (MB) imaging.

The primary benefit of SMS is a dramatic reduction in scan time. By shortening the acquisition window,

SMS is highly effective at minimizing motion artifacts, especially in fast-moving areas like the abdomen and heart. It can even make some free-breathing sequences feasible. The time savings can be used to acquire more slices, increase the spatial resolution of each slice, or improve the temporal resolution for dynamic imaging

1. Detailed Images (Functional & Multiparametric Imaging)

Beyond conventional anatomical imaging, functional and multiparametric MRI approaches offer quantitative insights into tissue health. There is substantial evidence to support their clinical usage, and they are essential for describing disease in abdominal organs such as the liver and pancreas.

a) **Diffusion- Weighted Imaging**

DWI measures the microscopic movement (diffusion) of water molecules within tissues. The signal is highly sensitive to the presence of cell membranes and macromolecules that restrict this movement.

Evidence: Because excessive cellularity (such as tumour's) restricts movement, water diffusion is measured by DWI. This results in brilliant images on DWI and low values on quantitative Apparent Diffusion Coefficient (ADC) maps. Research has demonstrated that demonstrated that DWI has a high perceptivity and particularity for relating and classifying nasty abdominal lesions. also, it's used to track how well a treatment is working; a rise in ADC values after remedy signifies cell death.⁽⁴⁾

b) **Glamorous Resonance Elastography (MRE)**

MRE is non-invasive fashion that measures towel stiffness, which is a crucial biomarker for fibrosis and other pathologies substantiation substantiation MRE is a veritably precise way to measure towel stiffness. It's allowed to be the most accurate non-invasive system for carrying liver fibrosis, surpassing indeed ultrasound elastography and serum testing. Because of its quantitative nature and high reproducibility, it's a vital tool for tracking the course of a complaint and assessing the effectiveness of treatment.

c) **Dynamic Differ- Enhanced (DCE)**

MRI This fashion is the most common for perfusion imaging and is frequently banded under the marquee of "functional imaging." It involves edging in a gadolinium- grounded discrepancy agent and fleetly acquiring a series of images as the discrepancy passes through the Akins. substantiation DCE- MRI provides information on blood inflow and vascular permeability by analysing the passage of a discrepancy agent through Akins. In oncology, this is especially helpful for describing tumour's according to their distinct vascular patterns. Clinical data supports the use of DCE- MRI to track response to anti-angiogenic drugs, as perfusion differences can serve as an early predictor of treatment efficacy, constantly before a tumour's size changes.⁽⁸⁾

d) **MR Spectroscopy (MRS)** MRS is a Non-invasive fashion that provides a "metabolic point" of a towel by measuring the attention of different metabolites. substantiation the metabolic "point" of towel is handed by MRS. In order to diagnose and treat Non-Alcoholic Adipose Liver Disease (NAFLD), it's the gold standard non-invasive fashion for measuring liver fat content. Compared to liver

vivisection, MRS offers a direct dimension of fat that has been demonstrated to be veritably accurate and unremarkable.⁽⁷⁾

4. Application (Clinical operation)

Lesion Characterization MRI's capability to give multiparametric and functional information enhances its capacity for lesion discovery and characterization, particularly in solid organs like the liver, order, and pancreas. Bowel and Biliary Imaging New ways are expanding the operation of MRI to the evaluation of the pancreatic and biliary ductal systems, as well as the bowel itself

a) Prolivity- Weighted Imaging (DWI)

Operations-

Characterization and discovery of excrescences Distinguishing benign from nasty lesions in the feathers, liver, and pancreas. Remedy monitoring Following treatment, an increase in the ADC value may signify cell death and a successful remedial outgrowth.

Liver fibrosis One promising system for assessing inflammation and fibrosis.⁽⁴⁾

b) Dynamic Differ- Enhanced (DCE) MRI

Operations-Excrescence characterization Assisting in the isolation of colourful excrescence forms according to their distinct vascular patterns.

Monitoring anti-angiogenic curatives Assessing an excrescence's response to treatments that target its blood force is known as covering anti-angiogenic drugs.⁽⁵⁾

c) Glamorous Resonance Elastography (MRE)

* Operations- Liver fibrosis staging Compared to other non-invasive ways similar as blood testing and ultrasound- grounded elastography, MRE is allowed to be the most accurate way to identify and carry liver fibrosis.⁽⁶⁾

* Assessing other organs Research is ongoing into the operation of MRE to estimate renal, pancreatic, and splenic stiffness is still being studied.

d) MR Spectroscopy (MRS)

Operations-

Liver fat quantification the gold standard for quantitative, non-invasive liver fat dimension is MRS, which is essential for both diagnosing and tracking non-alcoholic adipose liver complaint (NAFLD).). Excrescence characterization Because nasty excrescences have advanced cell membrane development, they constantly have an enhanced choline peak. nasty excrescences frequently show an elevated choline peak due to increased cell membrane development .⁽¹⁰⁾

5. Conclusion

Individual imaging will be revolutionized by advanced abdominal MRI ways similar as glamorous Resonance Spectroscopy (MRS), Perfusion MRI, Diffusion- Weighted Imaging (DWI), and glamorous Resonance Elastography (MRE). These ways give a deeper sapience of cellular and metabolic changes within organs, going beyond conventional anatomical perspectives.⁽⁹⁾ They grease earlier illness identification and more accurate opinion by offering preliminarily unheard- of detail on towel function, stiffness, blood inflow, and chemical composition. unborn non-invasive diagnostics will probably calculate heavily on these slice- edge styles

since their combination with artificial intelligence and machine literacy has the implicit to greatly enhance health issues and customize patient care

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