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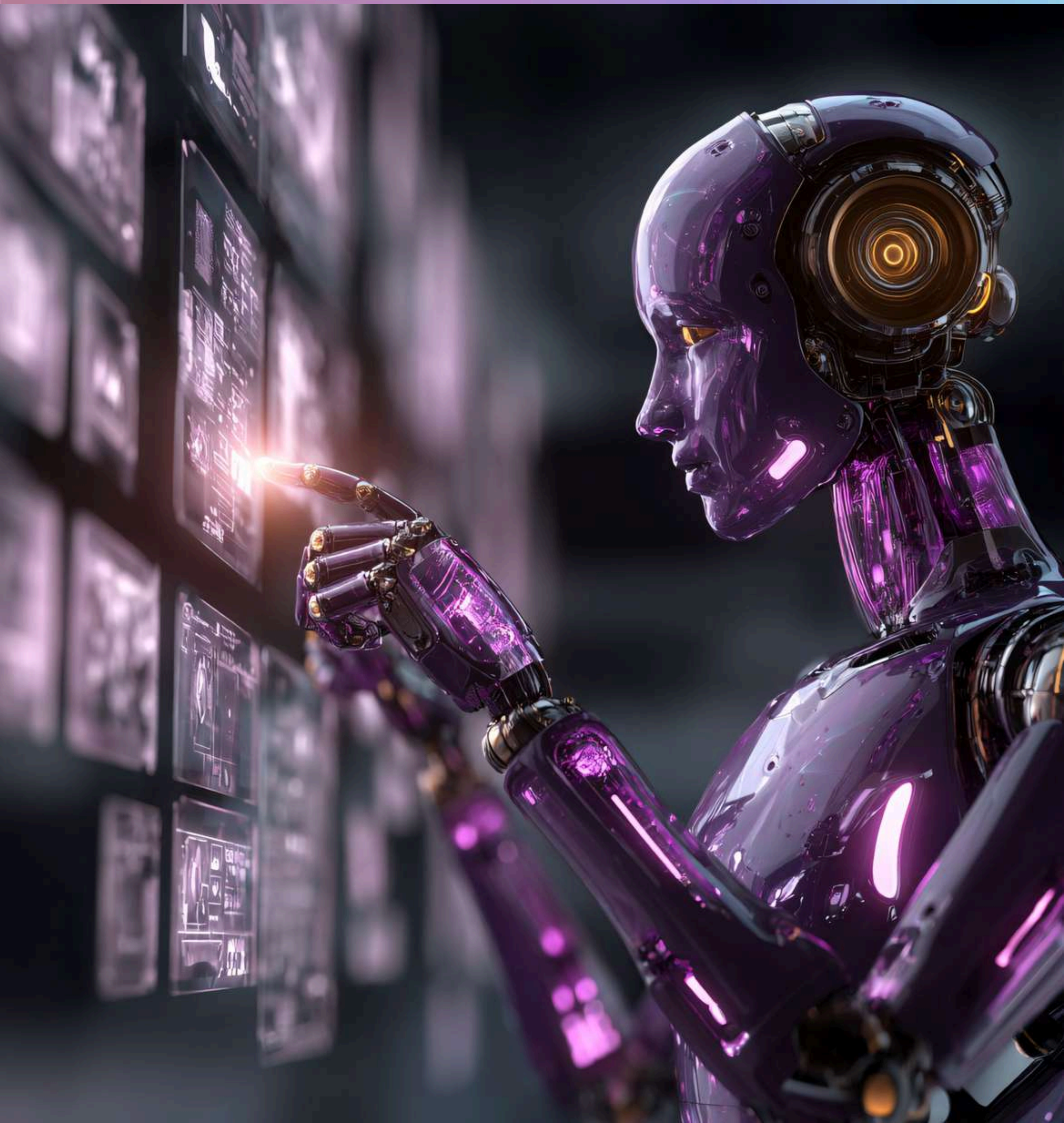
Radiographers' Journal

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

January 2026



Editorial

Shankar K. Bhagat
Editor-in-chief

Dear Readers,

As we begin the year 2026, the Radiographers Journal continues its commitment to advancing professional knowledge, clinical excellence, and patient-centered care in medical imaging. This January issue brings together a rich collection of scholarly articles that reflect the evolving role of radiographers in a rapidly transforming technological and clinical landscape. The contributions in this issue span communication skills, patient safety, advanced imaging technologies, and emerging innovations, highlighting both foundational practices and future directions in radiology.

The issue opens with an article on Effective Communication to Enhance Image Quality and Patient Care in Radiology, emphasizing that technical expertise alone is not sufficient for optimal imaging outcomes. The authors highlight how clear communication with patients—before, during, and after procedures—reduces anxiety, improves cooperation, minimizes motion artifacts, and ultimately enhances diagnostic image quality. This article reinforces the radiographer's role as both a technical expert and a compassionate healthcare professional.

Patient monitoring and safety are further explored in Continuous Glucose Monitoring During Radiological Imaging, a timely topic given the increasing number of diabetic patients undergoing imaging studies. The article discusses the integration of continuous glucose monitoring systems in radiology settings, outlining practical considerations, safety concerns, and workflow adaptations. It underscores the importance of interdisciplinary coordination to ensure patient safety without compromising imaging efficiency.

The concept of virtual replication in healthcare is examined in Digital Twin in Healthcare: Contemporary Advances and Limitations. This article introduces readers to the emerging application of digital twin technology in diagnostics, treatment planning, and predictive healthcare modeling. While highlighting its transformative potential, the authors also address current limitations such as data integration challenges, ethical concerns, and high implementation costs, providing a balanced perspective.

Musculoskeletal imaging takes center stage in X-Ray and Magnetic Resonance Imaging (MRI): Seeing the Truth Behind Low Back Pain. This article compares the strengths and limitations of X-ray and MRI in evaluating low back pain, emphasizing appropriate modality selection. It serves as a practical guide for radiographers to understand clinical indications and optimize imaging protocols for accurate diagnosis.

Advancements in MRI technology are further explored through MR Fingerprinting and Its Future Clinical Role, which presents this innovative technique as a promising tool for quantitative imaging. The article explains how MR fingerprinting enables simultaneous measurement of multiple tissue properties, paving the way for more precise diagnosis and personalized medicine in the future.

A structured approach to neuroimaging is provided in Optimization of MRI Sequences for Better Evaluation of the Brainstem: A Structured Narrative Review. This review highlights the challenges of brainstem imaging and discusses optimized MRI sequences that improve visualization of complex anatomy, offering valuable insights for radiographers involved in neuroimaging.

Patient safety remains a core concern in Adverse Reactions to Iodinated Contrast Media: A Standard Narrative Review Paper. The authors comprehensively review the types of contrast reactions, risk factors, prevention strategies, and management protocols. This article reinforces the importance of preparedness, vigilance, and adherence to safety guidelines in contrast-enhanced imaging.

The issue concludes with PET-CT and MRI Fusion for Neuroimaging, which explores the synergistic value of multimodality imaging. By combining functional and anatomical data, fusion imaging enhances diagnostic accuracy in neurological disorders, particularly in oncology and epilepsy evaluation.

Together, the articles in this January 2026 issue reflect the dynamic and expanding scope of radiography. They encourage radiographers to embrace lifelong learning, technological innovation, and patient-centered practice. We sincerely thank all contributors for their valuable insights and dedication to the profession, and we hope this issue inspires continued growth and excellence in radiological sciences.

14th State Conference of Radiographers' Association of Maharashtra

Date: 28th February & 1st March 2026

Venue: Saboo Hall, Ramniranjan Jhunjhunwala College, Opp. Ghatkopar Railway Station, Ghatkopar (W), Mumbai

RADIOVISION 2026

ISRRT INTERNATIONAL SOCIETY OF RADIOGRAPHERS & RADIOLOGICAL TECHNOLOGISTS

Organised by

Radiographers' Association of Maharashtra (Mumbai Unit)

In association with

Hindi Vidya Prachar Samiti's

Ramniranjan Jhunjhunwala College

(Empowered Autonomous Status)

Radiographers' Association of Maharashtra (RAM)

Radiographers' Association of Maharashtra (RAM), affiliated with the Society of Indian Radiographers (SIR), is a registered organisation under the Government of Maharashtra since 2001. As we proudly celebrate 25 years of empowering Radiographers, RAM remains committed to its vision of serving and promoting the professional interests of Radiographers across the state.

Our primary objective is to support unemployed and aspiring Radiographers by providing quality education, skill-based training, and professional guidance. Through continuous learning initiatives, we strive to enhance competence, confidence, and employability within the profession.

RAM regularly conducts seminars, workshops, and professional events focused on academic growth, technological advancement, and holistic development, ultimately contributing to the wellbeing and safety of patients. We actively foster academic excellence and promote a strong sense of professional unity and collaboration among our members.

We encourage our members to actively participate in public affairs and social initiatives, thereby contributing to public welfare and healthcare awareness.

To further academic and professional exchange, RAM publishes the Radiographers' Journal, providing a platform for sharing knowledge, research findings, and innovative practices. We also actively support and conduct research studies and encourage the publication of scientific literature in the field of Radiological Technology.

Ramniranjan Jhunjhunwala College

Hindi Vidya Prachar Samiti's Ramniranjan Jhunjhunwala College of Arts, Science and Commerce, established in 1963 by visionary philanthropist Shri Nandkishore Singh Jairamji, is an Empowered Autonomous Institution committed to academic excellence and holistic student development.

Over six decades, the college has evolved into a dynamic multidisciplinary institution, offering a wide spectrum of programmes across Science, Commerce, Management, Technology, and Liberal Arts, including emerging and future-ready domains such as Data Science, Artificial Intelligence, Biotechnology, and Visual Effects (VFX). With the successful implementation of NEP 2020, the college emphasizes skill-based, multidisciplinary education, community engagement, Indian Knowledge Systems, innovation, and sustainability.

Strategic collaborations with institutions such as the Maharashtra State Skill University have strengthened experiential learning and employability. The college's commitment to quality has been widely recognized through prestigious accolades, including the University of Mumbai's Best College Award, the IMC RBNQ Award for Performance Excellence in Education, and DBT Star College status.

Accredited by NAAC since 2001 and re-accredited in 2024 with an 'A' Grade (CGPA 3.10), the college also upholds ISO certifications, conducts regular environmental audits, and demonstrates global responsibility as a UN Sustainable Development Goals (SDG) signatory.

Further affirming its leadership in higher education, the college is recognized as a Mentor College under the UGC PARAMARSH Scheme and has been ranked 20th Best Autonomous College in Maharashtra (Education World 2025–26). Ramniranjan Jhunjhunwala College continues to set benchmarks in academic innovation, governance excellence, and societal impact.

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Conference Schedule

28th February 2026

2.00 pm to 4.00 pm: Pre Conference Workshop for Students*
4.00 pm to 4.30 pm: Inauguration of Conference
4.30 pm to 600 pm: Silver Jubilee Celebrations of Radiographers' Association of Maharashtra

* **Workshop Topics for Students (Participants may join any one workshop)**
- **Personality Development** Only 40 seats (First-come, first-served basis)
- **Communication Skills** Only 40 seats (First-come, first-served basis)
- **Leadership Skills** Only 40 seats (First-come, first-served basis)

1st March 2026

8.00 am to 9.00 am: Registration & Breakfast
9.00 am to 9.15 am: Inauguration of Scientific Programme
9.15 am to 1.00 pm: Presentations by Experts
12. 00pm to 1.00 pm: Quiz for College Teams
1.00 pm to 2.00 pm: Lunch Break
2.00 pm to 5.45 pm: PPT Presentation Competition for Students
5.45 pm to 6.00 pm: High Tea
6.00 pm to 6.30 pm: Prize Distribution & Valedictory Function

Radiographers interested in presenting academic papers or presentations are kindly invited to contact the Scientific Committee Chairpersons for further details.

PPT Presentation, Poster Presentation & Quiz Competitions for Student Radiographers

We are excited to announce a PPT Presentation, Poster Presentation & Quiz Competitions that provides a platform for student radiographers to display their knowledge, skills, and creativity in radiology.

Overview:
- **Event:** PPT Presentation, Poster Presentation & Quiz Competition
- **Target Audience:** Student Radiographers
- **Purpose:** To give students an opportunity to demonstrate their expertise, innovation, and public speaking abilities in the field of radiology.

Categories:

PPT Presentations:
- **Topic:** Relevant radiology-related content.
- **Focus:** Public speaking and effective presentation skills. Participation
- **Limit:** Two participants per institute.
- **Time:** 10 minutes total (8 minutes for the presentation, 2 minutes for Q&A).

Poster Presentations:
- **Topic:** Academic posters highlighting research, innovations, or developments in radiology. Participation
- **Limit:** No limit on the number of participants per institute.
- **Poster Size:** A3 (11.7 x 16.5 inches)

Quiz Competitions:
- **Teams:** 4 Students per team
- **Limit:** One Team participation per institute.

Eligibility: Open to all students of Medical Radiography & Imaging Technology and Internship Students

Rewards & Prizes:
Top performers: Receive a Prize and Certificate of Appreciation.
Other participants: Receive a Certificate of Participation.

Important Dates: Last Date for registration for Competitions: 31st January 2026

Additional Information:
No TA/DA: No travel or accommodation support will be provide, accommodation guidance will be provided.
Submission Requirements: Abstract and a certificate from the Head of Department.
How to Participate: Interested participants should contact the Scientific Committee Chairpersons for detailed submission guidelines and further instructions

Link for more details and Online Registration:

https://radiographers.org/events-calender/

- Only 600 Registrations available on First-come, first-served basis
- Separate registration is required to attend the Conference, Workshops, Inaugural Function, and RAM 25th Year Celebrations.
- Early registration is recommended
- No Spot Registrations available

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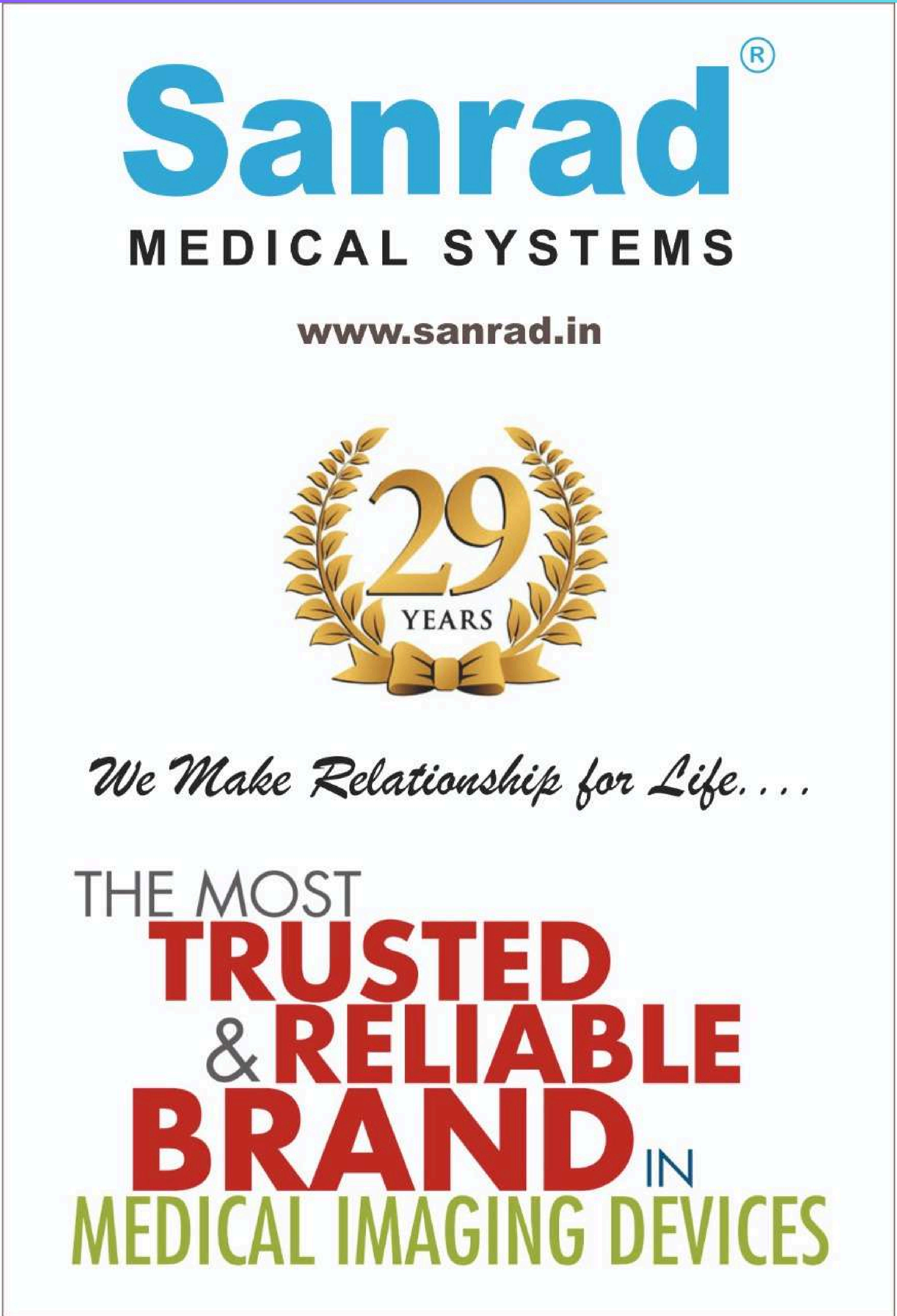
Scan QR Code for more details and Online Registration: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Effective Communication Enhance Image Quality and Patient Care in Radiology

Kratika Rawal, MRIT scholar, Subharti College of Allied and Healthcare, Meerut, UP

Abstract

An information exchange between a sender and a recipient is called communication. In the medical field, communication promotes the growth of a therapeutic alliance. Since the primary goal of a radiological diagnostic inquiry is to provide medical images, communication between patients and medical or nursing professionals is difficult. In order to produce clinically meaningful images throughout the operation and to make sure the patient is able to tolerate the investigation, the supportive role of the healthcare personnel is essential. Communication following the procedure is intended to convey the outcome and provide patients with the necessary assistance and guidance. By following several points that impacts on image quality and patient care : compassionate care, needs, build trust, understanding, medical term, focused, informed consent, openness, assurance, decrease motion, enhance cooperation and better technical protocols.

Key words: communication, patient care, image quality

Introduction

"The transmission or exchange of messages and information from an entity regarded as the sender to an entity regarded as the receiver" is the definition of communication. through a shared set of symbols, gestures, or behavioral patterns. A different definition that emphasizes "mutual contact between people which is characterized by understanding and a spirit of collaboration" is more pertinent to the objectives and nature of communication in the clinical context. The goal of communication in this context is to support and preserve patients' health.

A key element of delivering patient-centered and value-based treatment is improved communication between patients and the imaging team. In busy radiology departments that prioritize quick and precise diagnosis, patient communication can be difficult. Traditionally, the referring clinician receives the majority of the results directly. Nonetheless, the significance of direct communication between the radiologist and the patient is becoming more and more important, especially when it comes to in-person settings like rapid assessment and ultrasound clinics, interventional radiology, and written communication via electronic patient portals.

An estimated 44,000–98,000 medical error-related deaths occur each year as a result of communication problems, which are well acknowledged in the radiology literature and have been identified by The Joint Commission as the primary root cause in 65% of sentinel events that take place in hospitals. This finding has been corroborated by a number of authors, who report that communication errors account for 52% of serious occurrences in hospitals and up to 80% of situations with numerous errors, where an informational or personal communication error starts the chain of errors.

Increased patient satisfaction, better safety and results, better coordination of care, and lower healthcare costs can all be achieved through effective patient and healthcare team communication.

Communication and its classification:

Verbal (spoken, tone), nonverbal (body language, eye contact), written (reports, notes), visual (pictures, annotations), and listening (active, sympathetic) are the various forms of communication used in radiology. These techniques, which involve both direct patient interactions reporting, link radiologists, technologists, and patients and are essential for precise diagnosis, patient comfort, and clear explanation of findings.

Verbal Communication: Patient-Facing: Using straightforward language, asking questions, reassuring patients, and explaining procedures.
Inter professional: Talking about cases with staff members, including nurses and referring physicians comprises spoken words, pitch, loudness, and voice intonation.

Nonverbal communication: bodily language Language includes posture, gestures, facial emotions, and eye contact.
Professionalism: Touch (with permission), hygiene, and appearance.
Objective: Expressing confidence, curiosity, and empathy.

Written communication: Radiology Reports: The main written product, comprehensive interpretations delivered to referring physicians.
Patient Instructions: Care instructions or patient notes.
Medical Pictures: the primary visual data (MRIs, CTs, and X-rays).

Communication impacts on patient care and image quality:

- **Compassionate care:** Radiography practice should prioritize providing patients with compassionate, high-quality care . "Hello, my name is...and I am the radiographer responsible for your imaging today" is how you introduce yourself to each patient. Careful planning and organization are essential when communicating with patients or caregivers. To help all patients feel ready for their assessment, information about the imaging test should be made available in written, spoken, and/or other media.

- **Build trust:** Patients and radiographers, as well as other medical professionals, should have mutual trust. Information must be kept private and disclosed only with a patient's permission or as needed by law. Establishing secure areas for private conversations is crucial for departments.
- **Medical term:** It's crucial to avoid using medical jargon, so every communication should be patient-friendly and, if necessary, tailored to the patient. It could be useful to illustrate complicated processes with written text.
- **Understanding:** In order to provide patients with appropriate care, understanding must be checked. Radiographers should assist individuals in comprehending the risks and advantages of their imaging technique. To ensure that the patient's questions are addressed, it is crucial to take the time to listen to them.
- **Informed:** Throughout and after their treatment, patients and caregivers should be kept up to date on their radiology procedures, including when and how they will obtain their results and any other requirements for aftercare. The departments' phone numbers should be given to patients. In order for patients, family members, or caregivers to make educated decisions, it is critical that they have access to clear information. In order for patients or caregivers to be prepared, they should be informed about examinations ahead of time so they may comprehend their purpose and what will be entailed.
- **Informed consent:** The foundation of efficient and secure medical practice is informed consent, which is a crucial step in the procedure once patients or caregivers get information.
- **Assurance:** Radiographers should be able to reassure patients or caregivers that the personnel providing the services have the necessary education and training to enable the imaging examination's safe and efficient delivery.
- **Openness:** When something goes wrong with a patient's care, be transparent and truthful with them and their caregivers. When patients or caregivers voice concerns, listen to them and let them know that you will follow up right away. If required, escalate your concerns in accordance with rules and procedures.
- **Needs:** Radiographers should communicate in a way that is patient-centered and sensitive. Whenever feasible, it is crucial to determine the patient's needs before the test. To guarantee that patients receive the best treatment and support possible, patients with special needs should be encouraged to accompany a friend, family member, or caregiver.
- **Decreased Patient Motion:** Giving patients clear, detailed instructions both before and during an exam helps them remain motionless, which greatly reduces artifacts brought on by movement.
-
- **Enhanced Cooperation:** Patients are more likely to precisely comply with specific positioning or breath-holding instructions when they comprehend the reasons behind them, which improves diagnostic outcomes. Reduced Repeated Exposures According to 68.9% of radiologic technicians, better patient education can reduce needless radiation exposure and prevent recurrent exposures.
- **Better Technical Protocols:** The most pertinent diagnostic data is recorded when radiologists and technicians have clear communication about particular viewpoints or patient-specific difficulties.

In the radiology department, patient communication is essential to both the valuebased care we offer and the patient experience.We must adjust to the new technologies, our patientsevolving requirements, and their growing involvement.Clear, reliable Information that patients can comprehend is crucial at every level, regardless of the format. Our mission is to foster a culture of courteous and compassionate communication through leadership and training.

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QUIZ to Recapitulate

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

1. Which safelight (color or wave length) can be used While processing panchromatic films ?

2. Which lubricants are used inside X-ray tubes?

3. Lead foil in dental cassette is primarily used for?

4. What procedure is TACE?

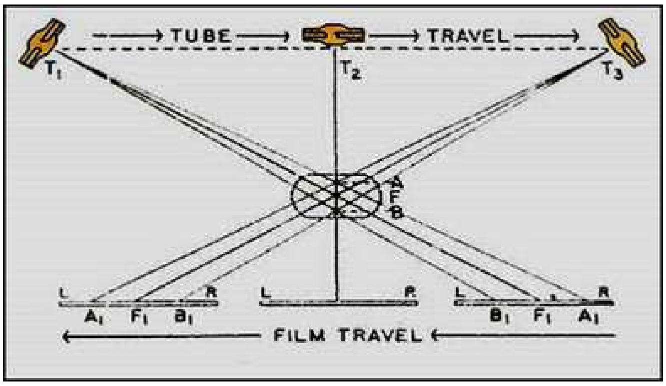
5. Which gas is /was commonly used in gas filled CT detectors?

6. What is best achieved resolution in conventional mammography films in lp/mm?

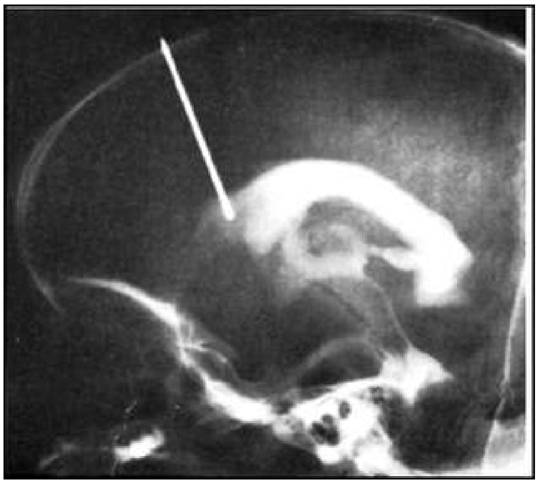
7. What is traditional and updated permissible fringe field safety threshold limit around an MR scanner ?

8. Name the procedure.

9. Identify the Technique/procedure.



10. Identify the investigation



- Please send your answers through email on **pkpopli@gmail.com** on or before **10th February 2026.**
- 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 **(Sponsored by JBD Publications).**
- 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 - December 2025 issue

1. Ammonium Thiosulfate .

2. Prone 15° - 20° LAO (Left Anterior Oblique).

3. To provide optimal distension of small bowel and to give a double-contrast effect.

4. Molybdenum, as it is a poor thermal conductor.

5. Magnesium Oxide or Titanium Dioxide.

6. In EBCT anode is a large fixed (stationary) semi-circular or annular ring of tungsten surrounding the patient aperture.

7. MR Conditional Pacemaker

8. Power Doppler

9. Polvinyl Alcohol (PVA) particles used for embolization

10. OPG for bilateral TM Joints, open and closed Mouth

Continuous Glucose Monitoring During Radiological Imaging

Rashmi Singh, M. Sc. Research fellow, **Deepak Katiyar,** Assistant Professor,
College of Paramedical Sciences, Teerthankher Mahaveer University, Moradabad, UP.

Abstract

Nonstop Glucose Checking (CGM) has revolutionized the administration of diabetes, permitting for real-time following of glucose levels all through the day. As of late, the integration of CGM frameworks amid radiological imaging methods has picked up consideration as a pivotal improvement for diabetic patients experiencing demonstrative tests. Customarily, imaging strategies such as CT looks, MRIs, and PET checks require fasting, which can altogether influence the blood glucose levels of diabetic patients, driving to complications or wrong comes about. By empowering real-time glucose observing amid these imaging methods, CGM frameworks offer the potential to improve the security and consolation of diabetic patients, progress the quality of demonstrative imaging, and give more personalized care. This investigate article investigates the mechanical headways in CGM frameworks, their application amid radiological imaging, and the potential benefits for diabetic patients. It analyzes the integration of CGM sensors with imaging conventions, examines clinical trials, and highlights the potential challenges. Moreover, it looks at how nonstop observing can help in minimizing dangers such as hypoglycemia, hyperglycemia, and changes which will meddled with the imaging handle. By empowering healthcare experts to mediate instantly, CGM innovation offers a modern measurement to diabetes administration, giving superior results for patients experiencing imaging methods. This paper examines the clinical importance of CGM in radiological imaging and investigates future opportunities for broader integration within the therapeutic field.

Introduction

Persistent Glucose Checking (CGM) frameworks have gotten to be a foundation within the administration of diabetes, permitting for ceaseless following of glucose levels through wearable sensors. CGM frameworks have altogether progressed the quality of life for people with diabetes by giving real-time glucose information that can be utilized to alter affront dosages, supper plans, and other perspectives of treatment. These frameworks are presently picking up consideration for their potential part in upgrading persistent care amid radiological imaging strategies. Conventional imaging tests, such as computed tomography (CT), attractive reverberation imaging (MRI), and positron outflow tomography (PET) looks, ordinarily require fasting earlier to the method to guarantee precise comes about. In any case, for diabetic patients, fasting can lead to fluctuating blood glucose levels, which can adversely influence their wellbeing and compromise the comes about of the imaging method. Hypoglycemia (moo blood sugar) and hyperglycemia (tall blood sugar) are two basic conditions that can happen amid fasting, particularly in patients who depend on affront or other medicines to oversee their blood glucose. By joining CGM frameworks amid radiological imaging, healthcare experts can screen glucose vacillations in real-time, guaranteeing that patients â blood glucose levels stay inside secure ranges all through the strategy. This integration makes a difference minimize the hazard of antagonistic occasions such as hypoglycemia, hyperglycemia, and lack of hydration, hence improving understanding security and moving forward the by and large quality of the imaging comes about.

The Role of CGM in Radiological Imaging

The part of CGM in radiological imaging is to supply persistent and real-time glucose information amid the imaging strategy, which is especially advantageous for diabetic patients. Diabetic people are frequently more powerless to blood sugar variances due to fasting some time recently imaging methods. Such variances can lead to a run of issues, counting discombobulating, perplexity, drying out, or more awful, more serious complications like diabetic keto-acidosis (DKA). The real-time information given by CGM frameworks permits for convenient mediations, such as glucose supplementation or alterations in affront treatment.

1. Real-time Monitoring and Intervention

Conventional glucose estimations, such as finger stick tests, as it were give discontinuous glucose readings and don't reflect real-time vacillations in glucose levels amid imaging. On the other hand, CGM frameworks ceaselessly track glucose levels, advertising a more energetic and exact observing framework. By following glucose in real-time, CGM frameworks caution healthcare suppliers of noteworthy changes in glucose levels, permitting for opportune mediations. This capability is fundamental in anticipating hypoglycemia or hyperglycemia, conditions that can complicate the imaging handle and possibly influence the exactness of demonstrative comes about.

2. Improved Patient Comfort and Safety

For diabetic patients, experiencing imaging methods can be unpleasant, particularly when they are required to quick for amplified periods. Persistent glucose observing amid the strategy can offer assistance reduce a few of the uneasiness and inconvenience related with fasting, because it empowers healthcare suppliers to closely screen and stabilize glucose levels all through the method. This moves forward persistent security and consolation, as real-time mediations can anticipate complications emerging from moo or tall glucose levels.

3. Enhanced Imaging Results

Vacillations in glucose levels amid an imaging method can meddled with certain symptomatic tests, especially those that require exact estimations, such as in oncology, where PET looks are utilized to identify tumors. Blood glucose levels can impact the take-up of radiotracers in PET imaging, possibly driving to wrong comes about. By keeping up ideal glucose levels all through the strategy, CGM can offer assistance guarantee that imaging comes about are exact, driving to way better symptomatic results.

Clinical Applications and Trials

Later clinical trials have illustrated the viability of CGM frameworks in progressing diabetic administration amid imaging strategies. For case, investigate has appeared that CGM integration within the setting of PET imaging altogether decreases the hazard of glucose changes, upgrading the unwavering quality of the looks. Also, the utilize of CGM frameworks amid CT and MRI methods has been appeared to progress persistent results by permitting for prompt mediations when essential. A few thinks about have moreover illustrated that CGM frameworks are useful in other imaging modalities, counting fluorodeoxyglucose (FDG)-PET checks. FDG-PET imaging is profoundly touchy to blood glucose levels, and hypoglycemia or hyperglycemia can altogether influence its accuracy. The capacity to preserve steady glucose levels amid this sort of imaging guarantees superior comes about and higher symptomatic precision.

Challenges and Limitations

Whereas the integration of CGM in radiological imaging has a few benefits, it too presents certain challenges. One restriction is the require for consistent integration between CGM frameworks and radiology divisions. Right now, there's a need of standardized conventions for coordination CGM information into the radiological workflow, which can lead to perplexity and wasteful aspects in clinical settings. Moreover, CGM frameworks may not be similarly successful for all diabetic patients, particularly those with sort 1 diabetes who involvement more noteworthy vacillations in glucose levels. Another challenge is the potential for mistakes in CGM readings, as a few CGM frameworks are less exact amid periods of fast glucose alter or in patients with destitute sensor adherence. Progresses in sensor innovation and continuous advancement within the integration of CGM with imaging workflows will be basic to address these impediments.

Conclusion

The integration of Persistent Glucose Observing (CGM) amid radiological imaging presents an energizing opportunity to progress the security and exactness of demonstrative strategies for diabetic patients. By giving real-time glucose information, CGM frameworks permit for prompt intercession when glucose levels vacillate, diminishing the hazard of complications like hypoglycemia or hyperglycemia. This integration upgrades quiet consolation, moves forward the quality of demonstrative imaging, and contributes to superior clinical results. Be that as it may, challenges such as integration with radiological workflows and sensor precision must be tended to. As CGM innovation proceeds to advance, its broader application in radiology is anticipated to upgrade the in general administration of diabetes and make strides demonstrative methods.

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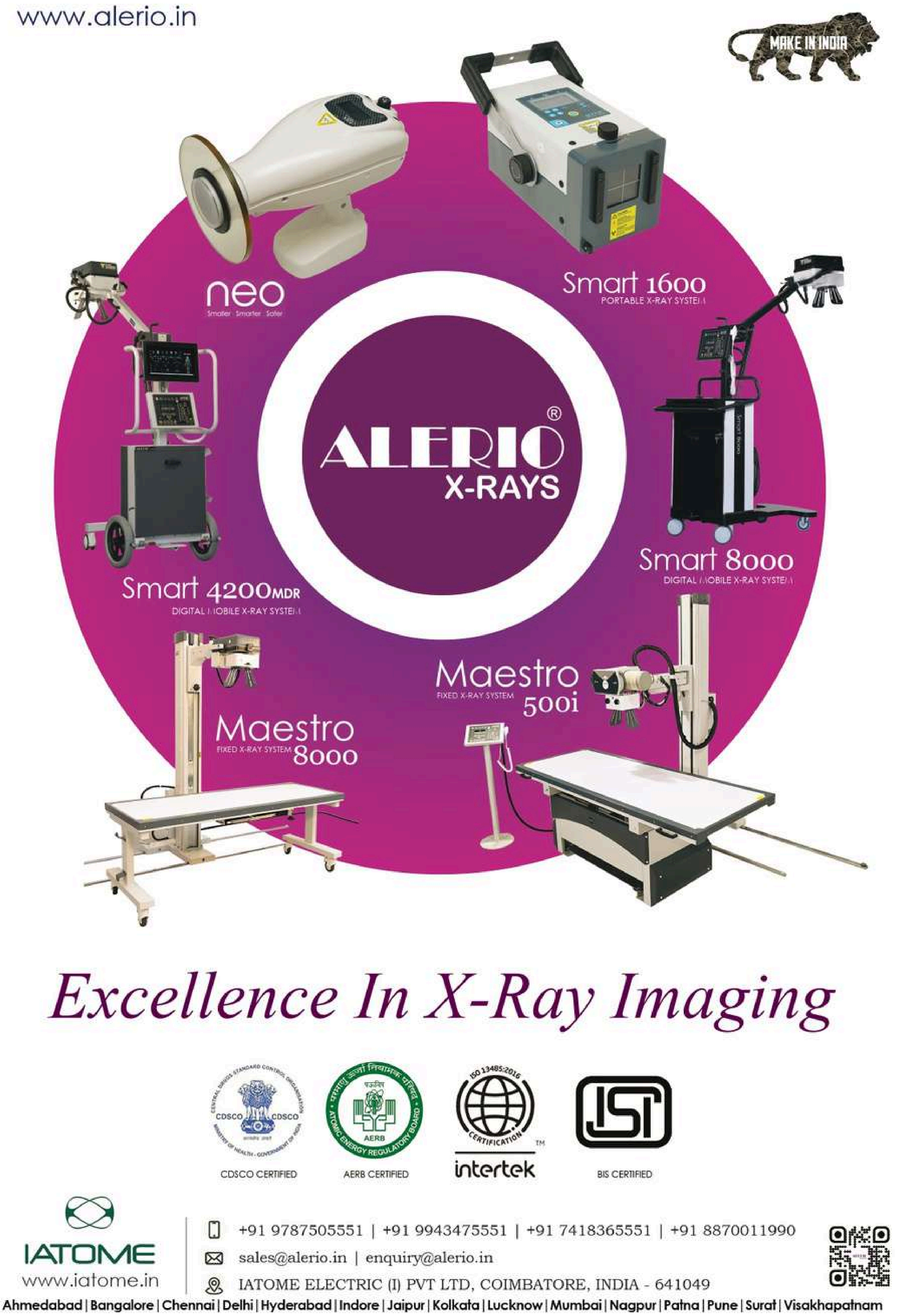
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Digital Twin in Healthcare: Contemporary Advance and limitation

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Abstract

A digital twin is a virtual model designed to accurately simulate a physical system or object. Developers of radiological devices can utilize a digital twin of their device to evaluate its characteristics, modify its design or materials, and test the outcomes of those adjustments in a simulated setting. Cutting-edge technologies such as omics sciences and artificial intelligence (AI) might enable the creation of patient virtual models that can be constantly updated with current health and lifestyle data. The progress in AI and digital twins could aid in analyzing and integrating vast amounts of diverse data from various sources. Consequently, this can improve the decision-making capabilities of medical professionals regarding diagnosis and treatment.

Key Words: Digital twin technology, Disease progression modelling, Biomedical modelling, Telemedicine integration, Wearable sensors, Clinical decision support, AI-driven diagnostics, Healthcare digitalization, Virtual patient simulations.

Introduction

The development and enhancement of items could be facilitated by the advent of digital twin technology, which would also assist industries in making necessary improvements before beginning production. Digital twins are useful follow and replicate the whole construction procedure, even after a new product has gone into production. The development of digital twins has the potential to significantly alter a number of industries, including healthcare. With the help of artificial intelligence (AI) technology, digital twins of radiology equipment like MRI and CT machines may enable remote examination and real-time status monitoring, diagnosing problems, testing solutions, and even averting problems before they arise.(1) This is essential for patients and healthcare providers to ensure continuity of care. A view of each device's past and possible upcoming achievement is what the digital twin generates. Early warnings, forecasts, optimization concepts, and—above all—a strategy to extend the lifespan of equipment can all result from this continuity of data. A physical device's sensors create a radiological digital twin equipment. For distant analysis, data are displayed. It needs extensive (human) understanding of a medical gadget to comprehend the data it transmits.(2) By combining machine learning with human expertise, a genuinely suitable remote virtual support of the radiological device might be offered (AI can also assist in identifying patterns in data). **Fig: 1.**

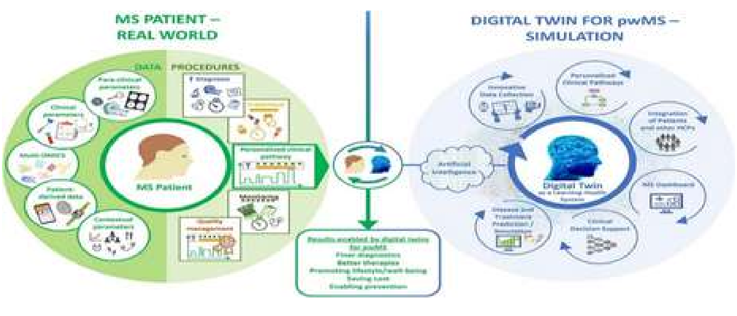


Figure 1: The digital twin life cycle of radiological devices: essential ideas and visuals

Understanding a digital twin in healthcare

- A digital or virtual depiction of an actual (physical) process or thing.
- A computerized representation of the actual object that details its characteristics
- A digital thread is a link that allows data to be shared across the digital and physical worlds.

The following section discusses the elements used to conceptualize the digital twin seen in Figure.

(a)and (e) physical world - Physical entities, associated procedures, and the data that represents them make up the physical universe. The automobile is used in manufacturing as a representation of reality word entity (a), which is made up of a variety of data from different sensors. In a similar vein, we view a patient as the physical world entity in (e) for healthcare. But a manufactured car is not nearly as complex as the human body. In contrast to (e), where a variety of information about the patient (such as clinical, genomic, and laboratory tests) are collected at various stages of cancer management on an as-needed basis and in response to requests from the treating clinician, (a) involves data collection in a more controlled setting and continuous acquisition through fixed sensors. (b) and (f) measured and reported data— The process of transmitting information collected from the real world to the digital realm is referred to as a "digital thread." For (b), the determined and reported battery data, including the battery's temperature, most-used area, and charging frequency, can be used in the digital world to create a digital model that estimates the battery pack's lifespan.(3) **Fig.2**

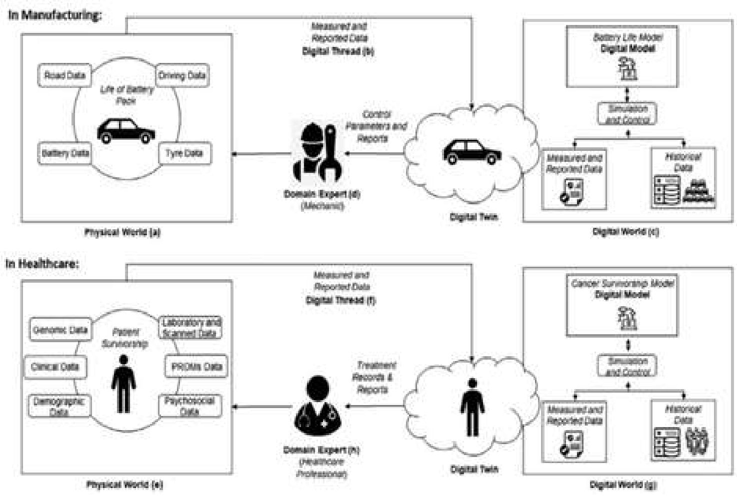


Figure:2 Mapping the digital twin concept from manufacturing to cancer treatment

Digital Twin in Radiology: Technological Instrument

In the field of radiology, a digital twin is a computational structure of a radiographic apparatus, system, or procedure that uses data, simulations, and artificial intelligence to replicate its actual performance in real time. Through ongoing operational and clinical data analysis, this technology makes Predictive repair and maintenance, performance optimization, and workflow efficiency possible.(4) Digital twins can be used in radiology to simulate imaging equipment such as CT or MRI scanners in order to improve calibration, predict malfunctions, and guarantee constant image quality They also ma ke remote training and diagnostics easier. Digital twins facilitate proactive decision-making by integrating with hospital IT systems, which lowers downtime and enhances patient outcomes. This invention is a significant step forward for intelligent healthcare.(5) Fig. 3

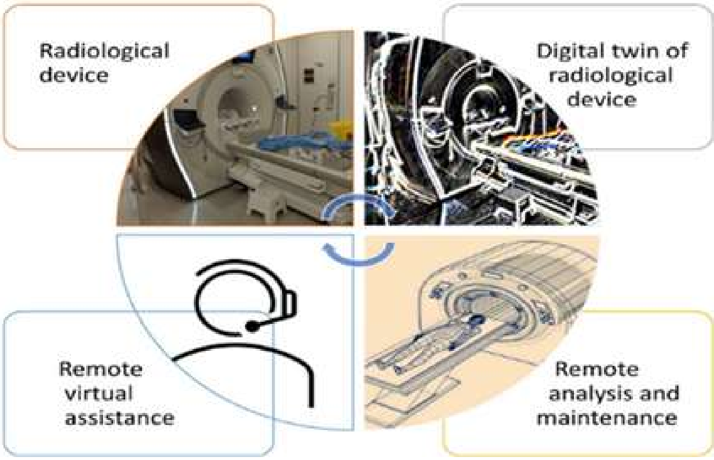


Figure:3. Key concepts and examples of radiological device digital twin life cycle

Digital Twins in an Era of Customized Medical Treatment: Transforming Digital Devices into Digital Patients

Widespread usage of digital health tools, such as wearables, smartphone apps, and remote monitoring systems, which continuously gather information on heart rate, blood sugar, sleep habits, and physical activity, is the first step toward the creation of digital twins. These data streams serve as the basis for creating the digital twin, an expansive, dynamic visualization of a patient, when paired with more sophisticated data (such as imaging, lab results, and genomes). Machine learning techniques are used to update these models, allowing them to adjust and become more accurate over time. Fig. 4

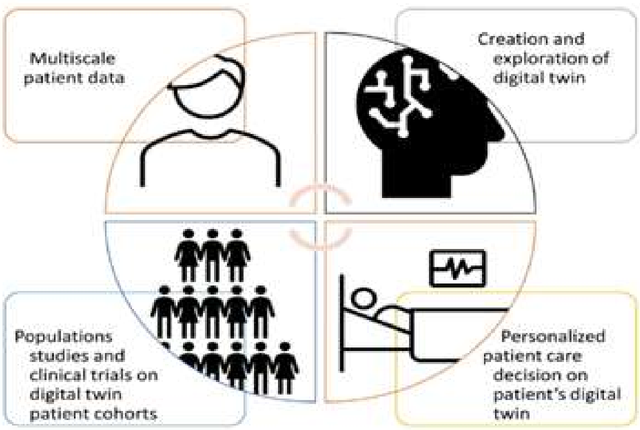


Figure:4 Examples and essential ideas of the patient digital twin life cycle

Clinical Application in Oncology

Oncology's use of digital twin technological advances is developing quickly and has the prospective to revolutionize every aspect of cancer care, from early detection to individualized therapy and survivorship planning. A digital twin of a cancer patient can mimic tumor evolution, forecast therapy results, and enhance clinical decision-making by combining multi-modal data, including genetics, imaging, histology, treatment history, and real-time biomarkers.(6)

a) Personalized Treatment Simulation: Before delivering therapies like chemotherapy, immunotherapy, or targeted drugs, physicians can use digital twins to model how a particular tumor would react to them. These predictive models aid in data-driven therapy selection based on the patient's genetic and molecular tumor profile, reducing the need for trial-and-error in oncology.

b) Radiotherapy Planning: Digital twins can be applied in radiation oncology to build biologically sensitive and anatomically correct models that take tumor dynamics, tissue sensitivity, and organ mobility into consideration. This improves dose distribution accuracy, reducing toxicity and increasing therapeutic efficacy.

c) Monitoring and Adaptive Therapy: Digital twins can change in tandem with the patient's state thanks to the constant incorporation of new data. Long-term results are improved by this real-time adaptability, which facilitates dynamic treatment modifications and early metastasis or relapse diagnosis.

d)Virtual Clinical Trials: To find the best candidates, shorten recruitment times, and model results, digital twin cohorts can mimic trial conditions. This is especially useful for aggressive or uncommon cancer subtypes where conventional trials are difficult.

Clinical Application in Cardiology: Cardiology is the study and treatment of heart and blood vascular diseases. Cardiology clinical applications include prevention, follow-up care, treatments, and diagnostics

Diagnostic Applications: The functioning of the heart is assessed with the use of diagnostic instruments such as cardiac stress tests, echocardiograms, and electrocardiograms (ECG). They are able to identify problems like damaged heart muscle, clogged arteries, and abnormal heart rhythms.

Therapeutic applications: Therapeutic applications begin after a diagnosis is made. These include drugs that lower cholesterol, prevent blood clots, or regulate blood pressure, such as statins, beta-blockers, and anticoagulants. In more extreme situations, treatments including cardiac valve replacements, stent implantation, or angioplasty (to open clogged arteries) can be necessary.

Electrophysiology: Electrophysiology is used to address rhythm issues with devices such as defibrillators or pacemakers. These can even stop sudden cardiac death by assisting the heart in maintaining a normal pulse.

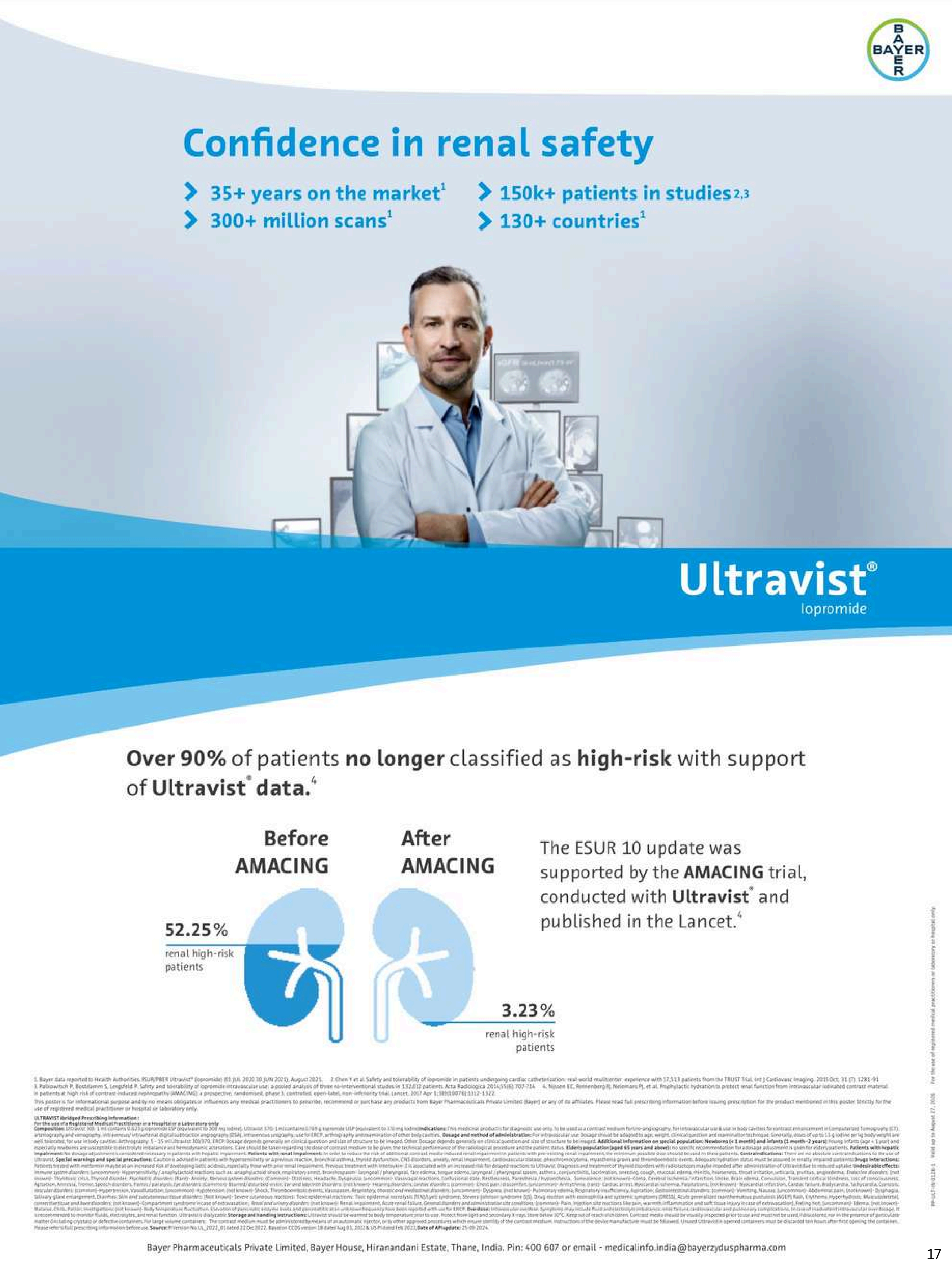
Preventive cardiology: The aim of preventive cardiology is to reduce the risk of heart disease through regular monitoring, good lifestyle choices, and the management of risk factors like diabetes or high blood pressure.

Clinical Application in Neurosciences

The screening, management, and rehabilitation of conditions impacting the brain and spinal cord, and the peripheral nervous system are the main goals of clinical applications in neuroscience. With the goal of improving patient outcomes for ailments ranging from stroke and epilepsy to neurological conditions such as Parkinson's and Alzheimer's, this profession connects fundamental brain research with real-world medical care.(7)

Diagnostic applications

Advanced imaging and neurophysiological technologies are essential for clinical neuroscience diagnostic applications. The brain and spinal regions can be seen in detail with the help of methods like Positron Emission Tomography (PET), Computed Tomography (CT), and Magnetic Resonance Imaging (MRI). While electromyography (EMG) and nerve conduction studies (NCS) aid in the diagnosis of neuromuscular illnesses, electroencephalography (EEG) is frequently used to track brain activity in patients with epilepsy or sleep disorders.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Therapeutic intervention

Both pharmaceutical and surgical methods are used in therapeutic interventions. Drugs are used to treat neurotransmitter imbalances, control symptoms, or halt the progression of diseases. For the treatment of intractable epilepsy, mobility abnormalities, brain tumors, and trauma, neurosurgical techniques such as deep brain stimulation (DBS), tumor excision, and spinal.

Present Digital Twin Technology Limitations and Difficulties: The development of digital twin technology shows promise, there are still a number of obstacles that prevent it from reaching its full potential in various industries. The high implementation costs and complexity are among the main obstacles. Advanced sensors, data integration frameworks, and a strong computing infrastructure are necessary to produce precise and useful digital copies of physical systems, but these might be time-consuming and expensive. This limits access for startups and smaller businesses. There are also major obstacles related to data availability and quality. Effective operation of a digital twin requires that it constantly receive precise, up-to-date data from its physical counterpart. Data silos, inconsistent formats, and incomplete or faulty data, however, might jeopardize the digital model's integrity. The problem is made more difficult by the need to guarantee compatibility across contemporary platforms and legacy systems. Cybersecurity is another important issue. Digital twins are prime targets for cyberattacks since they depend on continuous data sharing and are frequently included into vital systems. Sophisticated security procedures are needed to protect these systems against intrusions, and they are constantly changing in tandem with technology. Standardization and scalability are still issues. Although digital twins are effective in small-scale or controlled settings, controlling, updating, and maintaining the models becomes more difficult when they are scaled up to include entire cities, manufacturing processes, or massive infrastructure systems. Collaboration and integration across platforms and industries are also hampered by the absence of universal standards.

There is also a shortage of talent in the workforce. Expertise in fields like data science, IoT, systems engineering, and artificial intelligence is needed for digital twins, but there aren't enough professionals with these multidisciplinary abilities. Additionally, organizational resistance to change and an unclear return on investment in the early stages of the technology's adoption might occasionally delay it down.

All things considered, even if digital twin technology has revolutionary potential, these obstacles must be removed for wider and more successful implementation.

Future directions: Because digital twin technology allows for real-time, personalized, and predictive healthcare, radiography is undergoing a rapid transformation. As technology advances, a number of exciting new avenues are opening up.

a. Personalized Patient Modelling: Future radiology twins will evolve to model individual patients with high precision, incorporating real-time imaging, electronic health records, genomics, and even lifestyle data. Before acting in the real world, this would enable doctors to model the course of an illness or the effectiveness of a treatment on a virtual twin.

b. Predictive Diagnostics and Early Intervention: More precise disease development prediction will be possible thanks to radiology twins, especially in the fields of neurology, cardiology, and oncology. These technologies could identify small changes that occur before symptoms become apparent by continuously evaluating new imaging and health data, enabling earlier and more focused therapies.

c. Integration with AI and Machine Learning: Advanced AI in conjunction with digital twins will improve anomaly detection, therapy simulation, and picture interpretation.

d. Real-time Monitoring and Adaptive Imaging: Digital twins for radiography may soon make it possible to track implants, organ function, or cancers in real time. This would provide adaptive imaging protocols, in which the twin assists in modifying imaging methods in response to evolving patient circumstances throughout a scan.

e. Clinical Decision Support and Treatment Planning: Radiology twins can act as sophisticated decision-support tools by modeling the potential reactions of a tumor following stent implantation or radiation treatment. This enhances results, reduces adverse effects, and optimizes treatment regimens.

Interoperability and Standardization: In order to guarantee smooth integration and data sharing as adoption grows, standards for interoperability across imaging equipment, digital twin platforms, and hospital IT infrastructure must be established. In a number of medical specialties, digital twin technology is transforming customized treatment. For example, a cardiovascular digital-twin system (Trayanova and Prakosa, 2024) had been combined with hemodynamic data from MRI and CT to model the dynamics of the heart and blood flow, helping to forecast arrhythmias or blockages and enabling accurate intervention planning.

Cardiovascular System: Using imaging data from CT, MRI, and ultrasound scans, digital twin technologies. in radiology allows the development of realistic visualizations of a patient's circulatory system. Real-time simulations of cardiac function, blood flow, and vascular dynamics are made possible by these models, which enable individualized diagnosis and treatment planning. Doctors are able to forecast how a disease will develop, evaluate treatments (such as valve replacement or stenting), and track improvements over time. Precision cardiology is supported, non-invasive diagnostics are improved, and surgical results are improved. Cardiovascular digital twins assist in providing patients with heart and vascular disorders with safer, more efficient, customized therapy by constantly incorporating new data.

Central Nervous Systems: Digital twin radiology for the central nervous system (CNS) builds dynamic, patient-specific virtual models of the brain and spinal cord using sophisticated imaging data, including MRI and CT scans. Brain tumors, stroke, multiple sclerosis, and neurodegenerative illnesses can all be accurately diagnosed, treated, and monitored because to these models that mimic the structures and functioning of the brain.(7) Clinicians may digitally evaluate treatment approaches, forecast illness development, and customize therapies by merging real-time imaging with AI and computational modelling. Significant concepts and illustrations of the life cycle of a patient digital twin.

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Dear Radiograhers & Students,

It gives me immense pleasure to extend my warm greetings to all delegates, faculty members, and participants of the State Conference of the Society of Indian Radiographers, Kerala Chapter.

This conference provides a valuable platform for radiography professionals to come together, exchange knowledge, share experiences, and discuss recent advancements in medical imaging and radiological sciences. In an era of rapidly evolving technology, continuous professional development and academic interaction are essential to enhance the quality of patient care and professional standards.

I am confident that the scientific sessions, workshops, and deliberations during this conference will enrich our knowledge, inspire innovation, and strengthen unity among radiographers across the state. Such gatherings also reaffirm our collective commitment to ethical practice, skill development, and the growth of our profession.

I congratulate the organizing committee for their dedicated efforts in arranging this conference and wish the event a grand success. I hope all participants find this conference academically rewarding and professionally fulfilling.

With best wishes,
Linse George
General Secretary
Society of Indian Radiographers
Kerala Chapter

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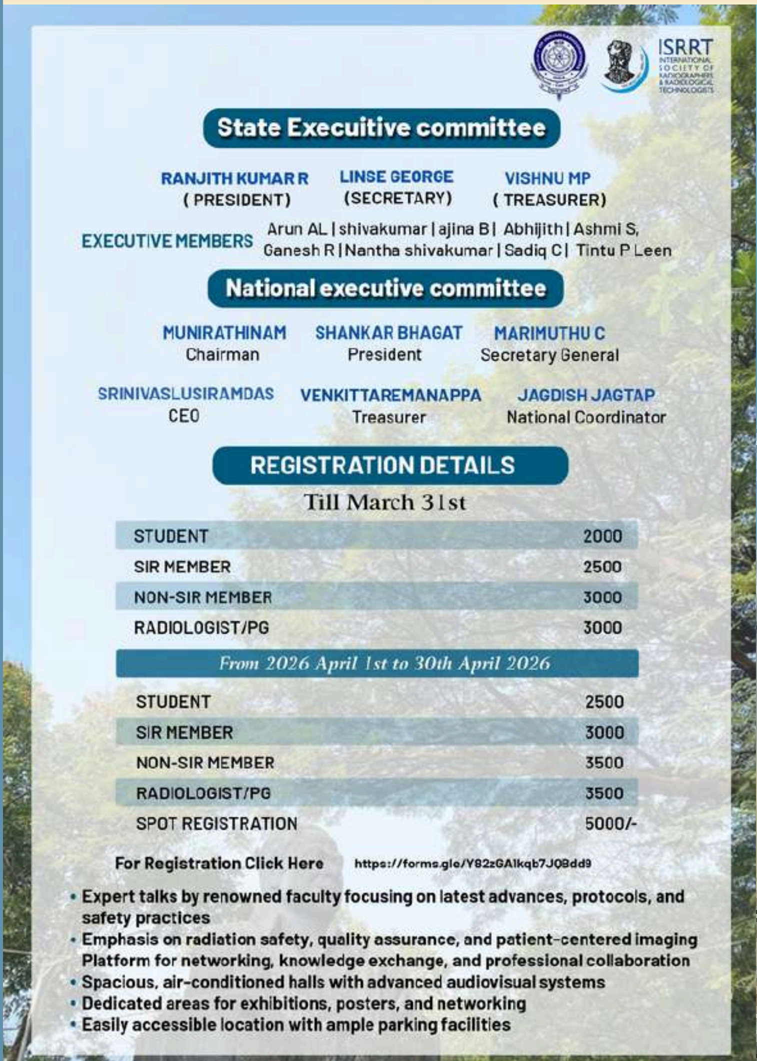

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X-Ray and Magnetic Resonance Imaging (MRI): Seeing the Truth behind Low Back Pain

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Introduction:

Low back pain (LBP) is one of the most frequent musculoskeletal complaints globally, affecting people across all age groups and significantly reducing quality of life. It is estimated that nearly two-thirds of individuals will experience LBP at some point in their lives. The burden of LBP is not only personal but also social, as it leads to reduced work productivity and healthcare costs.

For decades, conventional radiography (X-ray) has been the first-line investigation due to its low cost, simplicity, and availability. It provides a good overview of bony anatomy and helps identify fractures, deformities, and degenerative bone changes. However, its ability to detect early pathology or soft tissue changes is limited.

With the advent of Magnetic Resonance Imaging (MRI), a new era of spinal imaging began. MRI, with its excellent contrast resolution and multiplanar capability, allows detailed evaluation of intervertebral discs, nerve roots, ligaments, and marrow changes — without the risks of ionizing radiation. Today, MRI is considered the gold standard for diagnosing most causes of low back pain.

Figure: 1 Illustrates an individual experiencing lower back pain

Principle of Imaging Modalities

X-Ray Imaging:

X-rays are a form of ionizing radiation that pass through the body and are absorbed in varying amounts depending on tissue density. Bones, being dense, appear white, whereas soft tissues appear darker. This makes X-rays highly useful for assessing fractures, alignment, and gross degenerative changes. However, fine soft tissue details remain invisible.

Figure 2: Depicts a conventional X-ray unit widely used diagnostic tool for evaluating musculoskeletal and spinal disorders, serving as the first-line imaging modality in many clinical settings.

Magnetic Resonance Imaging:

MRI is based on the principle of nuclear magnetic resonance. When the body is exposed to a magnetic field, hydrogen protons align with it. A radiofrequency pulse temporarily disturbs this alignment, and when protons return to equilibrium, they emit signals that are captured to form images. These images provide exceptional soft tissue contrast, revealing discs, ligaments, nerves, and marrow with great clarity.

Figure 3: Shows Philips Achieva 1.5T MRI with Dedicated Lumbar spine coil used in MRI

Anatomy of the Lumbar Spine

The lumbar spine consists of five vertebrae (L1–L5), separated by intervertebral discs. These discs act as shock absorbers and allow mobility. Supporting ligaments and paraspinal muscles maintain stability, while nerve roots emerge through foramina to supply the lower limbs. Any disc degeneration can compress nerve roots, causing radiating pain. Osteophyte formation (bony outgrowths) narrows spaces and irritates nerves. Fractures or deformities disturb spinal alignment and contribute to pain. Understanding this anatomy is essential, as both X-rays and MRI target different structures within the same system.

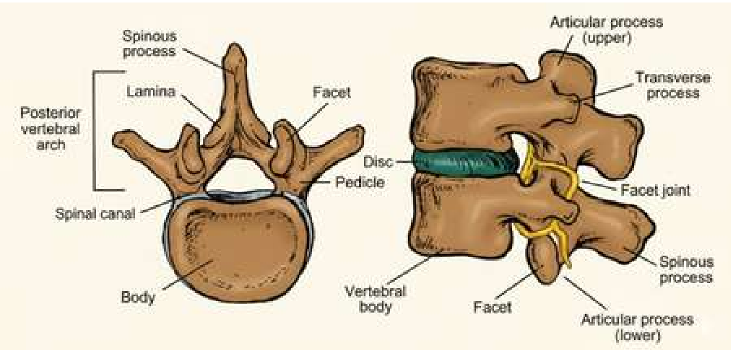

Figure 5: Anatomical diagram of the lumbar spine

Role of x-ray in lower back pain:

X-rays remain a practical first step in evaluating low back pain. They provide a quick overview and help rule out obvious abnormalities. Typical findings include: Disc space narrowing indicating disc degeneration. Osteophyte formation suggesting spondylosis. Alignment changes such as scoliosis, spondylolisthesis. Fractures or compression deformities. However, X-rays cannot differentiate whether a fracture is acute or chronic and cannot visualize discs or nerves. Their role is thus limited to gross structural evaluation.

Role of MRI in lower back pain:

MRI provides a comprehensive picture of the lumbar spine: Discs degeneration, desiccation, bulge, herniation. Spinal canal and foramina stenosis, nerve compression. Bone marrow edema in acute fractures, infections, tumors. Ligaments & soft tissues hypertrophy, injury, inflammation. One of MRI's greatest strengths is its ability to detect subtle and early changes long before they become visible on X-rays. For example, MRI can show bone marrow edema in an acute fracture, while X-rays may only reveal it months later.

Role of obesity in lower back pain:

Obesity places excess load on the lumbar spine, leading to: Faster disc degeneration. Increased osteophyte formation. Greater risk of spinal canal narrowing. MRI demonstrates these degenerative changes with clarity, while X-rays identify only advanced bone alterations. Thus, in obese individuals, MRI becomes especially important for early detection and management.

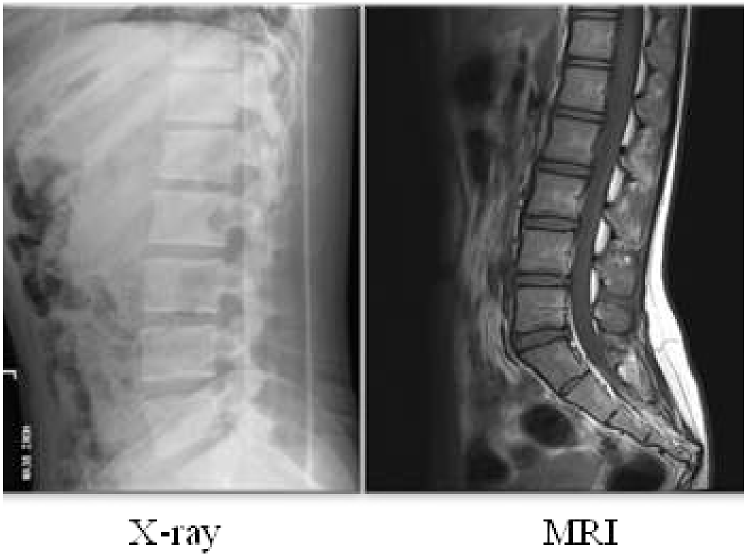

Figure 6. Shows the anatomical structure of Lumbar spine in X-ray and MRI.

Image interpretation

Case 1 – Vertebral Fracture on Lumbar Spine

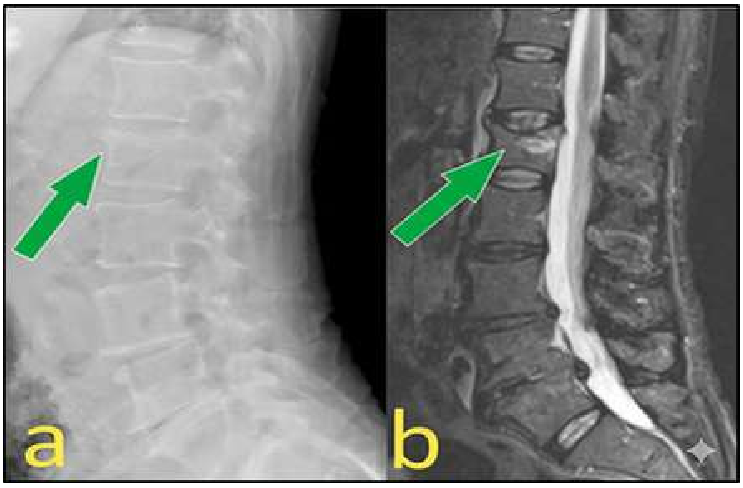

Figure 7: X-ray: A and B Shows a compressed vertebral body, but suggests it may be chronic. MRI: On STIR images, bone marrow edema is clearly visible confirms acute fracture.

Case 2 – Degenerative Disc Disease

Figure 8: X-ray: Displays disc space narrowing and spondylophyte formation. MRI: Shows disc desiccation, bulging, and associated nerve root compression. These highlight how X-rays detect bony alterations while MRI provides a deeper understanding of soft tissue and neural involvement.

Advantages and Disadvantages of X-Ray:

Advantages:
X-ray remains an inexpensive, rapid, and widely accessible imaging technique. It plays a crucial role in the initial assessment of musculoskeletal conditions, particularly for detecting fractures, degenerative changes, and other bony abnormalities.

Disadvantages:
Despite its advantages, X-ray has significant limitations. It cannot provide clear visualization of soft tissues, intervertebral discs, or nerve structures, which are often crucial in evaluating spinal disorders. In addition, it involves the use of ionizing radiation, which restricts repeated exposure.

Advantages and Disadvantages of MRI:

Advantages:
MRI provides excellent soft tissue detail, allowing clear visualization of muscles, ligaments, intervertebral discs, and neural structures. It is highly sensitive in detecting early pathological changes and subtle fractures that may not be visible on X-ray. Moreover, it is a radiation-free and safe imaging modality, making it especially valuable for repeated evaluations.

Disadvantages:
However, MRI has certain limitations, including higher cost and longer scan times compared to X-ray. In addition, access to MRI is often limited in resource-poor settings, which restricts its widespread use as a first-line imaging modality.

Conclusion:

Both X-ray and MRI are indispensable tools in evaluating low back pain. X-rays remain the first step, providing a cost-effective overview of bony structures. MRI, however, is the gold standard, revealing detailed information about discs, nerves, ligaments, and subtle fractures. In today's clinical practice, the two modalities complement each other: X-ray for initial screening and MRI for comprehensive assessment. With lifestyle changes and rising obesity contributing to earlier spinal degeneration, MRI plays a crucial role in timely diagnosis and effective patient care.

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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.

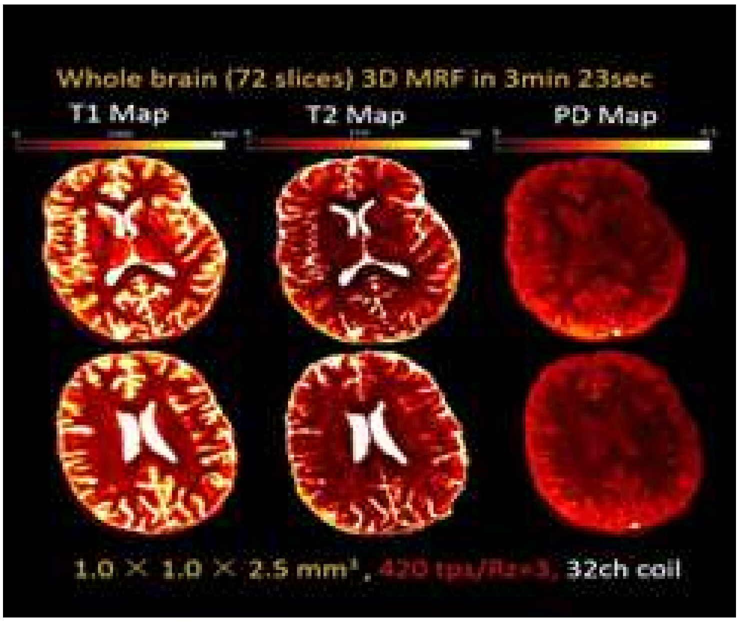
और एक बात, ये अंक हमने आप तक पहुंचाया, एक प्रबुद्ध रेडियोग्राफर के नाते अब ये आप की ज़िम्मेदारी बनती है कि इस अंक को आप भी और रडीओग्राफेर्स तक पहुंचाए यानि फॉरवर्ड करें.

अग्रिम धन्यवाद.

MR fingerprinting and its future clinical role

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

Magnetic resonance imaging has always been known for excellent soft tissue contrast. Yet for decades it remained largely qualitative. Images looked bright or dark. Interpretation depended on experience, visual comparison, and pattern recognition. Two radiologists could look at the same scan and describe it slightly differently. This subjectivity created a gap between imaging and true tissue characterization. MR fingerprinting emerged to address this gap.



MR fingerprinting, often abbreviated as MRF, is a quantitative MRI technique. Its main goal is simple. It measures tissue properties directly instead of inferring them from image contrast. The most common parameters measured are T1 and T2 relaxation times. These values are fundamental physical properties of tissues. They do not depend on scanner settings or operator choices in the same way conventional sequences do.

The idea behind MR fingerprinting is innovative yet logical. In conventional MRI, parameters such as repetition time and flip angle are kept constant. In MR fingerprinting, these parameters vary continuously in a pseudorandom manner during a single acquisition. As a result, each tissue produces a unique signal evolution over time. This signal evolution acts like a fingerprint.

The acquired signal pattern is then compared with a large precomputed dictionary. This dictionary contains simulated signal evolutions for many combinations of T1, T2, and other parameters. The closest match determines the quantitative values for that voxel. In simple words, the scanner listens to how tissues respond to changing conditions and identifies them based on known responses. This approach changes how MRI data is acquired and interpreted. Instead of relying on contrast weighting, MR fingerprinting provides numbers. These numbers can be measured, compared, stored, and followed over time. This makes MRI more objective and reproducible.

One of the biggest strengths of MR fingerprinting is efficiency. Traditional quantitative MRI requires multiple separate scans. One for T1 mapping. Another for T2 mapping. Sometimes more for proton density or other parameters. This increases scan time and patient discomfort. MR fingerprinting can obtain multiple parameters in a single acquisition. This is especially important in clinical practice where time is limited.

Another advantage is robustness. MR fingerprinting is less sensitive to system imperfections such as B1 inhomogeneity or patient motion. Because the signal pattern is matched to a dictionary, small variations do not significantly affect the final result. This improves reliability across different scanners and institutions.

The clinical applications of MR fingerprinting are expanding rapidly. Neuroimaging was one of the first areas to adopt this technique. In brain imaging, subtle tissue changes often precede visible abnormalities. Quantitative T1 and T2 values can detect these changes earlier.

In multiple sclerosis, for example, MR fingerprinting can differentiate between normal appearing white matter and diseased tissue. Conventional MRI may show normal signal, but quantitative maps reveal altered relaxation times. This helps in early diagnosis and monitoring disease progression.

Brain tumors also benefit from MR fingerprinting. Tumor tissue, edema, necrosis, and normal brain all have different quantitative signatures. MR fingerprinting helps in tumor grading and treatment response assessment. After radiotherapy, it can help distinguish recurrent tumor from radiation necrosis, a common diagnostic challenge.

Epilepsy imaging is another promising area. Subtle cortical dysplasia may be missed on routine MRI. Quantitative maps from MR fingerprinting can highlight abnormal cortical tissue and guide surgical planning.

In musculoskeletal imaging, MR fingerprinting offers precise evaluation of cartilage, muscle, and bone marrow. Early cartilage degeneration in osteoarthritis shows changes in T1 and T2 values before morphological damage appears. This opens the door for early intervention and disease monitoring.

In sports medicine, muscle injuries can be quantified more accurately. Instead of subjective assessment of edema, MR fingerprinting provides objective markers of tissue damage and healing. This helps clinicians decide when an athlete can safely return to activity.

Cardiac imaging is another area where MR fingerprinting shows strong potential. Conventional cardiac MRI already uses T1 and T2 mapping, but these require multiple breath holds and long acquisition times. MR fingerprinting can acquire multiparametric data in a shorter time. This is valuable for patients with limited breath holding capacity.

Quantitative myocardial tissue characterization helps in detecting fibrosis, edema, and inflammation. Conditions such as myocarditis, cardiomyopathies, and ischemic heart disease benefit from accurate tissue mapping. MR fingerprinting may improve diagnostic confidence and risk stratification.

Abdominal imaging presents unique challenges due to motion from breathing and bowel activity. MR fingerprinting has shown promise in liver imaging. Liver fibrosis, fat, and iron overload alter relaxation properties. Quantitative assessment helps in staging disease and monitoring therapy without invasive biopsy.
Prostate imaging is another emerging application. Multiparametric MRI is already standard in prostate cancer evaluation. MR fingerprinting can add quantitative data to existing protocols. This may improve lesion characterization and reduce interobserver variability.

One of the most important future roles of MR fingerprinting lies in precision medicine. Modern healthcare aims to tailor treatment to individual patients. Quantitative imaging biomarkers are essential for this approach. MR fingerprinting provides reproducible measurements that can be tracked over time.

In oncology, treatment response is often assessed by size reduction. This approach has limitations. Biological changes occur before size changes. Quantitative MRI can detect these early responses. MR fingerprinting may help determine whether a therapy is effective sooner, allowing timely modification of treatment.

Another key area is longitudinal follow up. Because MR fingerprinting produces absolute values, scans from different time points and even different scanners can be compared more reliably. This is crucial for chronic diseases such as multiple sclerosis, liver disease, and neurodegenerative disorders.

Artificial intelligence and MR fingerprinting are closely linked. Dictionary matching is computationally intensive. Machine learning techniques are now being used to speed up reconstruction and improve accuracy. Deep learning based approaches can reduce dictionary size and processing time. This makes MR fingerprinting more practical for routine clinical use.

AI also enables automated analysis of quantitative maps. Patterns across large datasets can be identified. This supports decision making and risk prediction. The combination of MR fingerprinting and AI represents a powerful future direction in imaging. Despite its promise, MR fingerprinting still faces challenges. Standardization is one major issue. Different vendors and research groups use different implementations. For widespread clinical adoption, standardized protocols and reference values are needed.

Validation is another important step. Large multicenter studies are required to establish normal ranges and disease specific thresholds. Clinicians need clear guidelines on how to interpret quantitative values in daily practice.

Education also plays a key role. Radiologists and radiographers must understand the principles and limitations of MR fingerprinting. Without proper training, quantitative data may be underused or misinterpreted.

From a radiographer perspective, MR fingerprinting changes workflow. Sequence setup is simpler, but understanding quality control becomes more important. Radiographers will play a crucial role in protocol optimization, patient preparation, and artifact recognition.

Looking ahead to the coming years, MR fingerprinting is expected to move from research to routine clinical use. Scan times will decrease further. Reconstruction will become faster. Integration with existing MRI protocols will improve. Quantitative maps may become as familiar as conventional T1 and T2 images.
Future developments may include expansion beyond T1 and T2. Parameters such as T2 star, diffusion properties, and perfusion metrics can be incorporated. This will provide a more complete tissue fingerprint.

Whole body MR fingerprinting is another exciting prospect. Comprehensive quantitative assessment in a single session could transform oncologic staging and systemic disease evaluation.

In summary, MR fingerprinting represents a major shift in MRI philosophy. It transforms imaging from qualitative observation to quantitative measurement. It improves objectivity, reproducibility, and clinical confidence. Its future clinical role lies in early diagnosis, treatment monitoring, and personalized medicine.

As technology advances and evidence grows, MR fingerprinting is likely to become a standard tool in modern radiology. It bridges physics and clinical care. It brings MRI closer to being a true quantitative biomarker platform. The coming years will define how fully this potential is realized, but the direction is clear and promising.

Optimization of MRI Sequences for Better Evaluation of the Brainstem A Structured Narrative Review

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Abstract:
Optimizing MRI sequences for the brainstem is essential due to the region's compact anatomy and mixture of nuclei and fiber tracts that challenge conventional neuroimaging. This review synthesizes evidence from structural, diffusion, and susceptibility-based imaging to outline key strategies for improving brainstem visualization. High-resolution diffusion tensor imaging (DTI), fast gray matter acquisition T1 inversion recovery (FGATIR), multi-echo gradient-echo (GRE) imaging at 7T, turbo spin-echo (TSE) microscopy, and Bayesian segmentation techniques have demonstrated substantial improvements in anatomical delineation and clinical assessment. Further advances in high-field MRI, susceptibility mapping, and multimodal approaches hold promise for enhanced diagnostic accuracy and functional interpretation. The review highlights sequence parameters, contrast mechanisms, hardware considerations, and clinical applications critical for optimizing MRI protocols targeting brainstem anatomy and pathology. "keywords:- DTI, FLAIR, DWI, SWI, MRI, GRE."

1. Introduction

The brainstem is a critical hub for sensory, motor, autonomic, and modulatory functions, yet its imaging has historically been limited by the constraints of conventional MRI. The close packing of nuclei, decussating fibers, and small anatomical structures hampers the ability of standard imaging sequences to differentiate internal components. As MRI technology evolves, the need for optimized imaging strategies tailored to the brainstem has become increasingly important for diagnosing diseases, planning neurosurgical procedures, and advancing functional neuroanatomy research. This review provides a structured synthesis of current approaches and innovations enabling improved visualization of the brainstem, drawing on high-quality evidence from recent imaging and neuroanatomical studies.

2. Overview of Brainstem Anatomy Relevant to MRI

The brainstem consists of the midbrain, pons, and medulla, each containing specific nuclei and fiber systems. The compact nature of the brainstem is underscored by average diameters as small as 14 mm in the medulla and the presence of nuclei often measuring less than 1 mm in diameter[1]. Classical structures such as the corticospinal tract, medial lemniscus, cranial nerve nuclei, inferior olivary complex, central tegmental tract, and reticular formation lie within millimeters of one another. The precision required to visualize these structures places strong demands on spatial resolution, signal-to-noise ratio (SNR), and contrast mechanisms in MRI sequences.

3. Challenges in Brainstem MRI

3.1 Low Inherent Contrast

Relaxation-based T1 and T2 contrast poorly distinguishes gray and white matter in the brainstem due to mixed tissue composition and low myelin density relative to supratentorial regions [2].

3.2 Susceptibility and Motion Artifacts

Proximity to the skull base introduces strong susceptibility gradients, especially at higher field strengths. Physiological noise (cardiac and respiratory) further degrades signal, particularly in functional and diffusion sequences [1].

3.3 Size Constraints

Many brainstem structures measure below the voxel dimensions of routine clinical imaging, causing partial volume effects and loss of detail.

3.4 Complex Fiber Architecture

Crossing fibers and interdigitating tracts complicate diffusion modeling, making standard tensor-based approaches insufficient for accurate tract representation.

4. Conventional MRI Sequences and Their Limitations

Standard T1- and T2-weighted MRI provide limited internal resolution of brainstem anatomy. While structural abnormalities can be identified, the fine-grain visualization of cranial nerve nuclei, peduncles, or internal tracts is typically not achievable. Even 3T systems offer only modest improvements unless sequences are specifically optimized.

Turbo spin-echo (TSE) T2 sequences offer better delineation of some gross anatomical structures but still lack the sensitivity to distinguish small nuclei. This limitation motivated the development of advanced structural sequences.

5. Advanced MRI Techniques for Brainstem Evaluation

5.1 Diffusion Tensor Imaging (DTI)

DTI provides detailed visualization of large white-matter tracts based on anisotropic diffusion.

Key findings:

- High-resolution 3T DTI with 1.8-mm isotropic voxels revealed inferior olivary nuclei, deep cerebellar nuclei, cranial nerves, and major tracts using SENSE parallel imaging to reduce distortions [3].
- 1.5T DTI allows identification of corticospinal tract, transverse pontine fibers, and medial lemniscus but struggles with smaller tegmental pathways due to SNR and resolution limits [2].

Limitations:

- Tensor model fails in regions with crossing fibers.
- Motion and susceptibility distortions affect accuracy.

5.2 High-Resolution TSE-Based Brain "Microscopy"

Hoch et al. demonstrated that optimized 3T TSE sequences can produce near-histologic contrast in postmortem whole-brain samples, clearly identifying key brainstem structures across specimens [4].

Optimization features:

- Long echo trains
- Narrow bandwidth
- Multiple orientations
- High isotropic resolution

5.3 FGATIR (Fast Gray Matter Acquisition T1 Inversion Recovery)

FGATIR uses a short inversion time to suppress white-matter signal, making gray-matter nuclei conspicuous.

Achievements:

- 0.8-mm isotropic in vivo FGATIR identified pedunculopontine nucleus, locus coeruleus, and surrounding tracts at 3T [5]
- Produces direct contrast-based discrimination without relying on diffusion.

Advantages:

- Ideal for neurosurgical planning (e.g., deep brain stimulation targets).
- More robust to susceptibility compared to GRE-based methods.

5.4 Ultra-High-Field MRI (7T)

At 7T, spatial resolution and susceptibility contrast increase dramatically.

Major findings:

- Multi-echo GRE at 7T visualized microstructures such as oculomotor nucleus, accessory olivary nucleus, and medial longitudinal fasciculus with 0.3 × 0.3 × 1.2 mm resolution in vivo [6]
- Susceptibility mapping (χ) outperformed magnitude images.

Limitations:

- Distortions due to B0/B1 inhomogeneity
- Limited clinical availability
- Safety considerations

5.5 Magnetic Resonance Histology (MRH)

Ex vivo imaging at 50–200 μm isotropic resolution demonstrated the full potential of brainstem MRI.

- Adil et al. segmented over 90 structures using high-resolution anatomical and diffusion MRH [7].
- The atlas informs new segmentation algorithms and sequence targets for in vivo imaging.

5.6 Functional MRI Techniques

BOLD, ASL, and CVR mapping of the brainstem require high temporal and spatial optimization.

Functional brainstem networks in pain, arousal, and autonomic regulation have been delineated in research environments but face challenges from physiological noise and small voxel sizes [1]

5.7 Bayesian Segmentation and Probabilistic Atlases

Automated segmentation improves interpretability and clinical feasibility.

- Bayesian segmentation accurately identified midbrain, pons, and medulla across T1 and FLAIR scans with <1-mm error and strong robustness across disease states[8].

6. Sequence Optimization Strategies for Brainstem Imaging

6.1 Enhance Spatial Resolution

- Aim for ≤1 mm isotropic voxel size whenever possible.
- Utilize parallel imaging (SENSE or GRAPPA) to maintain acquisition time and reduce distortion.
- Use multichannel head/neck coils to improve SNR.

6.2 Select Appropriate Contrast Mechanisms

- FGATIR for gray-matter nuclei
- DTI/DWI for tracts
- GRE/χ-maps for susceptibility-based visualization of iron-rich nuclei
- TSE-T2 for structural discrimination

6.3 Mitigate Physiological Noise

- Apply cardiac and respiratory gating in diffusion and functional scans.
- Use RETROICOR and ICA-based denoising.
- Utilize optimized slice orientation to avoid brainstem–skull interfaces.

6.4 Reduce Susceptibility Artifacts

- Select phase-encoding direction to minimize distortions.
- Apply pre-scan shimming and B0 optimization.
- Incorporate distortion correction techniques (TOPUP, field mapping).

6.5 Employ Complementary Sequences

No single sequence suffices; combining optimized T1/T2, DTI, and GRE sequences provides the most complete anatomical depiction.

7. Clinical Applications of Optimized Brainstem Imaging

7.1 Neuro-degenerative Diseases

Enhanced imaging helps detect microstructural changes in diseases such as progressive supranuclear palsy, Parkinson's disease, and Alzheimer's illness [8]

7.2 Neurosurgical Planning

FGATIR, TSE, and 7T GRE sequences assist in identifying surgical targets such as the pedunculopontine nucleus.

7.3 Pain Disorders

Diffusion tractography has mapped pain-related pathways and identified microstructural changes in chronic pain conditions [9]

7.4 Stroke and Demyelination

Improved visualization of brainstem tracts and nuclei aids in detecting lacunes, plaques, and involvement of cranial nerve nuclei.

8. Future Directions

Advancements likely to shape future brainstem MRI include:

- Parallel transmission at 7T to mitigate B1 inhomogeneity
- Compressed sensing for accelerated high-resolution imaging
- Multi-shell diffusion and advanced modeling (CSD, NODDI)
- Quantitative susceptibility mapping (QSM) for microstructural biomarkers
- Deep learning–based super-resolution reconstruction
- Integration of multimodal atlases derived from MRH data

These innovations could reduce scan time, improve tract specificity, and enhance visualization of submillimeter nuclei.

9. Conclusion

The optimization of MRI sequences for brainstem evaluation requires a careful interplay of high spatial resolution, tailored contrast mechanisms, artifact mitigation strategies, and advanced modeling. Innovations such as FGATIR, multi-echo GRE at 7T, high-resolution TSE, DTI tractography, MRH-based atlases, and Bayesian segmentation have considerably advanced the field. Continued development of ultrahigh-field MRI, faster acquisition techniques, and multimodal integration will further improve the ability to visualize and analyze this anatomically and functionally critical region.

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Adverse Reactions to Iodinated Contrast Media: A Standard Narrative Review Paper

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Abstract:
Iodinated contrast media plays an important role in modern diagnostic radiology and interventional radiology by enhancing image quality and improving diagnostic accuracy. Although major advancements have been made in contrast agents, adverse reactions to iodinated contrast media remains a matter of clinical concern. The adverse reactions range from mild, self-limiting symptoms to severe, life threatening events. As the use of contrast-enhancing imaging is increasing day by day, it highlights the need for comprehensive understanding of classification of contrast media, adverse reactions to contrast media, risk factors, prevention strategies, and emergency management. The narrative review summarizes the classification of contrast media on the basis of osmolality, ionicity, and molecular structure. It discusses about different types of adverse contrast reactions. Preventive approaches such as patient risk stratification, adequate hydration, and premedication protocols are reviewed, along with evidence-based recommendations for the prompt recognition and emergency management of contrast-related reactions.

Keywords: iodinated contrast media, adverse reactions, hypersensitivity reactions, contrast media classification, premedication, contrast reaction management.

Introduction

The use of contrast media has become essential to diagnostic imaging, specifically in computed tomography, angiography, and interventional radiology. Among different available contrast agents, iodinated contrast media (ICM) are most commonly used because of their high X-Ray attenuation properties and usefulness in intravascular and body cavity imaging(1,2)After the development of iodinated contrast agents in twentieth century, they have been modified over time to improve safety. Early high-osmolality ionic contrast agents were associated with higher risk of adverse reactions, this led to the development of low-osmolality and iso-osmolar non-ionic formulations.(3,4)Overall, the modern iodinated contrast agents are safe, but adverse reactions may still occur. Reported overall reaction rates are approximately 1% to 12%, while severe reactions are uncommon.(5,6)These reactions are unexpected and may occur in patients without any risk factors and may range from mild symptoms such as nausea, flushing and urticaria to severe, life-threatening events including bronchospasm, hypotension, arrhythmias and cardiovascular collapse.(4,7)

Adverse reactions to iodinated contrast media are commonly classified on the basis of timing, severity and pathophysiology. Immediate reactions occur within one hour of contrast administration and often mimic IgE-mediated anaphylaxis but usually non -IgE-mediated.(6,8) Delayed reactions occur hours to days after contrast administration and primarily T-cell-mediated skin reactions.(7) Contrast media can also cause physiological effects due to osmolality, viscosity, and ionicity, affecting cardiovascular, renal and neurologic function.(3)

Prevention and management of iodinated contrast reactions involve risk assessment, appropriate contrast selection, and emergency preparedness. Major risk factors include contrast reaction, asthma or atopy, cardiovascular or renal diseases and beta-blocker use (4,9)Common preventive measures include low-or-iso-osmolar non-ionic agents, adequate hydration and selective steroid-antihistamine premedication, though their ability to prevent severe reactions remains uncertain (4,6)

Staff preparedness for recognition and management of contrast reaction is crucial, yet studies shows significant knowledge gaps, especially regarding epinephrine use (10–12)These findings highlight the need for standardized protocols and regular training.

Historical Development of iodinated contrast media

Early iodinated contrast agents used in 1920s-1930s, such as sodium iodide, cause significant side effects. In 1950s, tri-iodinated benzene ring compounds were developed, which led to the use of high-osmolality ionic contrast media. These agents had osmolality much higher than blood and were commonly associated with nausea, vomiting, pain on injection and allergic -like reactions.(1,3,7)

During 1970s -1980s, low osmolality non-ionic contrast media were introduced, which were better tolerated by patients. Later, dimeric agents further reduced osmolality, and the most recent iso-osmolar contrast media have osmolality similar to blood, reducing osmotic stress while maintaining good image quality.(2–4)

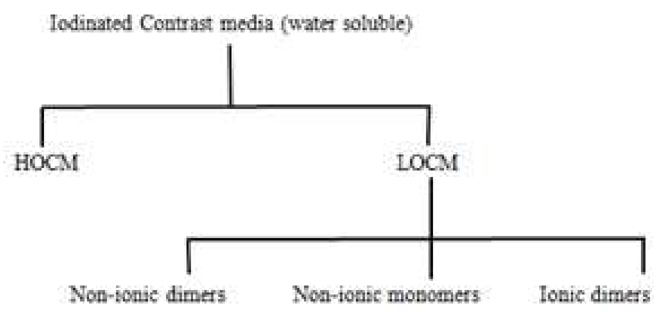

Table – 1 Classification of Iodinated Contrast Media (13)

Classification of ICM on the basis of Ionicity

Ionic contrast media get dissociate into ions when dissolved in water, increasing osmolality and contributing to a higher rate of adverse reactions. (3,4)

Non-ionic contrast media do not get dissociated in water or solution, resulting in lower osmolality and fewer adverse reactions with better patient tolerance. Their improved safety has led their near-universal use in modern intravascular imaging (2–4,14)

Classification based on osmolality

High osmolality CM (HOCM) have osmolality several times higher than plasma and are associated with increased rates of mild to moderate adverse reactions, including vasovagal symptoms, pain, and cardiopulmonary effects.(5)

Low osmolality contrast media (LOCM) have osmolality about two to three times that of plasma and are associated with significantly lesser adverse reactions, particularly anaphylactoid and cardiovascular events, compare to HOCM (4,7)

Iso-osmolar contrast media (IOCM) have plasma -like osmolality and are designed to reduce osmotic stress, making them useful in high-risk or renally impaired patients, but due to higher viscosity and higher cost the use is limited.(3,14)

Classification based on molecular structure

Monomeric contrast agents contain a single tri-iodinated benzene ring and can be ionic or non-ionic. Because of their low viscosity and ease of injection. Non-ionic monomeric LOCM are most commonly used in routine CT imaging.(2,4)

Dimeric contrast agents contain two linked tri-iodinated benzene rings, each molecule containing six iodine atoms. This structure increases the iodine-to-particle ratio and reduces osmolality. Non-ionic dimers form most iso-osmolar agents and have good safety profiles, though their higher viscosity may require slower injection rates.(3,7)

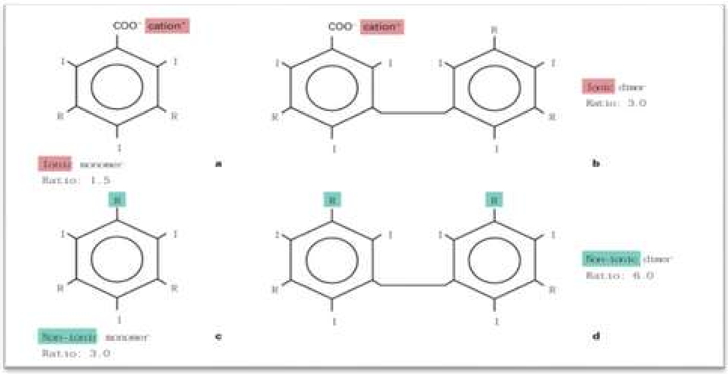

Figure 1. Classification of contrast agents on the basis of molecular structure: a. High osmolality ionic monomers, b. Low-osmolality ionic dimer, c. Low-osmolality non-ionic monomers, d. iso-osmolar non-ionic dimers(3).

Clinical Relevance of Contrast media Classification

Understanding of Iodinated contrast media classification is important for clinical decision -making, as ionicity, osmolality, and molecular structure affect the risk of adverse reactions. High-osmolality ionic agents cause physiologic reactions, whereas non-ionic low-and iso-osmolar agents are associated with fewer side effects and better patient comfort.(4)

Current radiology practice favours to select contrast media based on patient risk factors, clinical indication and procedural requirements. The broad use of non-ionic low-and iso-osmolar agents reflects efforts to reduce adverse reactions while maintaining diagnostic effectiveness. (4,14)

Physicochemical characteristics of Iodinated Contrast Media and Their Clinical Significance

The safety of iodinated CM depends on physicochemical properties. Parameters like osmolality, viscosity, iodine concentration, and ionicity affect both diagnostic performance of contrast agents and their potential to cause adverse reactions. Understanding these factors is essential for understanding the mechanisms of contrast -induced reactions and for selecting appropriate agents for patients.(3,4)

Osmolality is a key factor influencing toxicity of contrast media. High-osmolality agents cause fluid shifts and hemodynamic changes leading to warmth, nausea, flushing, and hypotension, especially in patients with cardiovascular diseases. (3,7) whereas low-and iso-osmolar agents are associated with fewer adverse effects. (4,14)

Viscosity affects the flow and injectability of contrast media and increase in low-and iso-osmolar agents. Higher viscosity may increase injection pressure and affect renal flow, specially in patients with kidney diseases, while warming contrast helps to reduce these effects. (3,4)

Iodine concentration Iodine concentration determine image contrast, with higher levels providing better enhancement but increasing viscosity and potential toxicity.(1)Hypersensitivity reactions are not dose -dependent, and modern CT allows lower iodine dose while maintaining image quality. (6)

Ionicity ionic contrast agents get dissociate into ions that can disturb cardiac and neural electrical activity, while non-ionic agents are associated with fewer cardiovascular adverse effects. (2,3,14) Osmolality, viscosity, Iodine concentration, and ionicity plays important role in contrast-induced reactions. Physiologic reactions are related to these properties and are dose-dependent, whereas hypersensitivity reactions are dose-independent and patient -specific (4,6)

Classification of Adverse Reactions to Iodinated Contrast Media

Categorization of reaction is based on **timing of onset, severity, and pathophysiological mechanism.**

Classification based on Timing of onset

Immediate reactions occur within one hour of contrast administration, with most reactions occurring within first 5-10 minutes. Immediate reactions range from mild symptoms such as nausea and urticaria to severe, life -threatening events including bronchospasm, laryngeal edema, hypotension, and cardiovascular collapse. (5,6)

Delayed reactions occur one hour after contrast administration and can develop several days later, typically within 24-72 hours. They are mostly cutaneous and self-limiting like maculopapular rashes, erythema, or pruritus. They are uncommon but have been reported. (7,8)

Classification based on severity

Mild reactions are self-limiting and do not require specific treatment. It includes nausea, vomiting, flushing, headache, metallic taste, pruritus, and limited urticaria.

Moderate reactions include extensive urticaria, facial or laryngeal edema without airway compromise, bronchospasm, tachycardia, or hypotension.

Severe reactions are life-threatening and require immediate emergency treatment. It includes severe bronchospasm, laryngeal edema with airway obstruction, profound hypotension, cardiac arrhythmias, seizures, loss of consciousness, and cardiopulmonary arrest. (5,10)

Classification based on Pathophysiological Mechanism

Hypersensitivity (allergic-like or anaphylactoid) reactions these reactions mimic true allergic reactions but are often not mediated by IgE. These reactions were called anaphylactoid, although some severe immediate reactions may be IgE-mediated, while most delayed reactions are T-cell mediated.(6,7) Immediate reactions occur due to mast cell activation and release of histamine, causing symptoms as hives, swelling, breathing difficulty, and low blood pressure. Delayed reactions affect skin. (8)

Physiologic (Chemotoxic) Reactions are caused by physicochemical properties of contrast media, are dose


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Management and treatment of adverse reactions to Iodinated contrast media

Symptoms	Notes	Treatment
Urticaria	-Monitor closely, mostly get resolve on their own. Treat if symptoms worsen. -If severe, step up treatment	-Diphenhydramine:1mg/kg PO/IM/IV -Epinephrine: IM 0.3-0.5 ml of 1:1000
Facial / laryngeal oedema	-In severe cases, call emergency medical team -If severely hypotensive epinephrine preferred	-O2 by face mask 6-10 L/min -EpiPen 0.3-0.5ml of 1:1000, can repeat for every 5-10 minutes up to 1mg total
Bronchospasm	-continuously monitor. If condition worsen call emergency medical team. -IV EpiPen for severe reactions -Call emergency medical team.	-O2 by face mask 6-10 L/min -Beta-agonist inhaler:180mcg; can repeat 3× - EpiPen 0.3-0.5ml of 1:1000, can repeat for every 5-10 minutes up to 1mg total
Hypotension with bradycardia	-usually self-limiting	- O2 by face mask 6-10 L/min -Elevation of leg -Saline 0.9%: 10-20 mL/kg - Atropine: IV 0.6-1.0 mg, saline flush, repeat till 3mg
Hypotension with tachycardia	-In case of severe hypotension, IV EpiPen is preferred	- O2 by face mask 6-10 L/min -Elevation of leg -Saline 0.9%: 10-20 mL/kg - EpiPen 0.3-0.5ml of 1:1000, can repeat for every 5-10 minutes up to 1mg total
Hypertension		-O2 by face mask:6-10 L/min -Labetalol: IV 20 mg over 2 min. -Furosemide: IV 20-40 mg over 2 min
Seizures	-Call emergency medical team, if seizures continuous	-Turn patient in lateral position to avoid aspiration. -Suction airway if needed -O2 by face mask:6-10 L/min - Give Lorazepam: IV 2-4 mg
Pulmonary oedema	-Call emergency medical team	- O2 by face mask:6-10 L/min -Elevate bed's head -Give IV furosemide 20-40 mg over 2 min. -Give IV Morphine 1-3 mg
Cardiac arrythmia, normotensive		- O2 by face mask:6-10 L/min
Unresponsiveness	-call emergency medical team	-IM Glucagon 1mg

dependent, and occur more often with high-osmolality ionic agents. Symptoms include warmth, nausea, flushing, bradycardia, and hypotension.(3,4)

Risk factors for adverse reactions

Prior contrast reaction: a history of previous moderate or severe iodinated contrast media reaction is the strongest predictor of a future reaction, increase the risk approximately by five-to six-fold.

Asthma and atopy: patients with poorly controlled asthma, and patients with severe allergies have a significantly increased risk of anaphylactoid reactions.

Medications: use of beta -blockers increase severity of reactions.

Patient Factors: cardiovascular diseases, anxiety, and certain malignancies, female sex have been associated with increased reaction rates.

Renal Dysfunction: pre-existing chronic kidney diseases, dehydration, diabetes mellitus, and advanced age increase the risk of contrast associated acute kidney injury.(3,4)

Prevention Strategies for Adverse Reactions

Patient Screening and Risk Stratification: a careful pre-procedural assessment is necessary to prevent adverse contrast reactions. Identifying prior reactions, allergies, asthma, and medications help to recognize high -risk patients and guide appropriate management (14)

Choice of contrast: use of non-ionic low-osmolality or iso-osmolar contrast media is recommended for all patients, specially those at high risk.(4)

Hydration: proper hydration before and after administration of contrast is important, particularly for preventing contrast-induced nephropathy. Both oral and intravenous hydration reduce renal complications and improve safety.(4,14)

Premedication Strategies in High-Risk Patients

Corticosteroids and antihistamines are commonly used in patients with prior history of contrast reactions. Typical treatment plan includes oral corticosteroids administered at least 6-12 hours before contrast exposure, commonly combined with antihistamines. Premedication can reduce mild and moderate reactions it does not completely prevent severe or life-threatening reactions. (4,6)Reactions can still occur regardless of premedication; emergency preparedness is essential.

Premedication is less effective for delayed-cell-mediated reactions. Routine premedication is not universally recommended for delayed reactions, and alternative imaging should be considered for patients with severe delayed reactions.(8)

Management of Acute Adverse Reactions

Acute contrast reactions require quick assessment of airway, breathing, and circulation, stoppage of contrast administration, giving prompt treatment, oxygen supplementation and continuous monitoring of vital signs are essential.(5)

Epinephrine is the first-line treatment for severe hypersensitivity reactions, including anaphylaxis and severe bronchospasm. Intramuscular administration is preferred due to rapid absorption and favourable safety profile(10)

Antihistamines and **corticosteroids** play supportive role but should never delay epinephrine administration in severe contrast reactions. Depending on severity, bronchodilators, IV fluids and advanced life support may be needed.(4)

Conclusion

Iodinated contrast media plays an important role in modern diagnostic imaging, yet adverse reactions remain an important clinical concern. Advancements in contrast chemistry have improved safety, however, no contrast agent is completely risk free. A broad understanding of contrast media classification, physiochemical properties, risk factors, and management strategies are essential for safe clinical practice. Effective prevention depends on careful patient assessment, appropriate contrast selection, selective premedication, and well-trained radiology personnel. Ongoing research, training and following of evidence-based guidelines are necessary to reduce contrast-related adverse reactions.

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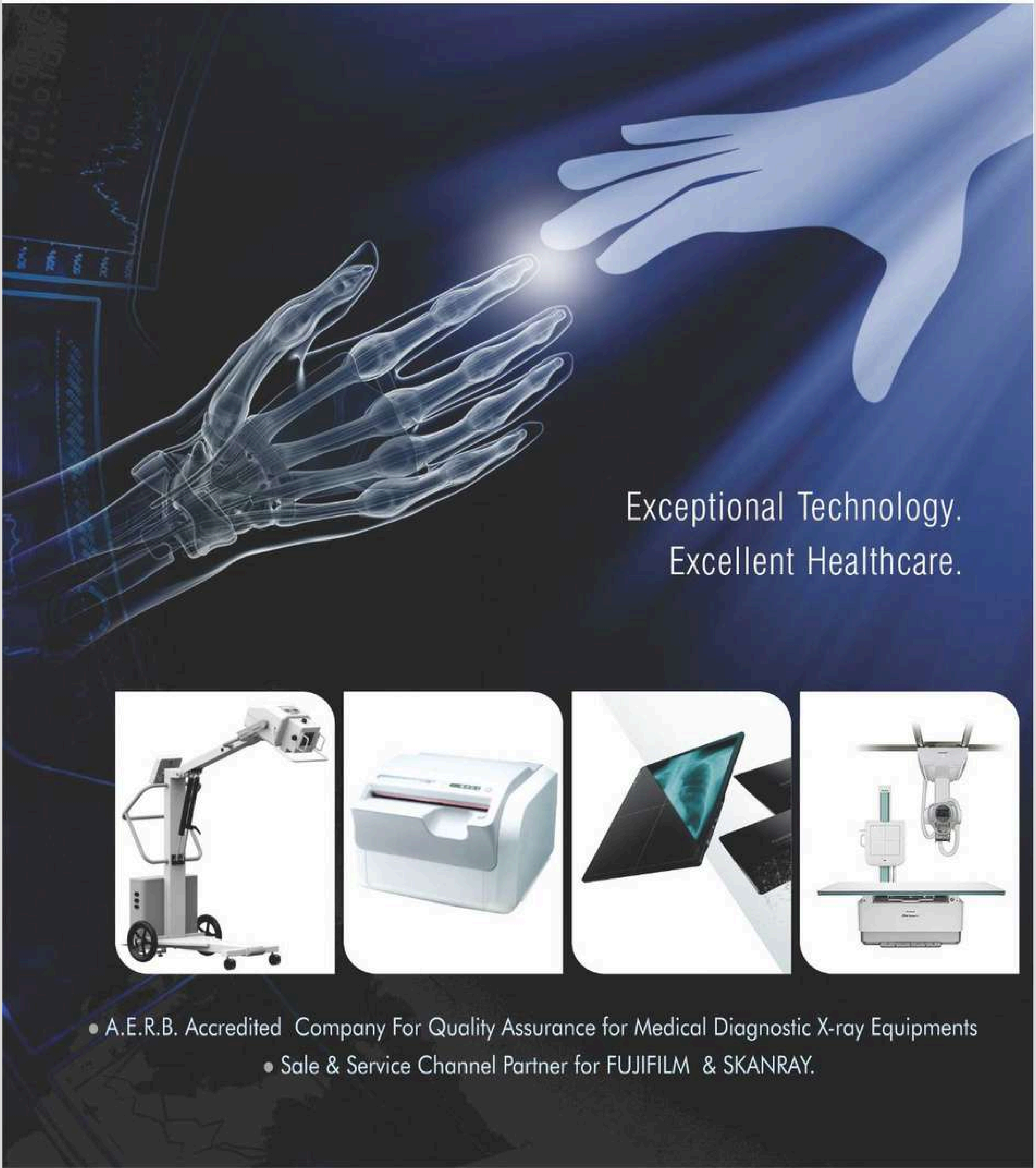
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PET-CT and MRI Fusion for Neuroimaging

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Abstract

Positron Emission Tomography (PET), Computed Tomography (CT), and Magnetic Resonance Imaging (MRI) have been integrated as a result of advancements in multimodal neuroimaging, providing a thorough framework for assessing the structure, function, and metabolism of the brain. The clinical and technological roots of PET-CT/MRI fusion are examined in this review, which also emphasizes the diagnostic benefits of this technique in complicated neurological illnesses such stroke, brain tumors, epilepsy, and neurodegenerative diseases. Lesion identification, illness characterisation, and treatment planning are improved when the metabolic insights of PET are combined with the morphological clarity of CT and MRI. While lowering radiation exposure for patients, specialized hybrid systems—such as brain-specific PET/MRI scanners—have further enhanced spatial and temporal resolution. Despite its potential, high expenses, complicated workflows, and the requirement for standardized imaging methods prevent widespread implementation. By automating picture registration and enhancing diagnostic precision, emerging solutions—especially those that make use of artificial intelligence—are well-positioned to get past these constraints. This study highlights the potential of PET-CT/MRI fusion to revolutionize clinical practice and neuroscience research by examining its present uses, constraints, and future prospects in neuroimaging.

Keywords

PET-CT fusion, MRI, neuroimaging, hybrid imaging, multimodal neuroimaging.

Introduction

By allowing for the non-invasive visualization of brain structure, function, and metabolism, advances in neuroimaging have greatly improved the diagnosis and treatment of neurological disorders. Magnetic Resonance Imaging (MRI), Computed Tomography (CT), and Positron Emission Tomography (PET) are three important imaging modalities that each provide unique but complementary diagnostic capabilities. By identifying radiotracer activity, PET provides quantitative functional information that enables evaluation of metabolic processes like glucose consumption, receptor binding, and pathological protein accumulation. For anatomical localization and attenuation correction in PET imaging, CT provides quick imaging with superior bone and calcification contrast. In contrast, MRI offers detailed structural and functional brain imaging without ionizing radiation and superior soft-tissue contrast. Combining PET, CT, and MRI is a potent multimodal strategy that improves each modality's diagnostic potential.(1) The ability of PET-CT to integrate functional and anatomical data in a single imaging session has made it a widely accepted clinical standard. The development and growing use of PET-MRI systems, which offer better soft-tissue resolution and functional capabilities like diffusion-weighted imaging (DWI), functional MRI (fMRI), and MR spectroscopy. By integrating molecular, structural, and functional data, combining all three modalities—either consecutively or via software-based image registration—allows for a thorough understanding of the brain. In complex neuroimaging applications, such as the assessment of brain tumors, epilepsy, neurodegenerative diseases, and neuroinflammation, this tri-modality fusion is particularly beneficial. It enables more accurate diagnosis, more precise localization of lesions, and better treatment planning. The combination of PET, CT, and MRI is set to revolutionize clinical practice and neuroscience research as hybrid imaging technologies advance and become more widely available. The use of PET-CT and MRI fusion in clinical settings is fraught with difficulties, despite its many benefits. Widespread adoption is hampered by the high expense of multimodal imaging, the demand for specialist equipment, and the need for professional interpretation. Furthermore, as differences in imaging methods throughout institutions might impact diagnostic consistency, standardization of fusion imaging protocols is still a crucial concern. By automating image fusion procedures and increasing diagnostic precision, developments in artificial intelligence and machine learning may be able to overcome these issues. Real-time PET-CT and MRI data processing is made possible by AI-driven algorithms, which lessens the need for human interpretation and improves workflow effectiveness. The benefits and drawbacks of combining PET-CT and MRI for the diagnosis of brain diseases are compiled in the Table 1 below.(2)

PET/MRI Tomographs specifically designed for the Brain

Collaboration between industry and academics produced the first PET/CT design, which was a clinical prototype for humans that sparked a commercial reaction and ultimately resulted in the creation of PET/CT for imaging small animals. PET/MR, on the other hand, started with small-animal designs in the middle of the 1990s. Then, more than ten years later, a PET/MR prototype was created for scanning the human brain, and in November 2006, it took its first pictures.(3) The components of the system are the pinnacle of both technologies: HRRT PET, which offers great sensitivity and spatial resolution because of the geometrical and physical properties of the scanner detectors, and MRI at 7 T, which permits improved sensitivity and resolution. A revolving shuttle bed with precise calibration connects these two brain-dedicated units(3).

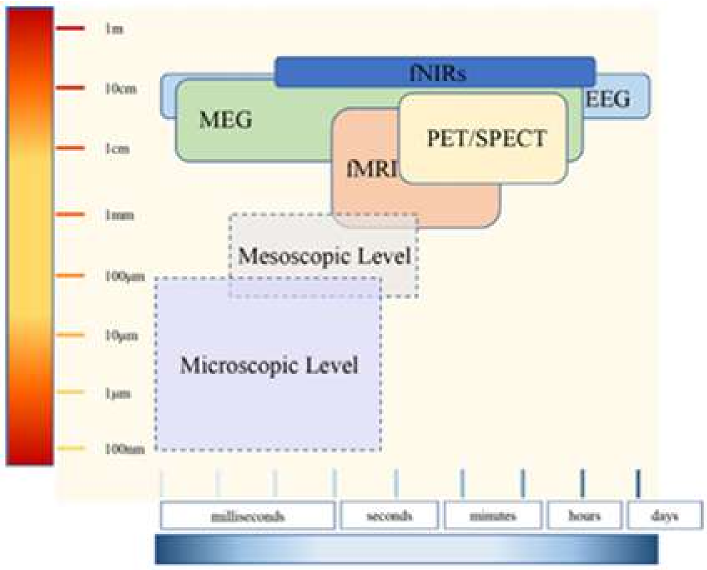

Fig.1 The temporal and spatial ranges for the most widely used non-invasive functional imaging techniques for humans.(4)

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Benefits of PET-CT/MR Fusion

Improving spatial and temporal resolution

Fig.1 demonstrates the most popular non-invasive functional neuroimaging modalities' spatiotemporal resolution profile. With indicators of pertinent time periods and brain structures, the logarithmic scale displays temporal resolution on the horizontal axis and spatial resolution on the vertical axis. Enhancing the spatiotemporal resolution of brain process characterisation is thus a clear benefit of integrating several imaging techniques. The better spatial resolution of one modality is coupled with the superior temporal resolution of the other modality. The combination of data is known as validation in situations with comparable spatiotemporal resolution (e.g., cerebral blood flow assessed by ASLMRI and water PET)(4)

Just one imaging session

A primary benefit of hybrid imaging technology is the ability to acquire all pertinent imaging data in a single session, either concurrently or sequentially, dependent upon the architecture of the tomograph.(5)

Enhanced characterisation of brain pathology

Characterizing brain diseases is much improved by combining high-resolution anatomical MRI images with PET data, which represents metabolic activity. This is especially helpful in cancer, since it helps distinguish between changes brought on by therapy and tumor recurrence, which is sometimes difficult to do with traditional imaging.(5)

Improved monitoring and planning of treatments

Planning radiation therapy benefits greatly from PET-MRI fusion as it precisely identifies areas with metabolic activity. Furthermore, personalized dosage modifications to optimize the therapeutic effect are made possible by real-time input on treatment response.(5)

Better patient comfort and less radiation exposure

The 'one-stop-shop' imaging technique is PET-MRI fusion. It reduces radiation exposure by eliminating the need for several scans. Additionally, because we only employ one MRI 3D fluid-attenuated inversion recovery (FLAIR) sequence, patients are more cooperative and relaxed due to the faster scan periods.(5)

Multimodal data image fusion challenges

Ignoring Early Warning Indications

The majority of neurological disorders arise from slight metabolic changes that are typically undetectable by standard imaging. The most drastic therapies, such as dementia, may not be appropriate until the structural alteration is evident.(5)

An excessive amount of overlap

The reason for this is because numerous brain disorders have very similar MRI or CT readings, making diagnosis extremely difficult. It's similar to trying to identify a bird based on the silhouette it makes.(5)

Small Modifications, Huge Effect

It is feasible to categorize the brain disorders according to the fact that some develop very slowly or have very slight changes that are not discernible by detailed MRI scans. As a result, many people may be diagnosed later than is appropriate and receive subpar treatment.(5)

Conclusion

A significant development in neuroimaging, the combination of PET-CT and MRI provides a comprehensive method for assessing the anatomy, function, and metabolism of the brain. This tri-modality fusion allows for better lesion localization, more precise diagnosis, and more efficient treatment planning for complex neurological conditions like brain tumors, epilepsy, stroke, and neurodegenerative diseases by combining the metabolic sensitivity of PET, the quick anatomical localization of CT, and the superior soft-tissue resolution and functional imaging capabilities of MRI. By reducing patient radiation exposure and improving spatial and temporal resolution, brain-dedicated PET/MRI systems have significantly progressed the discipline. Despite these important clinical benefits, broad adoption is hampered by practical issues such high prices, technological complexity, and a lack of standardized imaging methods. Artificial intelligence integration, on the other hand, presents encouraging answers to these challenges, allowing for automatic picture fusion, real-time data interpretation, and enhanced diagnostic consistency. PET-CT and MRI fusion is anticipated to become a vital tool in clinical and research contexts as multimodal imaging technology advances, ultimately changing the field of neuroimaging and patient care.

References

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Imaging Aspect	PET-CT Advantages	MRI Advantages	PET-CT and MRI Fusion Benefits
Functional analysis	Detects metabolic changes early	Limited functional assessment	Combines structural metabolic and data for comprehensive diagnosis
Structural Resolution	Lower spatial resolution	High anatomical resolution	Improved localization of lesions and abnormalities
Disease Detection	Effective in detecting neurodegeneration	Provides detailed brain morphology	Enhanced accuracy in detecting neurodegenerative neurological disorders
Tumor Assessment	Differentiates between malignant and benign growth	Provides tumor location details	Better visualization and treatment planning
Stroke Evaluation	Assesses cerebral blood flow	Identifies ischemic lesions	Differentiates viable and infarcted tissue for optimized intervention

Table No 1. Benefits of tri-modality fusion (2)

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