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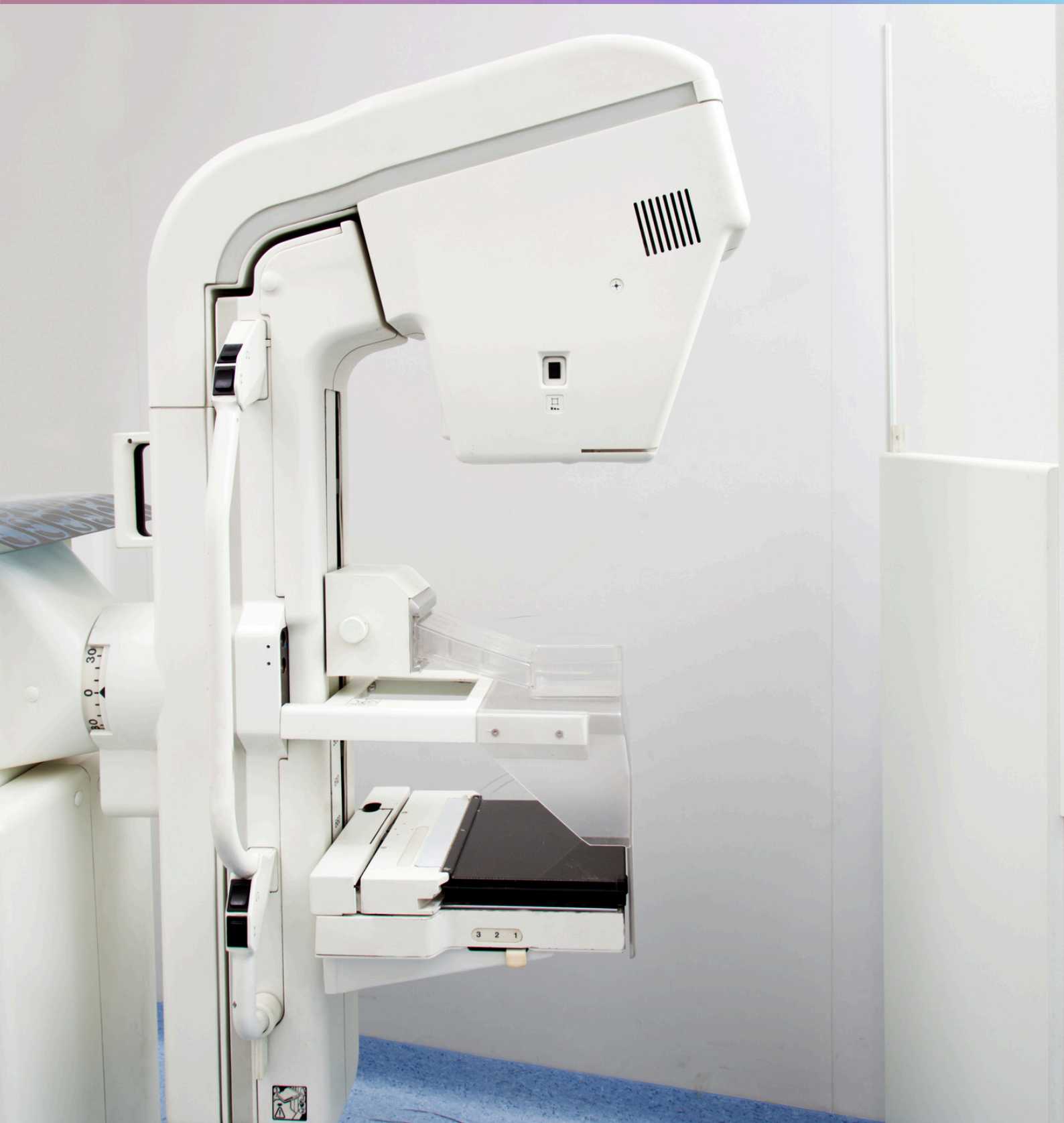
Radiographers' Journal

The official magazine of Society of Indian Radiographers (SIR)
Published by Radiographers' Association of Maharashtra (RAM)

July 2025



Editorial

Shankar K. Bhagat
Editor-in-chief

Exploring Innovation and Intelligence in Radiological Sciences

Dear Readers,

Warm greetings from the editorial desk of Radiographers Journal!

We are pleased to welcome you to the July 2025 edition of our journal. As we enter the second half of the year, this issue reflects a dynamic intersection of innovation, intelligence, and impact in the field of radiology. With significant contributions from students, practitioners, and researchers, the articles featured this month underline the rapid technological strides and evolving methodologies that are shaping the present and future of medical imaging.

Our lead feature, "Dark Field Radiography for Chest Imaging," introduces a novel radiographic approach that utilizes small-angle X-ray scattering to generate images with enhanced contrast. Unlike traditional radiographs, dark field imaging provides greater sensitivity in detecting microstructural changes in lung tissue. This makes it particularly effective in diagnosing early-stage pulmonary conditions such as emphysema and pulmonary fibrosis—conditions that often remain elusive on conventional imaging modalities. This article highlights the potential of this non-invasive method to revolutionize routine chest imaging in clinical practice.

In the next piece, "Applications of Artificial Intelligence in Musculoskeletal Radiology: Present and Prospective Technologies," the author presents a thorough review of how AI is streamlining workflows and enhancing diagnostic accuracy in musculoskeletal imaging. From automating fracture detection and joint assessments to aiding in bone tumor evaluation, AI tools are becoming indispensable. The article also casts light on future developments, such as AI-based predictive analytics and automated treatment planning, illustrating how artificial intelligence continues to evolve from a supportive tool to a diagnostic partner.

Another groundbreaking advancement is featured in "Deep Resolve Boost in MRI," which discusses a deep learning-based image reconstruction technology designed to improve spatial resolution and reduce scan times in MRI. The integration of such algorithms enables more detailed anatomical visualization while enhancing patient comfort through shorter exam durations. This development is poised to transform clinical imaging, particularly in high-volume settings, by making MRI both faster and more accessible.

We also explore the frontier of MRI contrast agents through two compelling articles. The first, "MRI Contrast Agents Based on Protein-Targeted Gadolinium: Structure, Workings, and Uses," focuses on the development of gadolinium-based agents that target specific proteins, improving both diagnostic precision and biological safety. By enhancing tissue-specific uptake, these agents help achieve clearer, more informative images while reducing systemic exposure. The second article, "New Horizons in MRI Contrast Agents: Revolutionizing Safety and Diagnostic Precision," offers a broader look at emerging alternatives such as manganese- and iron-based agents. These next-generation agents address long-standing safety concerns related to gadolinium retention, particularly in patients with renal impairments.

In the domain of neuroimaging, "Neuro Maps in Motion: Unveiling Brain Function via BOLD fMRI" provides a fascinating exploration of how Blood Oxygen Level Dependent (BOLD) functional MRI is being used to study brain activity. This article discusses how fMRI is aiding in the understanding of cognitive processes, neurological disorders, and surgical planning, marking a significant step toward integrating brain function imaging into routine diagnostic pathways.

Our final article, "AI-Powered Catheter Segmentation: Catheter Segmentation in X-Ray Fluoroscopy Using Synthetic Data and Transfer Learning with Light U-Nets," presents a technically sophisticated yet clinically valuable contribution. This study highlights how synthetic datasets and lightweight deep learning models can improve catheter localization in fluoroscopic images, thereby enhancing the accuracy and safety of interventional procedures. The use of transfer learning and optimized neural networks showcases how innovation in artificial intelligence is not only reshaping diagnostics but also procedural guidance.

Each article in this issue is a testament to the evolving role of radiographers as knowledge-driven, tech-savvy professionals committed to excellence. The depth, diversity, and quality of contributions received each month continue to inspire and affirm the journal's mission of fostering education, research, and clinical advancement.

We sincerely thank all our contributors for their scholarly efforts and our readers for their continued support and enthusiasm. Let us continue to move forward together, embracing the future of radiology with curiosity, courage, and collaboration.

Warm regards

A Remarkable Journey Through 60 Years in Radiology

By Anant V. Joshi | 5th July 2025

Reflecting on a Lifetime in Imaging and Innovation

Exactly sixty years ago, I took my first step into the field of Radiology—a field that would come to define not just my profession but the very rhythm of my life. Over these decades, I have witnessed incredible transformations in radiographic technology and practice—each advancement reshaping the way we see, diagnose, and heal.

The Early Days

My journey began with a 100 mA machine, limited to two basic positioning systems—Vertical and Horizontal. It was a humble beginning, but a solid foundation. Soon after, I trained on a 200 mA manually operated unit that introduced a third positioning option: Trendelenburg. Then came the 300 mA system—equipped with a motor-operated multi-positioning table. These machines featured foldable fluoroscopy screens, bucky tables, and some even had tomography attachments.

Progress Through Technology

A significant leap occurred with the arrival of the 1000 mA motor-operated machine. It had both-way tilting, an Image Intensifier (II), and a CC camera for fluoroscopy. This setup enabled single to multiple exposures using various cassette sizes, greatly enhancing image quality and precision—especially in procedures like barium meal studies and hysterosalpingography.

Back then, we performed cerebral angiographies by manually placing three cassettes in a wooden tray and taking three rapid exposures—removing the top cassette after each shot. It was only after 1980 that technologies like CT, MRI, or Sonography entered our world.

The CT Revolution

The invention of the CT scanner was nothing short of revolutionary. With its ability to capture 1 mm slices within seconds, deep-seated lesions could now be visualized with unprecedented clarity. It marked a turning point in diagnostic radiology—and I was fortunate to witness it unfold.

Mentors Who Shaped Me

Throughout my career, I had the privilege of working under some of the finest minds in radiology:

- Dr. E. M. Gole – HoD, St. George's Hospital
- Dr. Shashikant Sane – Professor, Grant Medical College
- Dr. M. M. Mehta – HoD, K.E.M. Hospital
- Dr. R. M. Shah – HoD, Bhabha Hospital
- Dr. Kronenberg – German Radiologist & HoD, Breach Candy Hospital
- Dr. Tayabali – Successor at Breach Candy, who taught me the art of reading X-rays in clinical context
- Dr. I. C. Dawoodbhoy - Dentist at Colaba, who taught me Dental X-ray techniques.

Each of them left a lasting impact on my professional growth and understanding.

My Service Path

Over the years, I worked at several institutions: ESIS, GT Hospital Diagnostic Centre, Cotton Exchange, Ismail Hospital (now Prince Aly Khan), Worli General Hospital, and more.

In 1981, I joined Sanjay Gandhi Hospital in Roha. Later in 1986, I served with the Akhil Jangira Utkarsh Mandal at Murud Medical Centre. Eventually, in 1996, I established my own X-ray clinic in Murud-Janjira, which I proudly ran until its closure on 31st December 2022.

Retirement and Reflections

Now retired and living with my son in Pune, I find myself often reminiscing. While writing this, many faces from my journey came to mind:

- Y. K. Vidhwans (Bombay Hospital)
- Karamarkar & Bhavnani (St. George's)
- Madhav Limaye (JJ Hospital)
- Avdhoot alias Baba Joshi, Madhu Joshi, Chandu Arolkar (BPT)
- S.Y. Relekar, D.Y. Relekar, M.N. Kothavale, K.M. Joshi, R. Tamhankar, A. Pendharkar, A. Mane, Vishwas Jadhav (Breachcandy Hospital)
- Prakash Marathe, Madhukar Bhambid, Trilokinath Mishra, Shekhar Tawate, Shankar Bhagat (Tata Hospital)
- Sharfuddin (Ismaili General Hospital)

Among my esteemed female colleagues were:

- Lauren Jafet Kapaia, Neena Malkani, Iona, Belinda, and Juliet

Many were incredible mentors. A few, though challenging, taught me valuable lessons in humility and leadership—particularly in how we treat our subordinates. For all of it, I remain deeply grateful.

A Life Well Lived in Service

Looking back, I can only marvel at how far we've come—from manual machines to advanced digital imaging, from heavy cassettes to real-time 3D scans. It has been a truly wonderful journey, and I feel blessed to have played a small role in the incredible story of Radiology.

Dark Field Radiography for Chest Imaging

Shivani Aswal, MRIT, **Raushan Kumar,** Assistant Professor,
College of Paramedical Sciences, Teerthankher Mahaveer University, Moradabad, UP.

Abstract

Common lung conditions like pneumonia, lung cancer, asthma, chronic obstructive pulmonary disease, and others are a socioeconomic burden and a leading cause of death or a decline in quality of life. For the majority of lung conditions, the therapeutic result depends on an early diagnosis. A key diagnostic pillar of pulmonary function testing is radiologic imaging, of which plain radiography is the most popular imaging modality due to its accessibility, affordability, and relatively low radiation exposure. Medical radiography has advanced and been improved for chest imaging, including more recent methods that concentrate on functional lung imaging, since W.C. Rontgen discovered x-rays in 1895. However, because of overlapping anatomy, it can occasionally be challenging to identify early-stage diseases using plain radiography. Because of their high contrast, the heart and ribs in particular can mask overlapping lesions or infiltrates.

Introduction

One new imaging technique in medicine is dark-field radiography. While dark-field radiography uses ultra-small angle x-ray scattering, which is analogous to dark-field computed tomography, conventional x-ray imaging relies on the differential attenuation of different organs and tissues. X-ray dark-field imaging was first used experimentally in 2008. X-ray dark-field radiography utilizes the wave characteristics of x-rays, particularly ultra-small-angle scattering occurring at the material interfaces within the specimen under investigation, in contrast to attenuation-based conventional radiography. Dark field in this context refers to the bright appearance of scattering objects on a dark background, which is analogous to dark-field light microscopy. Because of the numerous air-tissue contacts in the alveoli, healthy lungs show a comparatively strong signal because the contrast is produced by several refractions on microstructures. Due to the numerous air and soft tissue interfaces in the human lungs, dark-field imaging has drawn the greatest attention. It has the potential to assess a range of pulmonary diseases, including pneumonia, fibrosis, andemphysema and Dark-field radiography can help diagnose emphysema in patients with chronic obstructive pulmonary disease (COPD), according to exploratory investigations. Dark-field radiography systems also make it possible to recreate standard attenuation x-ray images with similar diagnostic quality.

Physical principle of dark field radiography

An developing medical imaging technique called dark-field radiography operates on a different physical premise than traditional x-ray imaging. Dark-field radiography uses ultra-small angle x-ray scattering, whereas traditional x-ray imaging relies on the diverse ways that different organs and tissues attenuate x-rays. This indicates that it is not only sensitive to the amount of x-ray absorption but also to the way that the microscopic structures within tissues deflect them.

Additional information regarding the structure of tissues that is not evident with traditional x-ray imaging may be provided by this approach. Because it can see the minute alterations in the alveolar structure that are typical of emphysema and other lung disorders, it has demonstrated promise in the diagnosis of these conditions.

Dark-field radiography is still a very new technology, though, and its application in clinical practice is still quite limited. To fully realize its potential and turn it into a trustworthy and efficient diagnostic tool, more research is required.

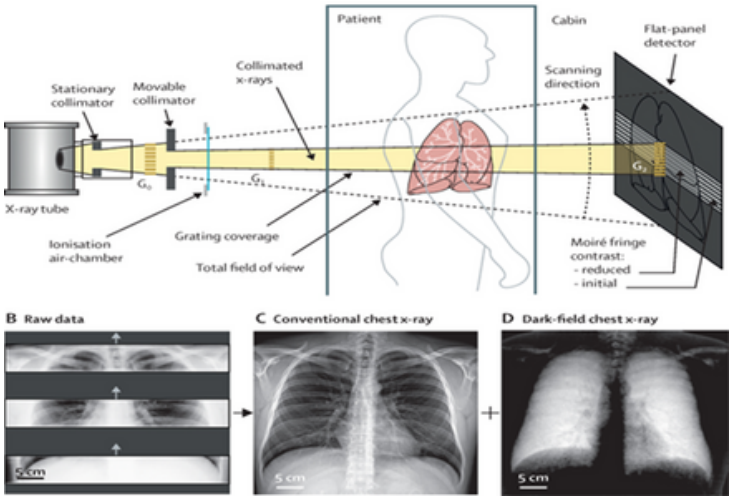


Figure 1 working of Dark field radiography

Use of dark field imaging in chest pathologies

In contrast to traditional chest X-rays, which use X-ray attenuation to produce pictures, dfCXR uses X-ray wave characteristics to identify ultra-small-angle scattering that takes place at the air-to-tissue transitions in the lungs' alveolar structure. This new method is useful for identifying illnesses that impact the alveolar structure since it offers distinct insights into the structural state of the lung parenchyma.

Dark Radiography in Chest Pathlogies

Emphysema: By identifying alterations in the alveolar structure, dfCXR is highly effective in identifying and staging emphysema45. Early diagnosis8 depends on the technique's ability to offer pertinent information about the structural state of the lung parenchyma.

Covid-19: When it comes to COVID-19 pneumonia, dark-field imaging is more sensitive than attenuation-based imaging23. It enhances the ability to see and identify lung abnormalities linked to the illness.3.

Cancer of lungs Cancer Fibrosis, and Ventilation-Induced Lung Damage: Research on animals has shown that lung conditions that affect alveolar structure, such as lung cancer, fibrosis, and ventilation-induced lung damage1, cause a decrease in the dark-field signal1.

Advantage of Dark Field Chest Radiography

Enhanced Sensitivity: When it comes to identifying COVID-19 pneumonia, dark-field imaging is more sensitive than traditional attenuation-based imaging23. Better diagnostic information is obtained when dark-field and attenuation-based pictures are combined.

Early Emphysema Detection: dfCXR is better than traditional chest radiography for diagnosing and staging emphysema4. While conventional approaches frequently depend on secondary

symptoms that manifest in later stages of the disease, it is capable of detecting emphysema in its early stages5. When the alveolar structure is compromised, the dark-field signal diminishes and shows up as dark patches on the lung image.

Reduced Radiation dosage: dfCXR is a safer substitute for repeated evaluations and follow-up because it provides a lower radiation dosage than computed tomography (CT) imaging.

Complementary Imaging: Dark-field imaging complements and improves conventional radiography for visualizing and detecting lung pathologies such as COVID-19-pneumonia.

Disadvantage of Dark field Radiography

Extended Acquisition Time: Compared to traditional chest radiography, dfCXR may require a longer acquisition time, which could result in motion artifacts, particularly in the vicinity of the aortic arch and the heart contour3. Interpreting images can be made more difficult by these artifacts.

Complexity: The influence of foreign bodies is more complicated in dark-field imaging, which relies on ultra-small-angle scattering, than in conventional attenuation-based radiography1. The material composition and microstructure of foreign entities must be taken into account when using dark-field radiography.

Qualitative Assessment: Rather than being quantitative, the assessment of foreign body-induced effects and artifacts on dark-field chest radiographs has primarily been qualitative1. For a more objective examination of the effect of foreign bodies on image quality, future research should create quantitative metrics for evaluating signal and artifact in dark-field chest radiographs.

Motion Artifacts: Narrowing the slot and lowering the number of frames for image extraction in impacted regions will help minimize motion artifacts, which are a consequence of longer dfCXR acquisition durations, particularly in the vicinity of the heart and aortic arch

Limited Clinical Applicability Studies: The clinical applicability of certain studies is limited because they fail to take into account possible patient diagnoses in foreign body-affected areas1. In order to see the impact of the decreased overlapping signals and artifacts in dark-field chest radiographs compared to conventional radiographs, future research should include lung disorders that cause local signal changes in the areas overlapped by the foreign body.

Global Signal abnormalities: One disadvantage is that some studies concentrate on patients who have conditions like COVID-19 and COPD that cause global signal abnormalities. In order to see the impact of the decreased overlapping signals and artifacts in dark-field chest radiographs compared to conventional radiographs, future research should include lung disorders that cause local signal changes in the areas overlapped by the foreign body.

References

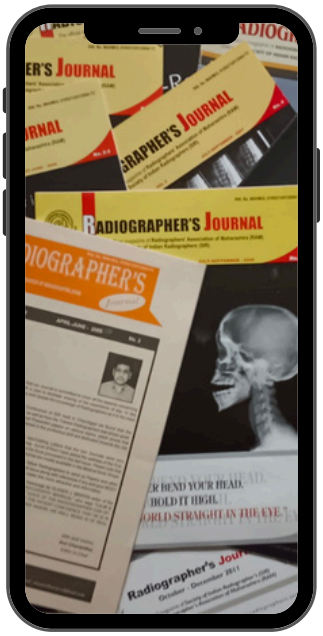
1.GBD 2015 Disease and Injury Incidence and Prevalence Collaborators. Glob al, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016;388(10053):1545–1602.

2.Schaefer-Prokop C, Prokop M. New imaging techniques in the treatment guidelines for lung cancer. Eur Respir J Suppl 2002;35:71s–83s.

3.Röntgen WC. Über eine neue Art von Strahlen. Vorläufige Mitteilung. Sit zungsberichte der Würzburger physik-mediz Gesellschaft 1895;137:132–141.

4.McAdams HP, Samei E, Dobbins J 3rd, Tourassi GD, Ravin CE. Recent ad vances in chest radiography. Radiology 2006;241(3):663–683.

5.Ravin CE, Chotas HG. Chest radiography. Radiology 1997;204(3):593–600.



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23RD NATIONAL CONFERENCE OF SOCIETY OF INDIAN RADIOGRAPHERS

IMAGINE

in association with

Society of Indian Radiographers
Karnataka Medical Radiographers and Allied Technologists Association
Karnataka State Government Radiology Imaging Officers Central Association

HOST: *Department of Radiodiagnosis and Imaging, Kasturba Medical College, Mangalore*

THEME: *Advancing Frontiers: Ushering in a New Era of Medical Imaging*

31st October - 2nd November 2025 | **TMA Pai Convention Centre, Mangalore**

WELCOME Message

Namaskara from Mangaluru,

We are delighted to extend a warm welcome for the 23rd National Conference of Society of Indian Radiographers – IMAGINE 2025, in association with Karnataka Medical Radiographers and Allied Technologist Association and Karnataka State Government Radiology Imaging Officers Central Association, hosted by the Department of Radiodiagnosis and Imaging, Kasturba Medical College, Mangalore (unit of Manipal Academy of Higher Education).

IMAGINE 2025 brings together leading researchers, clinical experts, industry pioneers, and aspiring professionals to explore the latest innovations, share groundbreaking research, and foster collaboration in the dynamic field of medical imaging.

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Organizing Committee...

Registration details (fees in rupees)				
#	Category	Till 10th July 2025	From 11th July 2025 to 30th September 2025	Spot Registration
1	Students (BSc, MSc)	Rs. 2,000/-	Rs. 2,500/-	Rs. 5,000/-
2	Members of SIR, KMRATA, KSGRIOCA (Faculty & PhD)	Rs. 2,500/-	Rs. 3,000/-	Rs. 5,000/-
3	Non-Members of SIR, KMRATA, KSGRIOCA (Faculty & PhD)	Rs. 3,000/-	Rs. 3,500/-	Rs. 5,000/-
4	Members of SIR, KMRATA, KSGRIOCA (Technologist)	Rs. 2,500/-	Rs. 3,000/-	Rs. 5,000/-
5	Non-Members of SIR, KMRATA, KSGRIOCA (Technologist)	Rs. 3,000/-	Rs. 3,500/-	Rs. 5,000/-
6	Radiology Faculty	Rs. 3,500/-	Rs. 4,000/-	Rs. 5,000/-
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9	Retired Technologist	Rs. 3,000/-	Rs. 3,500/-	Rs. 5,000/-
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IMAGINE

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Applications of Artificial Intelligence in Musculoskeletal Radiology: Present and Prospective Technologies

Sandeep Kumar, M.Sc. Research Fellow, **Rashmi Pandey,** Assistant Professor,
College of Paramedical Sciences, Teerthankher Mahaveer University, Moradabad, UP.

Abstract

An essential diagnostic technique for musculoskeletal infections, bone cancers, fractures, and other illnesses is musculoskeletal radiography. Currently used radiological methods include CT, MRI, ultrasound, and radiography; nevertheless, each has its own set of challenges. Artificial intelligence (AI) has the ability to address these problems and change the work of a musculoskeletal radiologist in several ways. AI-driven methods in MSK radiology were previously mostly employed for bone tumor detection or bone mineral density measurement. However, recent studies have expanded the application of AI in several other domains, such as image segmentation, enhancing resolution, detecting fractures, and automatically diagnosing new musculoskeletal conditions. This review article looks at a lot of both earlier and more recent studies to show how the development and use of AI-based approaches have changed in the field of musculoskeletal radiography and how their applicability may be improved in the future.

Keywords: Artificial Intelligence (AI), Musculoskeletal Radiology, Medical Imaging, Machine Learning, Deep Learning, Radiology Diagnostics, Bone Fracture Detection, Musculoskeletal Disorders, Automated Diagnosis

Introduction

Several professions, including musculoskeletal radiology, are rapidly changing due to artificial intelligence (AI). From identifying minor fractures to forecasting the likelihood of future musculoskeletal issues, artificial intelligence (AI) algorithms are being created and used to help radiologists with a range of tasks. This could enhance patient care, efficiency, and diagnostic accuracy. The identification and categorization of fractures is one of the main uses of AI in musculoskeletal radiology. X-rays and CT scans can be analysed by AI algorithms to detect fractures, even those that are subtle, and categorize them according to their type and severity. This can assist radiologists in diagnosing patients more quickly and accurately, which will enable them to receive treatment more quickly. AI can also be used to evaluate the degree of osteoarthritis, which includes joint space constriction, bone spurs, and cartilage degradation. Physicians can use this data to tailor therapy regimens and monitor the disease's course. (1)

AI may also be used to identify bone age from hand and wrist X-rays, which is crucial for tracking puberty and detecting growth issues. Additionally, AI can be used to identify and describe cancers in soft tissues and bones, assisting radiologists in differentiating between benign and malignant tumors. AI can also be utilized to enhance musculoskeletal picture quality, which will reduce the need for repeat scans and make the images easier to read. AI is being utilized to create new technologies that could further revolutionize musculoskeletal radiology in addition to these existing uses. For instance, using a patient's medical history and imaging data, AI can forecast the likelihood of developing musculoskeletal issues in the future, such as osteoarthritis or fractures.

Personalized therapies and preventative measures could be created using this data. (2) AI can also be utilized to create individualized treatment programs for musculoskeletal disorders based on the unique traits and imaging results of each patient.

Radiologists can increase productivity and save time by using AI to create automated reports from musculoskeletal pictures. AI can also be utilized to develop augmented and virtual reality environments for patient education and surgical planning. But before AI is completely incorporated into musculoskeletal radiology, there are other issues and concerns that must be resolved. The quality and accessibility of data are one difficulty. For AI algorithms to train efficiently, a lot of high-quality data is needed. The explain ability and openness of AI algorithms presents another difficulty.(3)

For radiologists to have confidence in the outcomes, it is critical to comprehend the decision-making process of AI systems. Furthermore, for AI solutions to be useful, they must be smoothly incorporated into current clinical workflows. Lastly, before AI-based medical gadgets may be utilized in clinical settings, regulatory agencies must approve them. AI has the potential to revolutionize musculoskeletal radiology, enhancing patient care, diagnostic precision, and efficiency despite these obstacles. (4) We may anticipate seeing many more inventive uses of AI technology in the future as it develops.

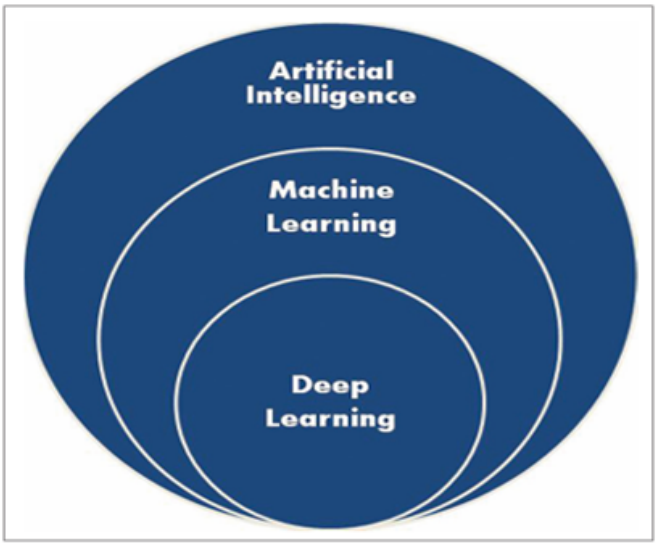


Figure:1 An illustration of the hierarchy of artificial intelligence techniques using a Venn diagram

The History

AI has been developed over the last ten years to enhance the interpretation of a broad range of radiological examinations related to the musculoskeletal system. But prior to that, AI-based models had mostly been created for uses like femoral and tibial feature segregation, bone mineral density measurement, and bone tumor recognition, among other related activities. Lodwick et al. created a method in 1963 that was able to predict five different kinds of bone malignancies from X-ray images with an accuracy of over 80%. Among these tumors were periosteal sarcoma (100.3%), fibro sarcoma (81.8%), Ewing's sarcoma (81.8%), chondroblastoma (87.5%), and GCT (100%). (5)

Currently

Applications of artificial neural networks in musculoskeletal radiology

Musculoskeletal radiology is undergoing a revolution thanks to artificial neural networks (ANNs), which are modelled after the structure of the human brain. These networked nodes are able to help radiologists in several ways by processing data and learning from it. Artificial Neural Networks (ANNs) are highly effective at detecting and classifying fractures. They can accurately identify fractures on CT and X-ray scans and even categorize them by type and severity for quicker, more accurate diagnoses. By evaluating X-rays and MRIs to determine the severity of the condition, they also serve a critical role in osteoarthritis assessment, helping physicians monitor progression and customize treatment. Additionally, ANNs automate the process of determining bone age from wrist and hand X-rays, which is crucial for the diagnosis of growth problems. (6)

Additionally, ANNs improve tumor detection and characterisation by recognizing and categorizing soft tissue and bone tumors on MRI and CT images, assisting in the differentiation of benign from malignant growths. As ANNs improve musculoskeletal pictures, they also improve image quality by minimizing the need for repeated scans and simplifying interpretation. In addition to these present uses, ANNs are advancing predictive modeling by predicting the likelihood of upcoming musculoskeletal issues like osteoarthritis or fractures. By customizing procedures according to each patient's unique characteristics and imaging findings, they also support individualized therapy planning. Another interesting topic that could increase radiologists' productivity is automated report generation from musculoskeletal imaging. (7)In summary, as technology develops, ANNs have the potential to revolutionize musculoskeletal radiology by increasing diagnostic precision, optimizing workflows, and eventually enhancing patient care.

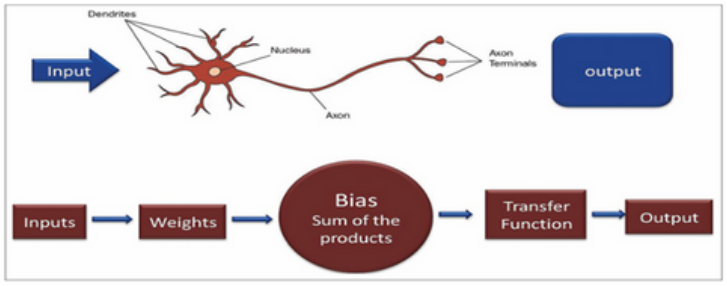


Figure:2 An illustration of a biological and artificial neuron. Data is received through the dendrites, multiplied by the corresponding weight for each input, and the sum of all the multiplications.

Preprocessing images

Image pre-processing is essential in musculoskeletal radiology to maximize the effectiveness of further analyses, such as those driven by artificial neural networks (ANNs). Despite their strength, ANNs frequently gain from improved and standardized input data. In order to facilitate the extraction of significant information by ANNs, pre-processing approaches seek to enhance image quality, minimize noise, and highlight pertinent characteristics.1 For example, noise reduction methods can reduce X-ray or MRI artifacts, resulting in sharper images and more precise diagnoses. By emphasizing minute variations in tissue densities, contrast enhancement techniques can help identify malignancies or fractures. (8) Consistency across datasets is ensured by normalizing image intensity values, which is crucial when training artificial neural networks (ANNs) on big and diverse image collections. In order to facilitate comparison and study of disease development, pre-processing may also include image registration, which aligns images from several modalities or time points. 4 By isolating particular anatomical regions, region of interest (ROI) extraction might increase efficiency by directing the ANN's attention to pertinent features. Pre-processing methods greatly expand the potential of ANNs in musculoskeletal radiology by enhancing image quality and emphasizing relevant information. This results in more precise diagnoses, individualized treatment regimens, and eventually better patient outcomes.

Obtaining images

Different modalities are used to obtain musculoskeletal pictures, and each one offers a different set of details regarding the musculoskeletal system. The most common and easily available type of X-ray provides fine-grained bone and joint viewing, which is essential for identifying fractures and dislocations. Computed tomography (CT) scans provide more thorough views of bones and soft tissues by using X-rays and computer processing to create cross-sectional images. These scans are especially helpful for complex fractures or malignancies. For assessing damage to soft tissues including muscles, ligaments, tendons, and cartilage, magnetic resonance imaging (MRI) uses radio waves and magnetic fields to produce incredibly detailed images. (9) Using sound waves, ultrasound offers a non-invasive and economical way to image soft tissues; it is frequently used to evaluate muscles, ligaments, and tendons. The particular clinical question being addressed determines which imaging modality is best.

Analysis of images

In order to detect anomalies and make diagnoses, musculoskeletal image analysis entails a methodical assessment of numerous characteristics. Radiologists carefully analyse pictures, noting the density, size, shape, and placement of structures. They examine the integrity of the bone, searching for fractures, dislocations, or indications of deterioration. Soft tissues are examined closely for signs of inflammation, edema, or rips. Comparing results with normal anatomy and identifying patterns linked to certain disorders are common tasks in image analysis. For example, radiologists search for cartilage loss, bone spurs, and narrowing of the joint space in osteoarthritis. (10) They detect angulation, displacement, and fracture lines in fractures. Cutting-edge methods such as artificial intelligence (AI) and computer-aided diagnostics (CAD) can help with image analysis by supplying quantitative measures or flagging possible problem areas. In the end, the radiologist makes a diagnosis and directs therapy choices by combining picture results with clinical data.

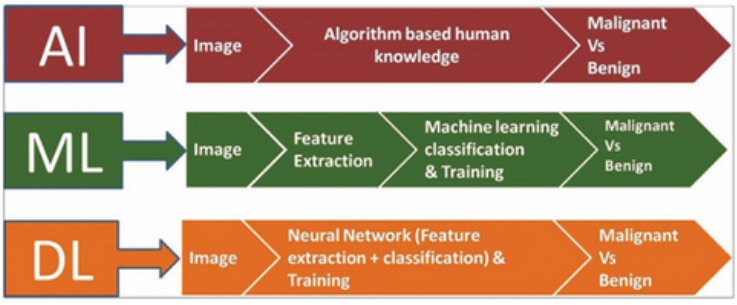


Figure:3 Procedures and fundamental variations in data processing between deep learning, machine learning, and artificial intelligence.

NLP (natural language processing) in radiography of the musculoskeletal system

Musculoskeletal radiology is changing as a result of natural language processing (NLP), which increases productivity, accuracy, and workflow automation. NLP improves communication between radiologists and referring physicians, standardizes terminology, and extracts important data from radiology reports. It lessens reporting variability and helps identify trends linked to soft tissue disorders, arthritis, and fractures. Large-scale dataset training enables machine learning models to find pertinent clinical data, enhancing research and decision support applications. (11) NLP helps with automatic report structure, guaranteeing completeness and consistency while identifying possible inconsistencies for additional examination. Enhancing patient management and follow-up recommendations, integration with electronic health records (EHR) enables real-time data extraction. Radiologists are assisted by NLP-driven tools that summarize previous imaging results, compare recent reports, and spot missed anomalies. Workflow efficiency and prioritization are improved by automatically classifying imaging investigations according to clinical indications. NLP also helps with predictive analytics, which evaluates how musculoskeletal disorders progress and how well a treatment is working. The requirement for high-quality annotated datasets, medical jargon, and differences in report styles are among the difficulties. Constant improvements in contextual language models and deep learning are improving NLP's capacity to analyze unstructured radiology text, resulting in more accurate and useful insights about musculoskeletal imaging. (12)

What's to come (Future):

In musculoskeletal radiology, artificial intelligence (AI) is transforming diagnostic precision, productivity, and workflow automation. Using deep learning models built on enormous imaging datasets, current AI applications include automated fracture identification, bone age assessment, and arthritis grading. Radiologists benefit from AI-powered algorithms that minimize diagnostic errors, shorten reporting times, and identify abnormalities. Machine learning models improve quantitative imaging by assisting in the evaluation of joint degeneration, muscle quality, and bone density. AI-driven image reconstruction methods will be incorporated into future developments, enhancing scan quality while lowering radiation exposure and scan duration. Triage systems driven by AI will give priority to critical cases, guaranteeing quicker tumor, infection, and fracture detection. By standardizing terminology and condensing clinical results, natural language processing (NLP) will improve report production and facilitate communication with referring physicians. (13) Early illness detection and treatment response tracking will be made possible by predictive analytics, especially in the cases of osteoporosis and inflammatory joint diseases. Precision medicine and individualized treatment strategies will benefit from the extraction of comprehensive imaging biomarkers by AI-driven radionics'.

Conclusion

In musculoskeletal radiology, artificial intelligence (AI) has the potential to revolutionize patient care and diagnostic capabilities. AI helps radiologists provide precise and effective care by improving image analysis, standardizing reports, and promoting early disease diagnosis. Precision medicine will be made possible by future advancements that offer tailored treatment regimens using radionics' and predictive analytics. The continuous development of AI technologies has significant advantages for patients and physicians, although difficulties with model validation, ethical issues, and legal barriers. AI's incorporation into clinical practice will result in better outcomes, more efficient workflows, and more focused, patient-centered musculoskeletal imaging therapy as it develops.

References:

- Pattern Recognition in Musculoskeletal Imaging Using Artificial Intelligence - PubMed [Internet]. [cited 2025 Feb 10]. Available from: https://pubmed.ncbi.nlm.nih.gov/31991451/
- Automated Muscle Segmentation from Clinical CT Using Bayesian U-Net for Personalized Musculoskeletal Modeling - PubMed [Internet]. [cited 2025 Feb 10]. Available from: https://pubmed.ncbi.nlm.nih.gov/31514128/
- Chaudhary AS, Fang Z, Kogan F, Wood J, Stevens KJ, Gibbons EK, et al. Super-resolution musculoskeletal MRI using deep learning. Magn Reson Med. 2018 Nov;80(5):2139–54.
- Computer-Aided Diagnosis of Different Rotator Cuff Lesions Using Shoulder Musculoskeletal Ultrasound - PubMed [Internet]. [cited 2025 Feb 10]. Available from: https://pubmed.ncbi.nlm.nih.gov/27381057/
- Cao Y, Wang H, Moradi M, Prasanna P, Syeda-Mahmood TF. Fracture detection in x-ray images through stacked random forests feature fusion. 2015 IEEE 12th International Symposium on Biomedical Imaging (ISBI). 2015 Apr;801–5.
- Artificial Intelligence in Musculoskeletal Imaging: Current Status and Future Directions - PubMed [Internet]. [cited 2025 Feb 10]. Available from: https://pubmed.ncbi.nlm.nih.gov/31166761/
- Artificial Intelligence in Musculoskeletal Imaging: Current Status and Future Directions - PubMed [Internet]. [cited 2025 Feb 10]. Available from: https://pubmed.ncbi.nlm.nih.gov/31166761/
- The Lodwick classification for grading growth rate of lytic bone tumors: a decision tree approach - PMC [Internet]. [cited 2025 Feb 10]. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC8854272/
- Geraets WG, Van der Stelt PF, Netelenbos CJ, Elders PJ. A new method for automatic recognition of the radiographic trabecular pattern. J Bone Miner Res. 1990 Mar;5(3):227–33.
- Lundervold AS, Lundervold A. An overview of deep learning in medical imaging focusing on MRI. Z Med Phys. 2019 May;29(2):102–27.
- Radial Basis Function Neural Networks : A Review | Computer Reviews Journal [Internet]. [cited 2025 Feb 10]. Available from: https://journals.indexcopernicus.com/search/article?articleId=2245153
- Generative models: an upcoming innovation in musculoskeletal radiology? A preliminary test in spine imaging | European Radiology Experimental | Full Text [Internet]. [cited 2025 Feb 10]. Available from: https://eurradiolexp.springeropen.com/articles/10.1186/s41747-018-0060-7
- Deep Learning for Musculoskeletal Image Analysis - Northwestern Scholars [Internet]. [cited 2025 Feb 10]. Available from: https://www.scholars.northwestern.edu/en/publications/deep-learning-for-musculoskeletal-image-analysis

75th Birthday celebrations of Shri. Dilip Relekar
Ex. President of Radiogarphers' Association of Maharashtra

Deep Resolve Boost in MRI

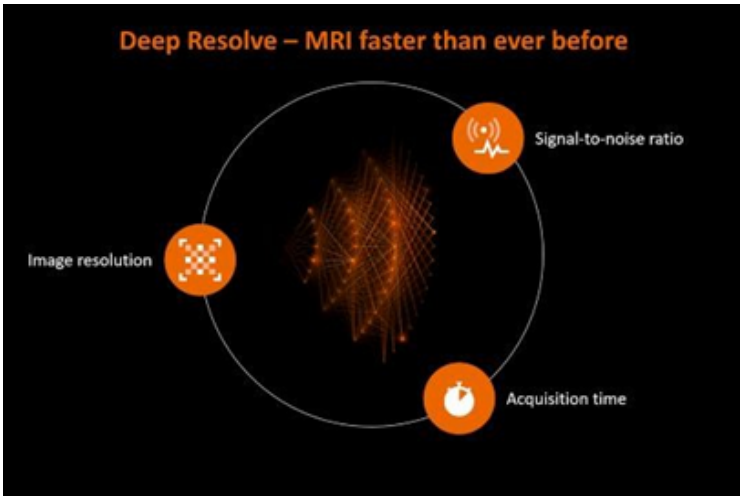
Khushi Ghelani, B.Sc. MRIT Student, M S Ramaiah University of Applied Sciences, Bangalore, Karnataka

Abstract

Deep Resolve Boost (DRB), an innovative artificial intelligence (AI)-based reconstruction technology developed by Siemens Healthineers, revolutionizes magnetic resonance imaging (MRI). By employing deep neural networks, DRB addresses the conventional trade-offs between acquisition speed, image resolution, and signal-to-noise ratio (SNR). This review explores DRB's technical framework, clinical applications, and future prospects. Integrating raw data into an iterative reconstruction process with noise-specific priors, DRB achieves up to 62% faster scan times while enhancing image quality. Clinical studies validate its effectiveness across neuroimaging, musculoskeletal, abdominal, and diffusion-weighted imaging protocols, maintaining diagnostic accuracy. Despite challenges such as artifact management and computational requirements, advancements in 3D sequencing and open innovation platforms signal broader adoption. DRB exemplifies AI's potential to transform MRI efficiency and accessibility.

Introduction

Magnetic resonance imaging (MRI) is a cornerstone of modern diagnostics, valued for its exceptional soft-tissue contrast and lack of ionizing radiation. However, lengthy scan times often cause patient discomfort, motion artifacts, and operational inefficiencies. Traditional acceleration methods, such as parallel imaging (e.g., GRAPPA, SENSE) or Compressed Sensing (CS), typically compromise SNR or resolution to shorten acquisition times. The emergence of AI-driven solutions has disrupted these limitations, with Deep Resolve Boost (DRB), part of Siemens Healthineers' Deep Resolve suite, offering a groundbreaking approach. By leveraging deep learning, DRB decouples the traditional constraints of speed and quality.



Technical Workflow and Mechanism

DRB employs a raw-data-to-image reconstruction framework that integrates physics-driven models with AI-based deep learning. Its architecture consists of three iterative stages:

Pre-cascades: Produce an initial image estimate from under sampled k-space data.

Convolutional Neural Network (CNN) Cascades: Utilize a U-Net-like architecture, trained on over 25,000 annotated slices, to denoise images while preserving anatomical details, mitigating acceleration-related artifacts.

Data-Consistency Post-cascades: Ensure alignment with acquired raw data, reducing the risk of hallucination artifacts.

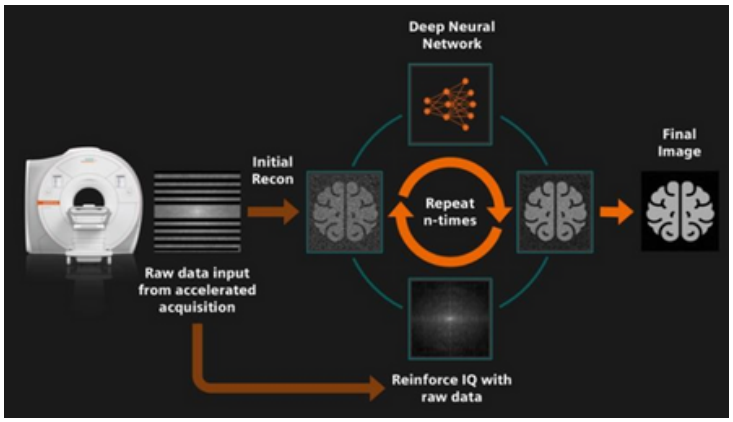
Key Innovations:

Noise-Specific Priors: DRB generates noise maps from raw data without additional scans, enabling targeted denoising in wavelet domains.

Adjustable Denoising: Offers three levels (low, medium, high) to adjust regularization strength.

Hybrid Reconstruction: Combines parallel imaging (e.g., PAT factor up to 4) with AI, extending CS principles to 2D Cartesian imaging.

Unlike traditional interpolation methods, DRB's CNN predicts high-frequency k-space data, improving resolution beyond the acquired dataset.



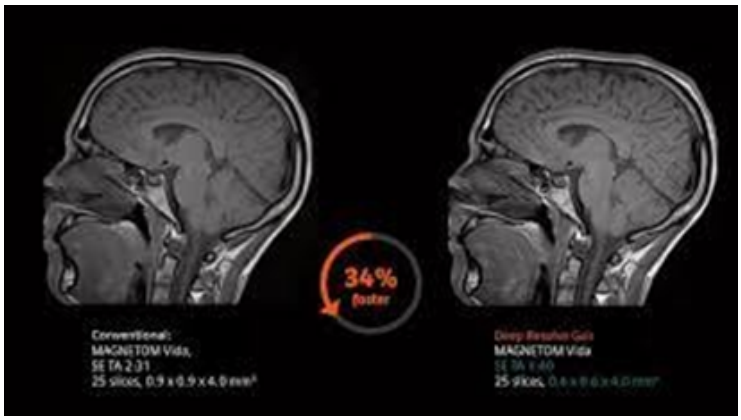
Clinical Applications and Benefits

DRB has proven effective across various anatomical regions:

Neuroimaging

Brain Protocols: Reduces scan times by 29–40% for T1, T2, and diffusion-weighted imaging (DWI) sequences, with SNR improvements of 30% and sharpness gains of 25%. In DWI, apparent diffusion coefficient (ADC) values remain consistent (±3% vs. ground truth) despite acceleration.

Swift Brain Protocol: Combines DRB with multi-shot EPI, enabling comprehensive brain scans (T1, T2, T2*, Dark Fluid, DWI) in under 2 minutes.

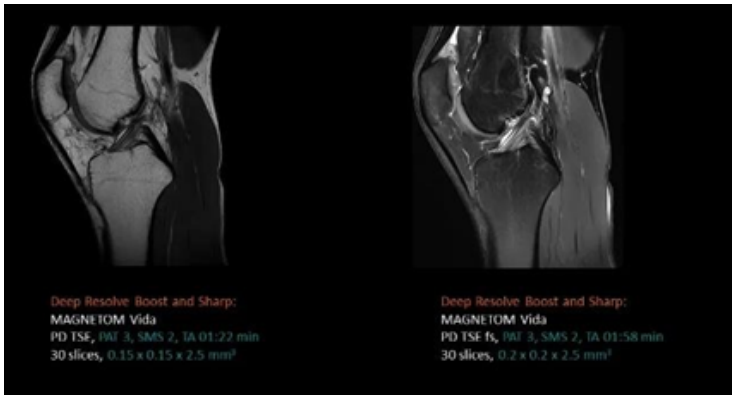


Sagittal brain MRI using SE T1 sequence, comparing conventional and Deep Resolve Gain methods, with the latter providing 34% faster acquisition and improved resolution.

Musculoskeletal Imaging

Knee and Spine Exams: Achieves 25–62% faster acquisitions (e.g., full knee exam in 2 minutes). Highresolution T1, T2, and STIR sequences maintain quality at PAT4-SMS2 acceleration.

Lumbar Spine: Reduces scan times by 28% while preserving visualization of discs and nerve roots.

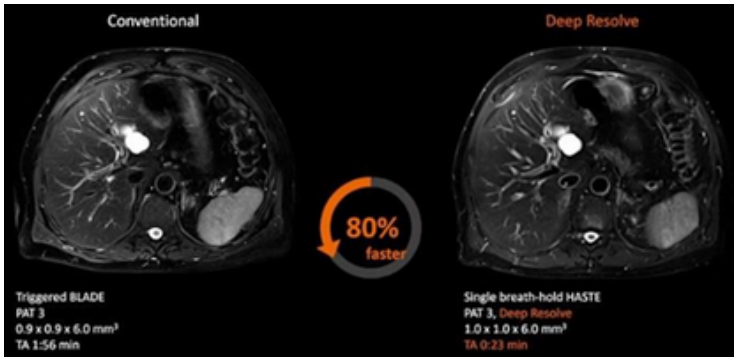


PD TSE MRI knee with Deep Resolve Boost in musculoskeletal imaging.

Body Imaging

Liver and Breast DWI: Maintains ADC reproducibility ($p > 0.05$ vs. conventional methods) with 25– 32% faster scans.

Prostate: Accelerates high-resolution T2-weighted imaging (0.2 mm³) by 20%, enhancing tumor margin definition.



Single breath-hold HASTE MRI of the abdomen with Deep Resolve, achieving 80% faster scan time (TA 0:23 min) compared to conventional BLADE (TA 1:56 min), while maintaining comparable resolution (1.0–0.9 mm in-plane).

Patient-Centric Benefits

- Facilitates imaging for claustrophobic or pediatric patients.
- Minimizes motion artifacts in uncooperative subjects.
- Boosts scanner throughput by 24% (e.g., from 2,602 to 3,231 studies/month).

Operational Efficiency

DRB delivers significant operational advantages:

Throughput Increase: Accelerates protocols by 20–32% (e.g., lumbar spine: 28%, wrist: 44%), enabling 24% more monthly scans (2,602 to 3,231) on existing systems (Hughes et al., 2024).

Cost Savings: Estimated at $436,000 USD annually per scanner by reducing backlogs and optimizing resources (Brennan, 2023).

Resource Optimization: Equivalent to adding a sixth scanner without additional capital investment, maximizing return on infrastructure (Hughes et al., 2024).

Complementary Technologies: Integrated AI Ecosystem

DRB integrates seamlessly with Siemens' reconstruction suite (Behl, 2024):

Deep Resolve Sharp: Enhances spatial resolution via super-resolution CNNs, achieving 3T-like clarity on 1.5T systems and doubling matrix size (e.g., 384×512 to 768×1024) without extending scan times.

Deep Resolve Gain: Improves SNR by 30% in low-signal regions using adaptive noise suppression derived from raw-data noise maps.

Protocol Stacking: Combining Boost and Sharp reduces nee exams to under 2 minutes (vs 17+ minutes conventionally) while enhancing resolution (Behl, 2024).

Implementation Challenges and Solutions

Artifact Management

Edge Enhancement: Over-sharpened cartilage borders may mimic pathology; addressed by adjustable denoising settings (Lee et al., 2023).

False-Positive Pathology: Non-existent cartilage defects detected in 5% of musculoskeletal scans; mitigated through radiologist-AI co-reading protocols (Birkbeck, 2024).

Aliasing: Phase-direction ghosting in accelerated axial sequences; resolved by increasing phase oversampling by 15–20% (Birkbeck, 2024).

Protocol Optimization

Anatomic-specific presets ensure diagnostic fidelity (Siemens Healthineers, 2024):

Anatomy	De-noising Level	Acceleration	Key Adjustment
Brain	Level 3 (High)	PAT3 + SMS2	Prioritize SNR for gray-white matter contrast
Joints	Level 1 (Low)	PAT4	Preserve cartilage texture details
Abdomen	Level 2 (Medium)	PAT3	Balance motion suppression and resolution

Limitations and Challenges

Artifacts: Wrap artifacts in axial sequences (e.g., lumbar spine) require protocol adjustments like phase oversampling.

Computational Load: GPU-intensive reconstruction may challenge existing infrastructure.
Training Data Dependence: Performance relies on diverse training datasets; underrepresented anatomies may yield suboptimal results.
Regulatory Hurdles: DRB applications for diffusion and 3D sequences (SPACE/VIBE) remain investigational

Future Directions
3D Sequencing Expansion: Extend DRB to SPACE and VIBE protocols for isotropic highresolution abdominal and pelvic imaging with CAIPIRINHA acceleration.
Open Innovation: Support third-party algorithm integration via Gadgetron/ISMRM raw data standards for online prototyping.
Low-Field MRI: Optimize DRB for 0.55T systems (e.g., MAGNETOM Free.Max) to enhance accessibility.
Artifact Correction: Develop AI-driven solutions to reduce distortions in EPI sequences.

Conclusion
Deep Resolve Boost redefines MRI by integrating deep learning with physics-based models, overcoming the traditional constraints of speed, resolution, and SNR. Clinical validations demonstrate its diagnostic equivalence across neuroimaging, musculoskeletal, and body imaging, with scan time reductions of up to 62%. Despite challenges like artifacts and computational demands, DRB's integration into 3D sequences and open innovation platforms paves the way for accessible, high-precision MRI. As AI evolves, DRB will play a critical role in addressing rising diagnostic demands while enhancing patient care.

References

- Behl, N. (2021). Deep Resolve – Mobilizing the power of networks. MAGNETOM Flash, 78(2), 2–9.
- Behl, N. (2024). Deep Resolve: Unrivaled speed in MRI. MAGNETOM Flash, 89(4), 1–11.
- Birkbeck, M. (2024). Deep Resolve Boost in lumbar spine imaging on Siemens Sola. Newcastle NHS Foundation Trust Case Study.
- Brennan, N. (2023). AI integration with MRI imaging: The clinical perspective. RCSI Technical Report, 1, 1–19.
- Hughes, L., Courtney, D., & Bergin, D. (2024). The use of deep machine learning reconstruction in MRI. Galway University Hospitals.
- Lee, H.-S., Nickel, D., Thoermer, G., & Benkert, T. (2023). Deep Resolve Boost (DRB) and Sharp (DRS) for diffusion: ADC phantom evaluation. MAGNETOM Flash, 84(2), 38–43.
- MPO Magazine. (2023, May 24). Siemens Healthineers improves magnetic resonance imaging with Deep Resolve. Medical Product Outsourcing. https://www.mpomag.com/contents/view_breaking-news/2023-05-24/siemens-healthineers-improvesmagnetic-resonance-imaging-with-deep-resolve/
- Siemens Healthineers. (2024). Deep Resolve Boost: Product overview. https://www.siemenshealthineers.com/magnetic-resonance-imaging/options-and-upgrades/clinicalapplications/deep-resolve-boost
- Siemens Healthineers. (2024). Deep Resolve Boost protocol optimization guide. Erlangen, Germany.

आप भी अपना पाठक धर्म निभाएँ

पत्रिका का अंक मिला, डाउन लोड किया, पढा और डिलीट कर दिया. केवल इससे पाठक धर्म नहीं निभ जाता. पत्रिका में प्रकाशित सामग्री से आप सहमत हो सकते हैं या उसमें आप कुछ और जोड़ सकते हैं, तो ऐसे मामलों में अपनी टिप्पणी अथवा प्रतिक्रिया हमें अवश्य लिख भेंजे. इसी प्रकार पत्रिका में जो मुद्दे उठाए गए हों, जो प्रश्न खड़े किए गए हों, उन पर भी खुल कर बहस करें और हमें लिख भेंजे. तात्पर्य यह है कि आप केवल पाठक ही न बने रहें, पाठक धर्म भी साथ में निभाते रहें इससे जहां अन्य पाठक बंधु लाभान्वित होंगे वहीं हमें भी विभिन्न रूपों से मार्गदर्शन मिलेगा. हाँ तो, जब भी समय की मांग हो, कलम उठाना न भूलें.

और एक बात, ये अंक हमने आप तक पहुंचाया, एक प्रबुद्ध रेडियोग्राफर के नाते अब ये आप की ज़िम्मेदारी बनती है कि इस अंक को आप भी और रडीओग्राफेर्स तक पहुंचाए यानि फॉरवर्ड करें.

अग्रिम धन्यवाद.
संपादक

QUIZ to Recapitulate

Pawan Kumar Popli, Chief Technical officer-Radiology (Retd.), AIIMS, New Delhi

1. Name the Council and regulatory body to regulate Radiography profession in India.

2. Where do we use Barium fluoro halide?

3. Name the vessels studied in four vessel angiography?

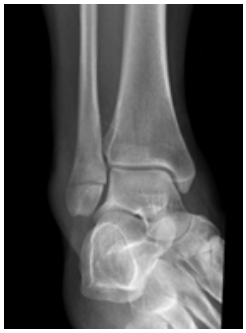
4. What is the recommended distance between X-Ray tube and radiographer in routine portable radiography?

5. Why do we do Peroral pneumocolon?

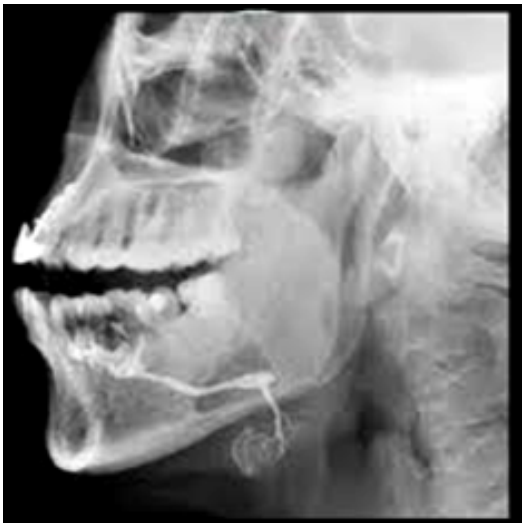
6. How much abdominal compression is given for IVU study on 7th day of pelvic surgery ?

7. 1.EMI - CT 1010 was which generation CT.
que

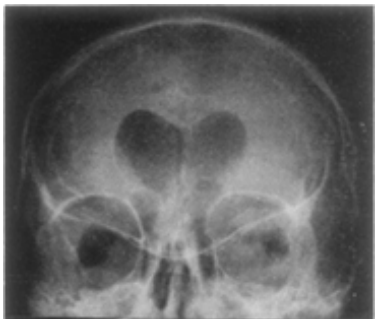
8. Name the view and its technique

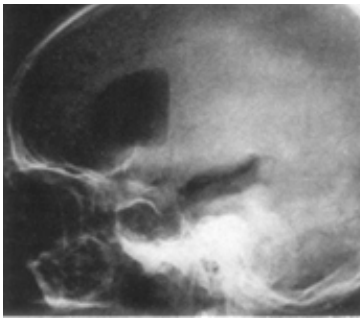


9. Name the investigation



10. Name the investigation & Purpose?





- Please send your answers through email on **pkpopli@gmail.com** on or before **10th August 2025.**
- Send your **Name with Hospital/Institution Information** and Passport size **photograph** along with the answers.
- **Best 3 participants** (early birds and correct) **in each month will get the prizes.**
- Correct answers will be published in the next issue.
- If required /requested by participants more details about any question can be provided in upcoming issues under title **"Your Requests"**

Answers for the Quiz - June 2025 issue

1. Increases the patient radiation dose

2. Keep the patient upright for some time and take expiratory chest PA radiograph

3. 15 degree medial rotation

4. Time, Distance & Shielding

5. Atomic Energy Regulatory Board (AERB) located in Mumbai

6. It was used for myelography

7. Slip Ring Technology

8. Limbal ring technique for intraocular foreign body localization

9. Double Contrast Barium Enema (DCBE)

10. Renal Double Curve (RDC) catheter for Renal arteriography

The following readers participated in the Quiz – June 2025 issue.

Gukanraj N,
Asst. Professor
Sri Venkateswaraa College of Paramedical Sciences, Puducherry.

Sriram. R,
Scientific Asst. (Radiography),
DAE Hospital-Kalpakkam,

G. Shathish
B. Sc. RIT Student
Madras Medical College, Chennai

Ekta Singh
MRIT Research Scholar,
Swami Vivekanand Subharti University, Meerut, UP

Nishat Siddiqui
B.Sc. RIT Student
Swami Vivekanand Subharti University, Meerut, UP

Ranjith Kumar R,
B.sc RIT Intern Student
Sri Ramakrishna Hospital, Coimbatore

Sakshi Jangde
AIIMS, New Delhi

Darji H. Kiritbhai
Institute of Kidney Diseases and Research Centre, Medicity, Ahmedabad

Simi Paxleal J
B.Sc. RIT intern
Dr. Jeyasekharan Medical Trust College of Allied Health Science, Nagercoil

Shivaraju L N
Rosy Royal Institute of Allied Health Sciences, Bangalore

Mori M Bharatsinh
IKDRC -Civil Hospital Campus Ahmedabad

Bhavya Sati
AIIMS, New Delhi

R. Ramiya
Lecturer
Panimalar College of Allied Health Sciences, Chennai.

B. Sc. RIT Students, Panimalar College of Allied Health Sciences, Chennai

Keerthika

Sanjana V

Prithiviraj P

Hariprasad R

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MRI Contrast Agents Based on Protein-Targeted Gadolinium: Structure, Workings, and Uses

Pratik Virat, Bharvi Joshi, M. Sc. Research fellows, **Raushan Kumar, Mamta Verma,** Assistant Professors,
College of Paramedical Sciences, Teerthankher Mahaveer University, Moradabad, UP.

Abstract

A major development in molecular imaging, protein-targeted gadolinium (Gd)-based magnetic resonance imaging (MRI) contrast agents provide higher sensitivity and specificity than traditional, non-targeted agents. In order to provide more accurate disease diagnosis, characterization, and monitoring, these agents are made to preferentially bind to particular proteins implicated in different disease processes. The shortcomings of traditional Gd-based drugs, which have low specificity and quick clearance and frequently make it difficult to see minute pathological alterations, are addressed by this focused strategy.

A Gd chelate, a targeting moiety, and a linker make up the tripartite structure used in the creation of these medicines. The paramagnetic characteristics required for MRI contrast enhancement are provided by the Gd chelate, which is usually based on DTPA or DOTA derivatives. Chelation is essential for reducing the toxicity of free Gd^{3+} ions. An antibody (or antibody fragment), peptide, aptamer, or small molecule with a high affinity for the target protein can all be the targeting moiety, which is in charge of selective binding. Peptides are smaller and simpler to make, but they may have a lesser affinity than antibodies, which have a higher specificity but might be big and possibly immunogenic. The length and flexibility of the linker, which joins the Gd chelate with the targeted moiety, can affect how well the agent works. Cleavable linkers can improve target specificity even more since they react to particular enzymes or circumstances. The precise interaction between the targeting moiety and the target protein is essential to the mechanism of action, which causes the Gd chelate to accumulate locally at the location of the sickness. The relaxation of neighbouring water protons is greatly enhanced by this elevated local concentration of Gd, producing a stronger signal on T1-weighted MRI scans. The contrast enhancement may occasionally be further enhanced by a change in the Gd chelates relaxivity brought on by the binding event itself. These targeted contrast agents have demonstrated encouraging uses in a number of domains, such as cardiovascular imaging (targeting thrombosis and inflammation markers), neurological imaging (targeting tau tangles and amyloid plaques), cancer imaging (targeting tumor-associated antigens and receptors), and inflammation imaging (targeting adhesion molecules and chemokines). Targeting moiety affinity and specificity optimization, non-specific accumulation reduction, biocompatibility enhancement, and the development of multimodal imaging agents for improved diagnostic capabilities are the main areas of ongoing study. This focused strategy has enormous potential to enhance treatment monitoring, personalized therapy, and early illness identification.

Keywords: Targeted MRI contrast agents, Protein-targeted MRI, Gadolinium contrast agents, Molecular MRI, Antibody-targeted MRI, Peptide-targeted MRI, Relaxivity, Molecular imaging, Disease-specific targets (e.g., "EGFR MRI contrast," "amyloid MRI contrast")

Introduction

Because it provides high-resolution, non-invasive anatomical and functional imaging, magnetic resonance imaging (MRI) has emerged as a key component of contemporary medical diagnosis. However, the sensitivity and specificity needed for early illness diagnosis and accurate molecular-level characterisation of pathological processes are frequently lacking in conventional MRI. This restriction has prompted the creation of targeted contrast agents, especially those based on protein-targeted gadolinium (Gd), which mark a substantial advancement in molecular imaging. These substances are designed to connect to particular proteins that are linked to a number of illnesses, making it possible to see molecular signatures and offering vital information that goes beyond conventional anatomical data. Although they are good at highlighting vascular structures and regions with higher vascular permeability, conventional Gd-based contrast agents are unable to differentiate between various disease states using molecular markers. Their diagnostic value is limited by this lack of specificity, particularly in early-stage disorders when minute molecular changes occur before macroscopic anatomical abnormalities. By adding a targeting moiety—such as an antibody, peptide, or other ligand—that selectively identifies and binds to a target protein of interest, protein-targeted Gd-based therapies overcome this restriction. Enhanced sensitivity by focusing the contrast agent at the disease site, improved specificity by binding to disease-associated proteins selectively, and the possibility of earlier disease detection by observing molecular changes prior to significant tissue damage are some of the main benefits of this targeted approach. Three essential elements are usually included in the design of these agents: a targeting moiety to guarantee precise binding to the target protein, a linker to join the two, and a Gd chelate to supply the paramagnetic qualities for MRI contrast. By choosing the right targeting moieties for various disease targets, this modular design enables flexibility in customizing the contrast agent to particular applications. The complexities of this design, the ways in which these agents improve MRI contrast, and their wide range of medical applications—highlighting their potential to revolutionize disease diagnosis, monitoring, and treatment approaches—will all be covered in detail in the sections that follow.

Gadolinium chelates

The source of the paramagnetic qualities that improve image contrast in protein-targeted MRI contrast agents is the gadolinium (Gd) chelate. Due to its seven unpaired electrons, the rare earth metal gadolinium is strongly paramagnetic and can effectively reduce the relaxation periods of surrounding water protons. T1-weighted MRI images provide a stronger signal as a result of this shortening, making tissues and organs more visible. However, the human organism is extremely poisoned by free Gd^{3+} ions. A stable complex known as a gadolinium chelate is created when gadolinium is attached to a chelating agent in order to lessen its toxicity. By encasing the Gd^{3+} ion, the chelating agent stops it from interacting with biological molecules and producing negative effects.

A number of chelating agents are frequently found in MRI contrast agents, such as:

1. Diethylenetriamine pentaacetic acid, or DTPA, is a linear

chelating agent that combines with Gd^{3+} to produce a stable complex.
2. Compared to DTPA, DOTA (1,4,7,10-tetraazacyclododecane-1,4,7,10-tetraacetic acid) is a cyclic chelating agent that gives the Gd^{3+} complex more kinetic inertness and thermodynamic stability.
3. A DOTA derivative with one fewer acetate group, DO3A (1,4,7,10-tetraazacyclododecane-1,4,7-triacetic acid) is frequently utilized as a building block for the creation of more intricate contrast agents.

The Gd chelate's stability, relaxivity (the capacity to improve water proton relaxation), and overall safety profile can all be impacted by the chelating agent selection. In order to maximize the effectiveness and safety of Gd-based MRI contrast agents, researchers are still investigating novel chelating agents and chelate patterns.

Relaxivity

The ability of an MRI contrast agent to increase the relaxation rates of surrounding water protons is measured by its relaxivity, which is a crucial indicator of its efficacy. Water protons that have been excited and then relaxed back to equilibrium are the source of the MRI signal. A stronger signal results from the acceleration of this relaxation, especially T1 (longitudinal relaxation), by paramagnetic materials such as gadolinium. In particular, relaxivity (r1 and r2) indicates the rise in relaxation rate (1/T1 or 1/T2) for every unit of contrast agent concentration. Greater signal amplification for a given concentration is indicated by a higher relaxivity, which is preferable because it enables lower doses, potentially lowering toxicity. Temperature, the molecular makeup of the contrast agent, and the strength of the magnetic field produced by the MRI scanner all affect this feature.

Protein binding and relaxivity

In order to modify the relaxivity of gadolinium (Gd)-based MRI contrast agents, protein binding is essential. The molecular mobility of a contrast agent has a major impact on relaxivity, which is the effectiveness with which the chemical increases water proton relaxation and, consequently, picture brightness. A free Gd chelate in solution tumbles quickly, reducing the amount of time that water molecules and the paramagnetic Gd ion can interact. The relaxivity is decreased by this quick tumble.
However, because the protein is substantially larger, the Gd chelate's overall molecular motion is greatly slowed down when it binds to it. Because of this limited motion, water molecules near the Gd ion have a longer residence period, which promotes more effective relaxing and a significant rise in relaxivity. When it comes to tailored contrast agents, this phenomenon is especially pertinent since binding to the target protein at the disease site not only concentrates the agent locally but also improves its capacity to generate contrast. A brighter signal on MRI scans results from the enhanced relaxivity upon binding, enhancing the imaging method's sensitivity and diagnostic precision. A crucial design factor in the creation of high-performance tailored MRI contrast agents is this idea.

Relaxivity-influencing variables (hydration number, molecular tumbling rate, etc.)

Many important aspects of the contrast agent's molecular makeup and interactions with water molecules affect relaxivity, or how well it enhances the MRI signal.
1.Hydration number (q): This is the quantity of water molecules in the chelate that are directly coordinated to the gadolinium ion. Since more water molecules can directly interact with the paramagnetic Gd ion, a higher hydration number typically results in improved relaxivity. A balance is necessary since raising q can occasionally cause the chelate to become unstable.
2.Molecular tumbling rate (τr): This explains how the contrast agent molecule rotates in solution. Higher relaxivity results from slower tumbling, which is frequently accomplished by adhering to bigger molecules like proteins. This lengthens the period that water protons and Gd interact.
3.Water exchange rate: This is the rate of exchange between bulk water and water molecules in the inner coordination sphere of Gd. In order to effectively promote relaxation, the exchange rate must be at its ideal level; if it is too slow, the interaction with water is limited, and if it is too quick, the interaction is too short.
4.Electronic relaxation: This has to do with the electron spin relaxation of the Gd ion, which affects how well energy is transferred to water protons.
5.Magnetic field strength: The MRI scanner's magnetic field strength affects relaxivity as well.

These variables affect relaxivity in intricate ways and are interrelated. Developing high-performance MRI contrast agents requires careful molecular design to optimize these properties.

Targeting moiety

A protein-targeted MRI contrast agent's targeting moiety is its essential component that enables it to selectively attach to a certain molecular target, usually a protein, linked to a disease. A concentrated rise in gadolinium concentration and an improved MRI signal result from this selective binding, which guarantees the contrast agent accumulates at the place of interest. There are many different kinds of targeting moieties, such as aptamers, peptides, small compounds, and antibodies (or their components like Fab and scFv). Although they can be big and possibly immunogenic, antibodies have a high specificity and affinity. Although they are simpler to make and smaller, peptides may have a lesser affinity. Short DNA or RNA sequences called aptamers have a high affinity, are stable, and are simple to synthesize. Small molecules may have lesser selectivity even when they are easily produced and have good tissue penetration. The contrast agent's ability to achieve sensitive and accurate molecular imaging is ultimately determined by the targeting moiety's size, binding affinity, biocompatibility, and target expression levels in sick tissue.

Types of targeting moieties

1.Antibodies: The immune system produces proteins called antibodies, or immunoglobulins, which are known for their great affinity and specificity for target molecules, or antigens. Antibodies or their fragments (Fab, scFv) function as targeting moieties in tailored MRI contrast agents, allowing for selective binding to indicators linked to disease. The contrast agent accumulates locally as a result of this exact targeting, improving the MRI signal at the illness site. Although antibodies have high specificity, their size can prevent them from penetrating tissue, and their potential immunogenicity necessitates careful consideration in both clinical and design settings.
2.Peptides: Because of their tiny size, simplicity of synthesis, and lower immunogenicity than antibodies, peptides—short sequences of amino acids—are utilized as targeting moieties in MRI contrast agents. They can be made to bind particular target molecules, enzymes, or receptors. Peptides may have lesser binding affinity and specificity than bigger macromolecules like antibodies, despite their benefits in tissue penetration and cost-

effectiveness; hence, careful design and optimization are necessary for efficient targeting.

3.Aptamers: Similar to antibodies, aptamers are short, single-stranded DNA or RNA oligonucleotides that may fold into distinctive three-dimensional structures and bind target molecules with high affinity and specificity. Aptamers have a number of benefits as targeting moieties in MRI contrast agents, including minimal immunogenicity, chemical stability, resistance to degradation (with modifications), and very simple and affordable synthesis. Better tissue penetration is also made possible by their lower size in comparison to antibodies. Even though chemical changes can increase their stability, their vulnerability to nuclease degradation in vivo is still a factor.

4.Small molecules: Because of their high tissue penetration and ease and affordability of production, small molecules—organic compounds with a low molecular weight—are used as targeting moieties in MRI contrast agents. They can be made to attach to particular biological targets, such as enzymes or receptors. Small molecules typically have lesser specificity and binding affinity than bigger macromolecules like antibodies or aptamers, despite having advantages in terms of manufacture and distribution. To increase their targeting efficiency, careful design and optimization are necessary because this can result in off-target binding and decreased contrast enhancement at the intended site.

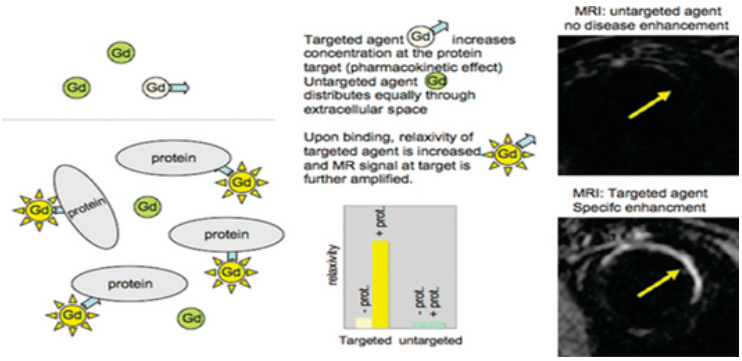
5.Other targeting moieties: In addition to small molecules, aptamers, peptides, and antibodies, other compounds can function as targeting moieties in MRI contrast agents. Vitamins, such as folate, can be delivered precisely because they are actively carried into some cells, especially cancer cells. Because certain carbohydrate structures are recognized by cell surface receptors, they can also be used. These other targeting techniques have special benefits, such focusing on particular carbohydrate epitopes or taking use of cellular absorption mechanisms. Their binding affinity and specificity, however, can differ, necessitating a thorough assessment for every application.

Mechanism of action

The way protein-targeted gadolinium (Gd)-based MRI contrast agents work depends on a precisely planned series of actions that eventually result in improved image contrast at the target location. These substances enter the circulatory system and are dispersed throughout the body after being administered intravenously. The targeting moiety's precise binding to the matching target protein is the critical step. This targeting moiety, which may be a small molecule, aptamer, peptide, or antibody, is made to identify and bind to a molecular marker linked to a certain illness or condition with high affinity and specificity. This marker is frequently a protein that is either exclusively found in the impacted tissue microenvironment or overexpressed on sick cells. The contrast agent's localization at the illness site is started by this molecular recognition event.

The local concentration of gadolinium ions at the target site rises noticeably as a result of the targeting moiety's preferential binding to the target protein. The foundation of the contrast enhancement mechanism is this build-up. Due to their unpaired electrons, gadolinium ions produce a confined magnetic field, making them paramagnetic. The MRI signal originates from the relaxation characteristics of adjacent water protons, which are significantly impacted by this local magnetic field. In particular, the T1 relaxation time of water protons is shortened by gadolinium ions. When excited protons are disturbed by a radiofrequency pulse inside the MRI scanner, they revert to their equilibrium condition, a process known as T1 relaxation. This return to equilibrium is accelerated when gadolinium is present.

A stronger MRI signal coming from the targeted location is the result of this increased T1 relaxation. This results in the targeted tissue or region appearing brighter on the final pictures of T1-weighted imaging. The contrast between the surrounding background tissues and the targeted tissue, where the contrast agent has accumulated, is significantly increased by this increased signal strength. This enhanced contrast makes it easier to see and describe the illness or condition being studied. Additionally, some sophisticated contrast agent designs include a responsive element, in which the contrast agent itself undergoes a conformational shift in response to the targeting moiety attaching to the target protein. This conformational shift has the potential to further alter the gadolinium chelate's relaxivity, which would increase the contrast effect and provide the imaging method an additional layer of sensitivity and specificity.



Applications:

1.Cancer imaging

Protein-targeted Gd-based magnetic resonance imaging contrast agents provide important benefits for early cancer detection, diagnosis, and treatment tracking. These medicines can particularly accumulate in tumor tissue by targeting angiogenesis indicators (like VEGF), growth factor receptors (like EGFR or HER2), or tumor-associated antigens (like CEA or PSMA). By improving MRI contrast, this focused accumulation makes it possible to identify small tumors, distinguish benign from malignant lesions, stage and grade cancers accurately, and track the exact effectiveness of treatments like radiation or chemotherapy. Additionally, this focused strategy facilitates image-guided surgery, which enables more accurate tumor excision

1.Cardiovascular imaging

Because they make it possible to see important pathological processes at the molecular level, protein-targeted Gd-based MRI contrast agents have enormous potential to improve cardiovascular imaging. The identification of susceptible plaques that are prone to rupture and subsequent thrombotic events is made possible by these agents' ability to target a variety of markers linked to cardiovascular illnesses, including inflammatory markers (VCAM-1, ICAM-1) expressed on activated endothelial cells in atherosclerotic plaques. Direct imaging of blood clots inside the heart or blood arteries is made possible by targeting thrombosis markers like fibrin or platelets. This helps with the diagnosis and treatment of diseases like pulmonary embolism and deep vein thrombosis. Additionally, during a myocardial infarction (heart attack), these substances can target myocardial damage signals like cardiac myosin or troponin, which are secreted from damaged heart muscle.

This makes it possible to precisely evaluate the extent of the infarct and the health of the surrounding tissue, which is essential for directing treatment strategies and forecasting patient outcomes. With regard to cardiovascular illness, this focused approach holds promise for early diagnosis, risk assessment, and individualized treatment plans.

3.Neurological imaging

Protein-targeted Gd-based MRI contrast agents have the ability to diagnose neurodegenerative disorders early and accurately in neurological imaging. These agents can visualize the molecular alterations linked to Alzheimer's disease and other tauopathies by focusing on important pathological hallmarks such as neurofibrillary tangles, which are aggregation of tau protein, and amyloid plaques, which are made of amyloid-beta peptide. Compared to traditional MRI, which usually only identifies structural alterations at a later stage, this enables earlier detection. Additionally, by analyzing changes in the amyloid and tau burden over time, these agents can be used to follow the development of the illness and assess the efficacy of therapeutic measures meant to lessen these pathological hallmarks. This focused strategy provides a potent instrument for improving our comprehension and treatment of neurodegenerative diseases.

4.Inflammation imaging

Gd-based MRI contrast agents that target proteins have great promise for identifying and detecting inflammation in a range of illnesses. These medicines can identify inflammation locations with great specificity by targeting particular markers implicated in the inflammatory process, such as adhesion molecules (integrins, selectins) that mediate leukocyte trafficking or signaling molecules like chemokines and cytokines. This makes it possible to image inflammatory diseases such as multiple sclerosis, rheumatoid arthritis, and inflammatory bowel disease, facilitating early diagnosis, evaluation of disease activity, and tracking of the effectiveness of anti-inflammatory treatments. Compared to traditional imaging methods, which frequently lack the sensitivity and specificity to identify modest inflammatory changes at an early stage, this tailored approach offers a considerable benefit.

5.Infectious disease imaging

By focusing on certain proteins found on the surface of pathogens such as bacteria, viruses, or fungus, protein-targeted Gd-based MRI contrast agents have the potential to enhance the imaging of infectious diseases. Compared to traditional imaging techniques, this tailored approach enables the identification and localization of infections with enhanced sensitivity and specificity. This can help with timely and effective treatment techniques, especially when identifying deep-seated infections or differentiating infections from sterile inflammation.

6.Gene therapy monitoring

By measuring the expression of therapeutic genes given to target cells, protein-targeted Gd-based MRI contrast agents can be extremely useful in gene therapy monitoring. Researchers can see the degree of gene expression in vivo and the success of gene transfer by using contrast agents that target the proteins encoded by these therapeutic genes. This makes it possible to evaluate the effectiveness of gene delivery, monitor treatment efficacy non-invasively, and optimize gene therapy regimens. This method helps create more efficient and focused gene therapies by offering insightful information on the spatiotemporal dynamics of gene expression.

Conclusion

An important development in molecular imaging is the use of protein-targeted gadolinium (Gd)-based MRI contrast agents, which have higher sensitivity and specificity than traditional agents. Because of their ability to bind selectively to particular proteins linked to disease, these agents allow for accurate monitoring, characterisation, and detection. The targeting moiety, the linker, and the Gd chelate are the three main parts of the design. The paramagnetic characteristics for enhancing MRI signals are provided by the Gd chelate, usually utilizing DTPA or DOTA. The chelating agent maximizes relaxivity while minimizing Gd^{3+} toxicity. Target specificity is determined by the targeting moiety, which might be tiny molecules, aptamers, peptides, or antibodies. Each has special benefits in terms of synthesis ease, size, and affinity. The linker affects flexibility, stability, and biodistribution by joining the targeted moiety and chelate.Local Gd build-up results from the mechanism's reliance on precise binding between the targeting moiety and the target protein. A stronger signal on T1-weighted imaging is the result of this rise in local Gd concentration, which also improves water proton relaxation. This targeted accumulation enhances contrast and makes it possible to see minute molecule changes, sometimes in conjunction with relaxivity modulation upon binding. These substances can be used to treat neurological disorders (targeting tau tangles and amyloid plaques), cardiovascular disease (targeting thrombosis, inflammation, and myocardial damage markers), cancer (targeting tumor antigens, receptors, and angiogenesis markers), and inflammation (targeting adhesion molecules, chemokines). Optimizing targeting, reducing non-specific accumulation, enhancing biocompatibility, and creating multimodal agents are the main areas of ongoing research that could transform illness diagnostics and individualized care.

References

1. https://www.abcam.com/en-us/products/proteins-peptides/recombinant-human-mri-protein-ab140733
2. https://www.pnas.org/doi/10.1073/pnas.1423021112
3. https://pubmed.ncbi.nlm.nih.gov/38180819/
4. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3463956/
5. https://www.pnas.org/doi/10.1073/pnas.1423021112
6. https://www.futuremedicine.com/doi/10.2144/btn-2021-0197
7. https://www.tandfonline.com/doi/abs/10.1080/07388551.2012.684120
8. https://www.intechopen.com/chapters/70929
9. https://arxiv.org/abs/2002.08059
10. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2692035/

Neuro-Maps in Motion: Unveiling Brain Function via BOLD fMRI

Akriti Johri, M.Sc. Research Fellow, **Mamta Verma, Raushan Kumar,** Assistant Professors,
College of Paramedical Sciences, Teerthankher Mahaveer University, Moradabad, UP.

Abstract

Functional Magnetic Resonance Imaging (fMRI) is a non-invasive technique that maps brain activity by tracking changes in blood flow through detecting fluctuations in the blood-oxygen-level-dependent (BOLD) signal. Since its introduction in 1990, fMRI has become an essential tool in both fundamental neuroscience research and clinical practice. This article provides an overview of the scientific principles underlying fMRI, examines its primary applications in research and medicine, discusses its advantages and limitations, explores technical challenges, and highlights emerging advancements in the field.

Keywords

Functional MRI; BOLD; hemodynamic response; spatial resolution; temporal resolution; neuroimaging; Advantages; clinical application.

Introduction

The introduction of BOLD contrast by Ogawa and colleagues in 1990 revolutionized neuroimaging by allowing scientists to visualize brain activity in living subjects through naturally occurring blood flow changes[1]. Later studies with humans confirmed that specific brain areas activated during tasks like the visual cortex during stimulus presentation can be accurately detected without needing injected tracers[1,2]. Today, functional MRI (fMRI) offers detailed millimeter scale spatial precision, covering the entire brain safely. It has improved upon PET scans and provides better localization than EEG or MEG, although it does come with less temporal resolution[3,4]. The discovery of intrinsic brain networks, such as the default mode network, in the late 1990s has further expanded fMRI's role in studying cognition and clinical conditions[5].

Core Principles of fMRI

MRI Fundamentals

fMRI is based on the principles of MRI physics. Specifically, it involves hydrogen protons aligning with a magnetic field, responding to radiofrequency pulses, and emitting signals that are used to generate detailed images of the brain's structure[1].

BOLD Contrast Mechanism

When neurons activate, they need more energy and blood flow to support it, which reduces deoxyhemoglobin levels and boosts the signal we see in T2*-weighted scans [1,6].

Hemodynamic Response

The hemodynamic response function (HRF) typically shows an initial dip, reaches its peak around 5 to 6 seconds after the stimulus, then undershoots again Post-stimulus before returning to baseline roughly 20 seconds later. This pattern helps define the temporal resolution of fMRI measurements[6].

Signal Source Specificity

BOLD signals happen because of changes in brain blood flow, blood volume, and how much oxygen the brain is using. Both intravascular and extravascular play a major role in making these signals precise in specific areas[7].

Applications

Task-Evoked fMRI

Block and event-related designs are helpful for understanding how different functions like motor skills, language, and memory work in the brain. They give us important information not just for research, but also for planning surgeries[2].

Component	Approx. Timing	Comment
Initial dip	~1–2 s post stimulus	Reflects early oxygen consumption but is small and variable
Peak	~5–6 s post stimulus	Main parameter for temporal modeling in fMRI
Post-stimulus undershoot	~10–15 s	Hemodynamic rebound before returning to baseline
Full return	~20 s post stimulus	Marks end of the typical hemodynamic cycle
Variability	±2 s peak timing	Varies across brain regions, subjects, and age

Table 1 Hemodynamic Response Function (HRF)

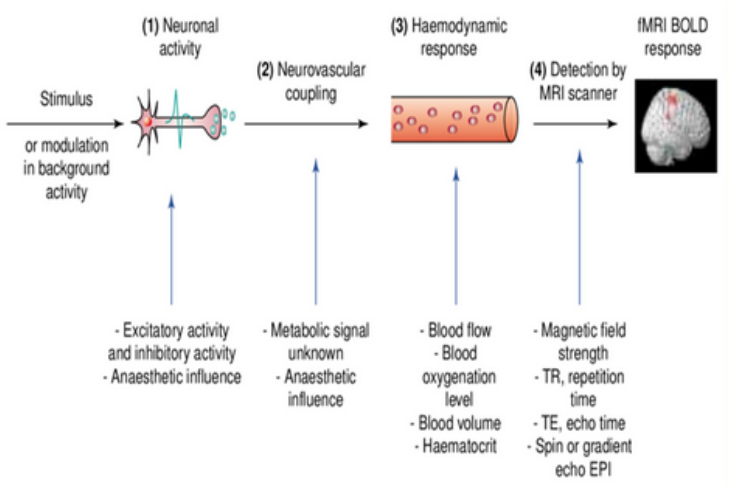


Figure 1. Four-stage breakdown of the fMRI BOLD process: neuronal activation → neurovascular coupling → hemodynamic response → MRI-based detection.

Resting-State Connectivity

Low-frequency (less than 0.1 Hz) BOLD fluctuations help us see the brain's default, salience, and executive control networks. This information is useful when studying how the brain develops, ages, or when there's some kind of problem going on[5,8].

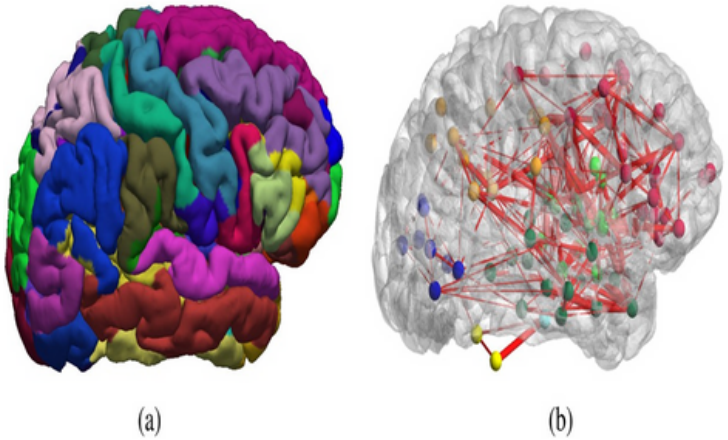


Figure 2. Visualization of resting-state fMRI connectivity workflow: (a) brain parcellation into regions, (b) connectivity network formed from inter-regional BOLD signal correlations.

Clinical Utility

Doing presurgical mapping of the language and motor areas in patients with epilepsy, tumors, or strokes can help improve the success of their surgeries[3].

Application Area	Use Case	Advantages	Limitations
Presurgical Mapping	Motor, language mapping before brain surgery	Non-invasive; integrates with DTI & cortical stim	HRF distortion near tumors; less reliable for language
Resting-State fMRI	Connectivity analysis in epilepsy/tumor cases	Useful for impaired patients; no task required	Variability of networks; motion-sensitive
Real-time fMRI & rt-BCI	Neurofeedback and brain–computer interfaces	Enables self-regulation; whole-brain decoding	Requires fast processing infrastructure

Table 2 Clinical Application

Multimodal Integration

Mixing fMRI with methods like EEG, fNIRS, or optogenetics can give us a much clearer picture of what's happening over time and make the physiological details easier to understand[2,9].

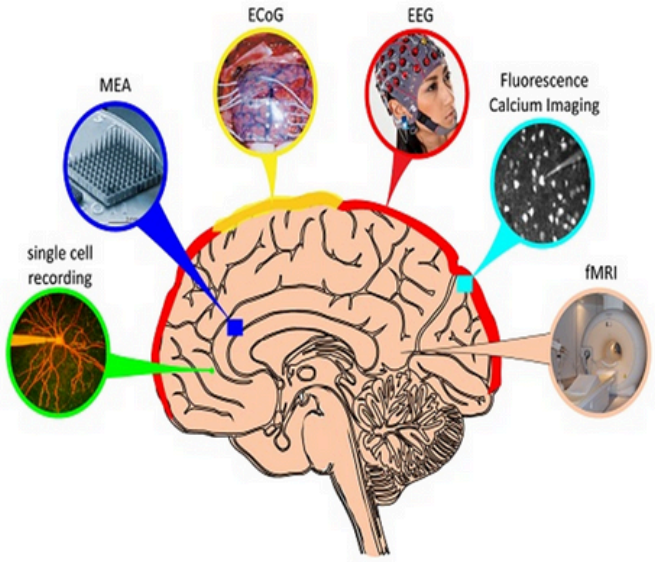


Figure 3. Comparing brain recording methods by their time and space detail. This image shows six ways to record brain activity—from very precise single-cell recording to broader whole-brain fMRI. It makes it easy to see that techniques like single-cell and MEA capture activity very fast but only in tiny areas, while fMRI covers the whole brain but with slower timing.

Advantages

- Non-invasive & radiation-free: No need for external tracers, which makes it safer for repeated scans [3].
- Sharp detail: Usually 1–3 mm clarity; at 7 T, you can get down to less than a millimeter [8].
- Whole brain coverage: Great for studying entire networks across the brain.
- Versatile research tool: Used across fields like cognitive neuroscience, psychiatry, pharmacology, and neurofeedback [5].

Disadvantages

- Temporal lag: HRF delay (~5 s) limits capture of rapid neural events [6].
- Motion sensitivity: Even minimal movements reduce data quality, requiring filtering like RETROICOR [3,10].
- High cost & infrastructure: MRI machines need a major investment.
- Indirect measurement: BOLD reflects vascular response, not direct neuronal activity [7].

Technical & Methodological Limitations

HRF Variability

HRF characteristics can vary between different people and different parts of the brain, which makes it tricky to interpret the data accurately[8,11].

Physiological Artifacts

Breathing and heartbeat changes can distort BOLD signals, but can be fixed that by using some regression filtering [10].

Trade-offs

Getting clear images often means taking slower scans, which can make the process more sensitive to motion issues[8].

Statistical Power & Reproducibility

Small sample sizes in studies can limit how much we can trust the results. That's why having standardized methods and pre-registering your study plans is important[5].

Interpretation Pitfalls

Just because activation happens doesn't mean it causes something else, "reverse inference" must be avoided [5].

Future Directions

- Ultra-High-Field (7 Tesla and above): Better at picking up tiny blood vessels and different layers in the brain's cortex [8].
- Machine Learning & Connectivity Modeling: Helps us decode neural signals and predict brain states more accurately [9].
- Portable Hybrid Systems: Combining fNIRS and EEG devices in a portable setup makes real-world testing easier and more natural [5].
- Open Science & Standardization: Projects like the Human Connectome Project encourage sharing data and methods to make research more reliable and repeatable [5].

Conclusion

fMRI has truly changed how we understand the brain. It's fascinating because it allows us to observe how different regions function without invasive procedures. Of course, there are some complexities, like the delay in signals and the influence of blood flow, but with ongoing technological advances, smarter analytical methods, and open science collaboration, the future of fMRI in neuroscience and healthcare looks very promising.

References

1. Ogawa S, Lee TM, Kay AR, Tank DW. Brain magnetic resonance imaging with contrast dependent on blood oxygenation. Proc Natl Acad Sci USA 1990;87(24):9868–72.
2. Logothetis NK. The underpinnings of the BOLD functional magnetic resonance imaging signal. J Neurosci 2003;23(10):3963–71.
3. Glover GH. Overview of functional magnetic resonance imaging. Neurosurg Clin N Am 2009;20(2):123–38.
4. Raichle ME. Behind the scenes of functional brain imaging: a historical and physiological perspective. Proc Natl Acad Sci USA 1998;95(3):765–72.
5. Smith SM, Beckmann CF, Andersson J, et al. Resting-state fMRI in the Human Connectome Project. Neuroimage 2013;80:144–68.
6. West KL, Zuppichini MD, Turner MP, et al. BOLD hemodynamic response function changes significantly with healthy aging. Neuroimage 2019;188:521–31.
7. Buxton RB. The physics of BOLD fMRI. J Magn Reson Imaging 2013;38(1):2–13.
8. Mahnke F, et al. High-field BOLD fMRI review. Materials (Basel) 2011;4(11):1941–55.
9. Franziska A, Schache D, Faber C, et al. Functional MRI readouts from BOLD and diffusion measurements. Front Neurosci 2019;13:481.
10. Dichter GS, Sikich L, Song A, et al. Regression filtering to remove respiratory noise in fMRI motor mapping. Int J Neurosci 2012;122:483–93.
11. Tsvetanov KA, Henson RN, Rowe JB. Separating vascular and neuronal effects of age on fMRI BOLD signals. Neuroimage 2020;209:116491.

AI Powered Catheter Segmentation

Catheter Segmentation in X-Ray Fluoroscopy Using Synthetic Data and Transfer Learning with Light U-Nets

Ashfiya Ali, B.Sc. MRIT Student, M S Ramaiah University of Applied Sciences, Bangalore, Karnataka

Abstract

Catheter-based endovascular procedures heavily rely on accurate visualization of instruments under X-ray fluoroscopy. Manual interpretation of these images can be time-consuming and prone to error, particularly in real time surgical environments. This study introduces an AI powered method for the automated segmentation and tracking of catheters and guidewires in 2D fluoroscopic images, enabling enhanced image guidance during minimally invasive procedures. This study proposes a lightweight version of the U-Net convolutional neural network (CNN), optimized through a transfer learning approach using synthetic fluoroscopic data.

Keywords: AI-powered segmentation, catheter tracking, deep learning, X-ray fluoroscopy, transfer learning, U-Net, endovascular procedures.

Introduction

Cardiovascular diseases (CVDs) continue to be the leading cause of death globally, as projected by the World Health Organization. With the growing adoption of minimally invasive surgery (MIS) for the treatment of cardiovascular diseases (CVDs), there is an increasing demand for accurate, real-time imaging tools to guide surgical instruments.

X-ray fluoroscopy is the predominant imaging modality used during these procedures due to its high temporal resolution and ability to provide continuous feedback.
Recent advancements in deep learning, particularly in the field of convolutional neural networks (CNNs), have shown promise for medical image segmentation tasks. The U-Net architecture, originally designed for biomedical segmentation, has proven effective in capturing both contextual and spatial information in grayscale images such as X-rays. Despite its success, a major limitation in training CNN-based segmentation models is the requirement for large volumes of pixel-level annotated data—a resource that is particularly scarce in surgical imaging domains.

To address this limitation, this study presents a novel approach for automated, real-time catheter and guidewire segmentation in 2D fluoroscopic images. The proposed method leverages a lightweight U-Net architecture, optimized through transfer learning to reduce the dependence on manually labelled data. The training process is divided into two stages: an initial phase using high-fidelity synthetic and phantom-generated fluoroscopic images with pre-defined segmentations, followed by a fine-tuning phase using a small set of annotated in-vivo fluoroscopic images.

Materials and methods:

Proposed CNN model

An adapted version of the basic U-Net architecture is developed for catheter segmentation in fluoroscopic images. The number of convolutional operations per layer is reduced from two to one, simplifying the model and decreasing the total learnable parameters. Each convolution is followed by Batch Normalization and a ReLU activation, with a final sigmoid activation used for pixel-wise classification.

To further reduce complexity, input images are resized to 256×256 pixels, resulting in a 55-layer model—half the size of the 110-layer architecture in [12]. The network takes a single grayscale image as input and outputs two complementary probability maps (catheter and background). Final segmentation is obtained by thresholding the catheter mask:

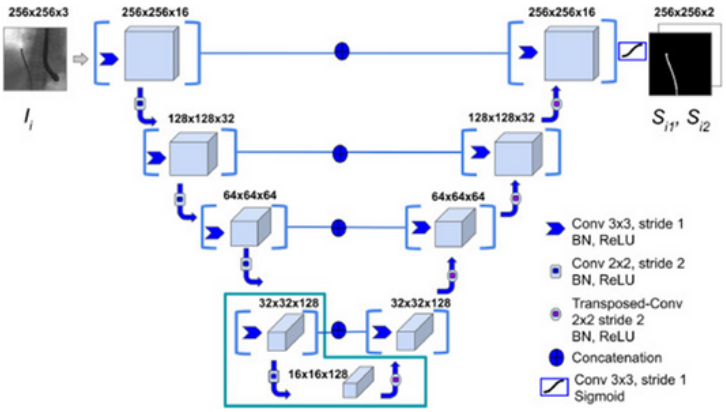


Figure: 1. The proposed lightweight U-Net architecture. A single grayscale Image Ii is fed into the model, which outputs the predictions Si1 and Si2. Each layer is composed of a convolutional block with a 3x3 kernel. The L-shape at the bottom of the architecture delimits the layers that undergo fine-tuning.

Methods:

Catheters and guidewires were manually annotated on 3831 fluoroscopy frames collected prospectively from 40 patients undergoing cerebral angiography. We proposed a topology aware geometric deep learning method (TAG-DL) and compared it with the state-of-the-art deep learning segmentation models, UNet, nnUNet, and TransUNet. All models were trained on frontal view sequences and tested on both frontal and lateral view sequences from unseen patients. Results were assessed with the centerline Dice score and tip-distance error.

Results:

The TAG-DL and nn UNet models outperformed TransUNet and UNet. The best-performing model was nnUNet, achieving a mean centerline Dice score of 0.98 ± 0.01 and a median tip-distance error of 0.43 mm (IQR, 0.88). Incorporating digital subtraction masks, with or

without contrast, significantly improved performance on unseen patients, further enabling exceptional performance on lateral view fluoroscopy despite not being trained on this view.

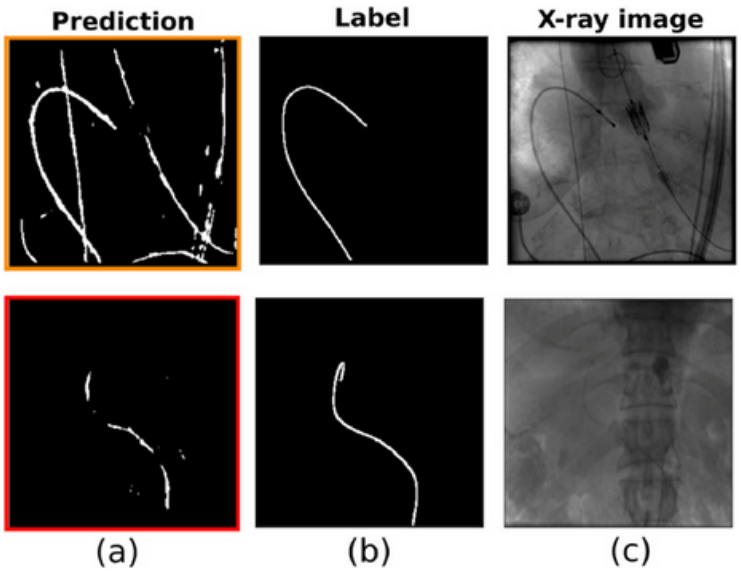


Figure:2. Segmentation results on two representative frames from T2 (upper panel) and T5 (lower panel), with the network fine-tuned on S1 (Experiment-1). The figure shows: (a) the network prediction, (b) the ground truth mask, and (c) the corresponding X-ray image.

without contrast, significantly improved performance on unseen patients, further enabling exceptional performance on lateral view fluoroscopy despite not being trained on this view.

Conclusions:

These results are the first step towards AI augmentation for robotic neurointerventional that could amplify the reach, productivity, and safety of a limited neurointerventional workforce. This article presents a novel approach for performing pixel-wise segmentation of surgical catheters in 2d X-ray fluoroscopy images. We demonstrate the applicability of using synthetic data and a streamlined training strategy for deep CNN networks intended for performing focused tasks. With the proposed transfer learning approach the amount of manually annotated data for training CNNs can be significantly reduced (only 240, 493, and 579 images were used for fine-tuning). We also show that our simplified U-Net architecture trained on randomly presented samples achieves comparable accuracy to the state-of-the-art CNN models for catheter segmentation, with an average Dice coefficient difference within 4%-5%, and can adequately segment the catheter on fluoroscopic videos from real endovascular procedures. Potential areas of future work include further investigation into the use of synthetic data for training and the application of more complex CNN architectures. In addition, post-processing techniques applied to the output segmentation mask, like extracting the catheter's centerline, can be exploited to improve the segmentation outcome and robustness of the method, particularly in challenging situations with low-contrast fluoroscopic imaging.

References:

1. Yamashita, R., Nishio, M., Do, R. K. G., & Togashi, K. (2020). Catheter segmentation in X-ray fluoroscopy using synthetic data and transfer learning with light U-nets. Medical Physics, 47(3), 1182–1191. https://pubmed.ncbi.nlm.nih.gov/32171151/

2. Kweon, H., Kim, S., Lee, H., Lee, H., & Kim, H. (2023). Automated catheter segmentation and tip detection in cerebral angiography with topology-aware geometric deep learning. Medical Physics, 50(8), 4984–4994. https://pubmed.ncbi.nlm.nih.gov/37344174/

3. Wang, Y., Cao, L., Zhang, Y., Wang, C., & Qian, X. (2020). Dynamic coronary roadmapping via catheter tip tracking in X-ray fluoroscopy with deep learning-based Bayesian filtering. Medical Image Analysis, 61, 101654. https://pubmed.ncbi.nlm.nih.gov/31978856/

4. Chen, X., Zhu, Q., Hu, Y., & Zheng, Y. (2023). ConTrack: Contextual Transformer for Device Tracking in X-ray. arXiv preprint arXiv:2307.07541. https://arxiv.org/abs/2307.07541

5. Li, Q., Liu, Z., Shen, C., Song, G., Liu, M., & Luo, J. (2024). Label-Efficient Data Augmentation with Video Diffusion Models for Guidewire Segmentation in Cardiac Fluoroscopy. arXiv preprint arXiv:2412.16050. https://arxiv.org/abs/2412.1605

6. Li, J., Wang, Y., Tang, W., & Wang, Y. (2020). Improved U-Net for Guidewire Tip Segmentation in X-ray Fluoroscopy Images. Proceedings of the ACM Conference on Bioinformatics, Computational Biology, and Health Informatics (BCB), 578–582. https://dl.acm.org/doi/10.1145/3373419.3373449:

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And one more thing, we have conveyed this issue to you, as an enlightened Radiographer, now it is your responsibility to forward this issue to other Radiographers.

Thanks in advance,
Editor

New Horizons in MRI Contrast Agents: Revolutionizing Safety and Diagnostic Precision

Firdous Nazir, Radiographic Technologist, DMST, Pulwama, Jammu & Kashmir

Magnetic Resonance Imaging (MRI) is a cornerstone of modern medical diagnostics, offering unparalleled insights into the body's internal structures without invasive procedures. A key component of many MRI scans is the use of contrast agents, which enhance image clarity by improving the visibility of tissues, organs, or pathological conditions. Recent innovations in MRI contrast agents have focused on addressing safety concerns, reducing toxicity, and expanding diagnostic capabilities. This article explores the latest advancements in MRI contrast agents, including macrocyclic gadolinium-based agents, high-relaxivity agents, manganese-based alternatives, iron oxide nanoparticles, and hyper polarized compounds, highlighting their impact on clinical practice and research.

Macrocyclic Gadolinium-Based Contrast Agents: A Safer Standard

Gadolinium-based contrast agents (GBCAs) have long been the gold standard for enhancing MRI images by altering the magnetic properties of tissues. However, concerns about nephrogenic systemic fibrosis (NSF) in patients with renal impairment and gadolinium retention in tissues prompted the development of safer alternatives. Macrocyclic GBCAs, such as gadobutrol (Gadovist), gadoteridol (ProHance), and gadoterate meglumine (Dotarem), represent a significant leap forward. Unlike older linear GBCAs (e.g., gadodiamide), macrocyclic agents have a cage-like molecular structure that tightly binds gadolinium ions, minimizing the risk of ion release. This stability has drastically reduced NSF cases and lowered concerns about gadolinium deposition in the brain and other tissues, even in patients with normal kidney function. Regulatory bodies like the FDA and EMA now recommend macrocyclic agents as the preferred choice, making them a cornerstone of modern MRI protocols for brain, vascular, and soft tissue imaging.

High-Relaxivity GBCAs: Enhanced Imaging with Reduced Doses

Another breakthrough in GBCA technology is the development of high-relaxivity agents like gadobenate dimeglumine (MultiHance) and gadoxetate disodium (Eovist/Primovist). These agents produce stronger contrast signals at lower doses, reducing the amount of gadolinium administered and minimizing potential toxicity. Gadobenate dimeglumine, for instance, enhances signal intensity across various applications, from brain tumors to vascular imaging. Gadoxetate disodium stands out for its hepatobiliary-specific properties, as it is taken up by hepatocytes and excreted into the bile. This enables functional imaging of the liver and biliary system, making it invaluable for detecting hepatocellular carcinoma, characterizing liver lesions, and evaluating biliary obstructions. By offering both anatomical and functional insights in a single scan, these agents improve diagnostic accuracy while addressing safety concerns about gadolinium retention.

Manganese-Based Contrast Agents: A Promising Alternative

To address lingering concerns about gadolinium, researchers are exploring manganese-based contrast agents, such as manganese chloride and experimental manganese chelates. Manganese, a naturally occurring element, is metabolized by the body, reducing the risk of long-term tissue accumulation. These agents show promise in liver and brain imaging, offering comparable contrast enhancement to GBCAs in preclinical studies. For example, manganese-based agents can highlight liver lesions and provide functional insights into neurological conditions. While still in early clinical or research stages, manganese-based agents could become a safer alternative for patients with renal impairment or those requiring repeated MRI scans, potentially reshaping the contrast agent landscape.

Iron Oxide Nanoparticles: Biodegradable and Targeted Imaging

Super paramagnetic iron oxide nanoparticles (SPIONs), such as ferumoxytol, are emerging as a biodegradable alternative to GBCAs. Unlike gadolinium, SPIONs are metabolized by the body's iron recycling pathways, significantly reducing the risk of long-term retention. Recent advancements have improved their stability and targeting capabilities, making them ideal for specific applications like lymph node imaging, liver lesion detection, and vascular studies. For instance, SPIONs can highlight metastatic lymph nodes in cancer staging or detect focal liver lesions with high specificity. Their biocompatibility and versatility position SPIONs as a promising option for patients who cannot tolerate GBCAs or require specialized imaging protocols.

Hyperpolarized Contrast Agents: A Frontier in Metabolic Imaging

Among the most cutting-edge developments are hyperpolarized contrast agents, such as hyperpolarized carbon-13 compounds (e.g., hyperpolarized pyruvate). These agents work by amplifying MRI signals through nuclear spin polarization, enabling real-time imaging of metabolic processes. Hyperpolarized agents are particularly valuable in oncology and cardiology, where they can track tumor metabolism or assess cardiac function at a molecular level. For example, hyperpolarized pyruvate can reveal metabolic changes in tumors, aiding in early cancer detection or treatment monitoring. While these agents are non-toxic and free of heavy metals, their use is currently limited to research settings due to the need for specialized equipment and the short duration of the hyperpolarized signal. Nonetheless, they represent a

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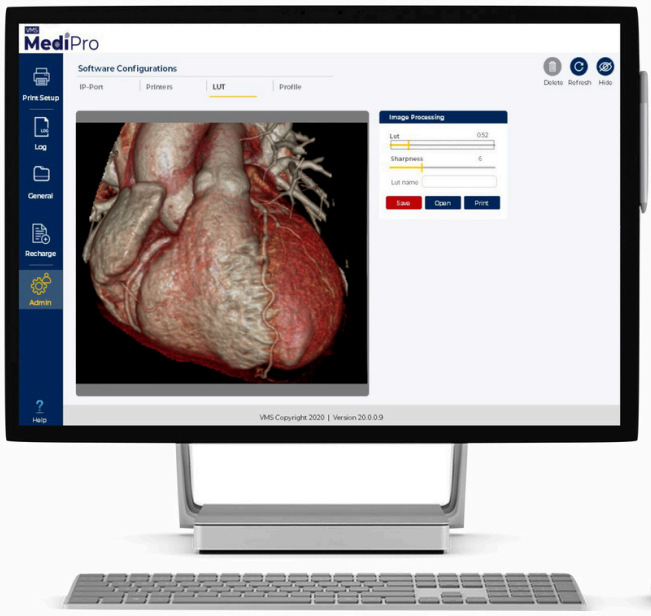

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Clinical and Research Impacts

The development of these new contrast agents has profound implications for clinical practice and research:

Enhanced Safety: Macrocyclic and high-relaxivity GBCAs, along with non-gadolinium alternatives, reduce risks like NSF and gadolinium retention, making MRI safer for vulnerable populations, including those with renal issues or requiring frequent scans.

Improved Diagnostics: Hepatobiliary-specific GBCAs and hyperpolarized agents provide functional insights, enabling earlier and more accurate diagnoses of conditions like liver cancer, brain tumors, and metabolic disorders.

Expanded Accessibility: Biodegradable agents like SPIONs and manganese-based compounds could lower costs and risks, making MRI viable in resource-limited settings or for patients with contraindications to traditional GBCAs.

Research Advancements: Hyperpolarized agents open new avenues for studying disease mechanisms at a molecular level, advancing fields like oncology, neurology, and cardiology.

Challenges and Future Directions

Despite these advancements, challenges remain. Manganese-based agents and hyperpolarized compounds require further clinical validation and infrastructure investment. The high cost of specialized equipment for hyperpolarized imaging limits its widespread adoption. Additionally, while macrocyclic GBCAs and SPIONs have improved safety, ongoing research is needed to fully understand long-term effects, particularly for patients undergoing repeated scans. Emerging technologies, such as AI-enhanced non-contrast imaging and low-field MRI systems, may further reduce reliance on contrast agents, complementing these innovations.

Conclusion

The evolution of MRI contrast agents—from safer macrocyclic and high-relaxivity GBCAs to manganese-based agents, iron oxide nanoparticles, and hyper polarized compounds—marks a new era in diagnostic imaging. These advancements enhance image quality, improve patient safety, and expand the scope of MRI applications, from routine diagnostics to cutting-edge metabolic research. As research progresses and clinical adoption grows, these agents promise to make MRI more precise, accessible, and tailored to individual patient needs.

Letter to the editor

Kedar Dharmadhikari, Ex- Bayer Pharma Radiology

I am in receiving this online journal of Radiographer's regularly.

After going through all issues this year, I am happy and elated to see various write ups and papers of fellow radiographer's. My observations-Itself Editorial is noteworthy and aptly written.

Further, importance or use of VR/ AR in Radiology article is worth reading.

The important subject/ point well written is " Ethics in Radiology". A detailed presentation.

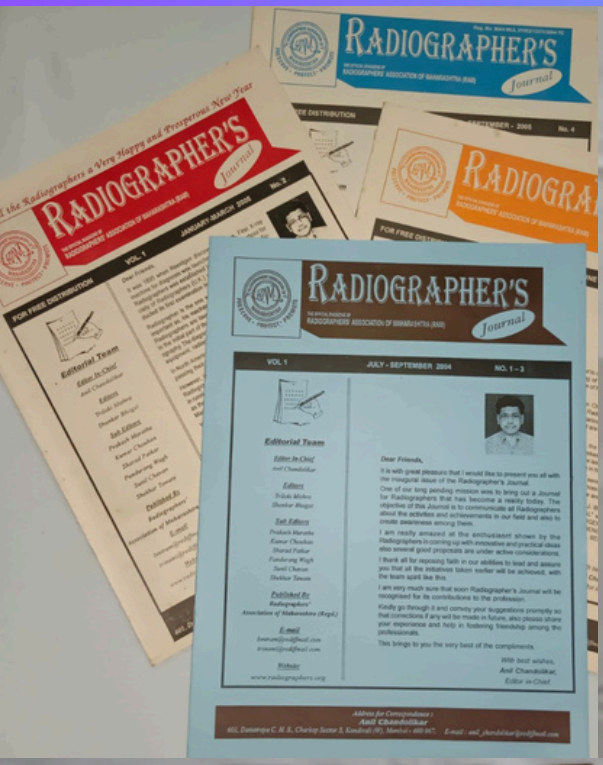
New avenues/ subjects like robotics in imaging and surgery, Spectral Mammography, Optical tomography, X-ray detection for Cancer care - well described.

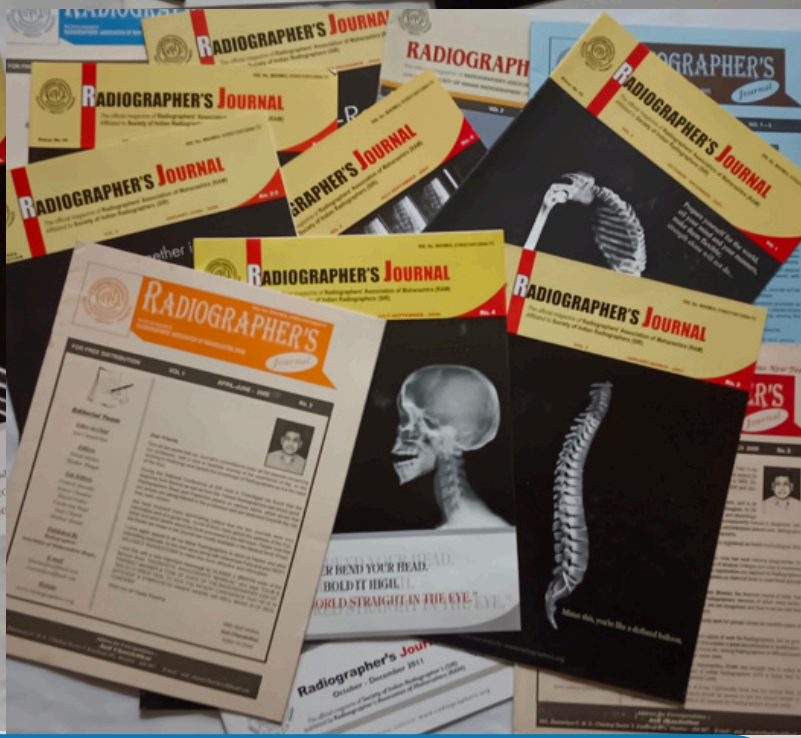
Suitable for today's radiologist that he/ she should be wellwarse with Machines used in the dept.

Contrast dose optimisation is new, hot and talked about concept which nicely described.

All this shows, how new generation radiographer's are making themselves more capable to developing arena. Glad to see modern subjects/ studies taken up by Radiographer's teaching institutes. Kudos to such institutions for upbringing, nurturing, encouraging their radiographic students to do such a great, educative and enriching work.

Kudos to Editorial team for their apt and encouraging work.





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