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Radiographers' Journal

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Editorial

Shankar K. Bhagat
Editor-in-chief

Radiography in Motion – Innovation, Ethics, and Adaptation

The May 2025 edition of the Radiographers Journal brings together a compelling collection of articles that reflect the remarkable pace of change in radiology. With all contributions now received, this issue stands as a collaborative snapshot of a profession that is simultaneously grounded in patient care and reaching boldly into the future.

We begin with a focus on **Virtual and Augmented Reality (VR/AR)** in both medical training and patient care. From immersive education tools for radiography students to VR-assisted techniques that ease patient anxiety during procedures, these technologies are transforming the way we teach, learn, and care.

Technological advancement also raises important ethical questions. In **Ethics in Radiology**, contributors explore the handling of incidental findings, the challenges of AI bias, and the evolving nature of informed consent. As machines increasingly influence clinical decisions, safeguarding patient autonomy and trust remains a core responsibility.

In **Fundamentals of AI in Radiology – Part 3**, readers gain deeper insight into how AI systems are developed and validated for clinical use. The article demystifies technical concepts and highlights the importance of clinician involvement in shaping AI tools that are safe, accurate, and transparent.

The integration of **Robotics in Medical Imaging and Surgery** is another major step forward. Robotic systems are enhancing precision in interventional procedures and surgical planning, offering consistency and safety in complex clinical environments.

As AI becomes more embedded in diagnostic practice, **How Machine Learning is Changing the Radiology Doctor's Role** explores the shift from image interpretation to clinical consulting, data validation, and collaboration with AI systems—redefining radiologists' professional identity.

We also showcase the **Swoop Portable MR Imaging System**, a groundbreaking development in brain imaging that offers rapid, bedside scanning in emergency settings. This mobility supports faster decision-making in stroke and trauma care.

Several articles explore AI's expanding applications, including **AI in Contrast Media**, which examines how machine learning can optimise dosage and personalise imaging protocols, and **AI-Powered Image Stitching**, which automates the creation of seamless, composite radiographs with improved quality and efficiency.

New imaging modalities are also featured. **Dark Field CT** offers microstructural insights with minimal radiation, while the **Dual-exposure Technique** improves image contrast by capturing low and high-dose exposures—particularly valuable in thoracic imaging.

Spectral Mammography and **Diffuse Optical Tomography** present enhanced breast imaging capabilities, enabling better lesion characterisation and functional imaging with reduced invasiveness.

Equally promising is the emergence of **Printable Organic Sensors**, enabling lightweight, flexible detectors for precise cancer diagnostics—bringing high-resolution imaging closer to the point of care.

Finally, in **Adapting Under Pressure**, we see a powerful example of radiographic problem-solving. Faced with acute stroke scenarios, radiographers adapted CT positioning protocols under time-critical conditions—a reminder that while technology evolves, professional adaptability remains essential.

This issue offers both a forward-looking perspective and a grounded understanding of the realities of modern radiography. To our contributors: thank you for your valuable insights. To our readers: we hope these articles inform and inspire your on-going journey in this vital and evolving profession.

Government Constitutes National Allied and Healthcare Advisory Council

The Ministry of Health and Family Welfare has announced the constitution of the National Allied and Healthcare Advisory Council, a body established to advise the National Commission for Allied and Healthcare Profession. This constitution, notified on May 23, 2025, is in pursuance of the provisions of the National Commission for Allied and Healthcare Professions Act, 2021.

The newly formed National Allied and Healthcare Advisory Council will comprise the following members:

1. Chairperson of the Commission – will also serve as the Chairperson of the Advisory Council.
2. All Members of the Commission – will be ex-officio members of the Advisory Council.
3. Principal Secretary dealing with medical education or their nominee from each State – will be a member.
4. Chairperson of each State Council – will be a member.
5. Principal Secretary dealing with medical education or their nominee representing each Union territory – will be a member.

This broad representation from both the National Commission and the State and Union Territory levels underscores the government's commitment to a collaborative and inclusive approach in shaping the future of allied and healthcare professions in India.

The primary function of the National Allied and Healthcare Advisory Council will be to provide expert advice and recommendations to the National Commission for Allied and Healthcare Profession on matters related to the regulation and development of these crucial sectors. This includes aspects such as education standards, professional conduct, ethical practices, and the overall enhancement of the allied and healthcare workforce.

The constitution of this Advisory Council marks a milestone in the implementation of the National Commission for Allied and Healthcare Professions Act, 2021, which aims to standardize and regulate the education and practice of allied and healthcare professionals in the country. The Council is expected to play a vital role in ensuring the delivery of quality healthcare services and fostering the growth of a skilled and competent allied and healthcare workforce.

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भारत का राजपत्र
The Gazette of India

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स्वास्थ्य और परिवार कल्याण मंत्रालय

अधिसूचना

नई दिल्ली, 23 मई, 2025

का.आ. 2310(अ).—केंद्रीय सरकार, राष्ट्रीय सहबद्ध और स्वास्थ्य देखरेख वृत्ति आयोग अधिनियम, 2021 (2021 का 14) की धारा 12 की उप-धारा (1) और उप-धारा (2) के उपबंधों के अनुसरण में, राष्ट्रीय सहबद्ध और स्वास्थ्य देखरेख वृत्ति आयोग को सलाह देने के लिए राष्ट्रीय सहबद्ध और स्वास्थ्य देखरेख सलाहकार परिषद का गठन करती है, जिसमें निम्नलिखित व्यक्ति शामिल होंगे, अर्थात्: -

(i) आयोग का अध्यक्ष - अध्यक्ष;

(ii) आयोग के सभी सदस्य - सदस्य, पदेन;

(iii) प्रत्येक राज्य के चिकित्सा शिक्षा से संबंधित प्रमुख सचिव या उनके द्वारा नामित व्यक्ति - सदस्य;

(iv) प्रत्येक राज्य परिषद के अध्यक्ष - सदस्य; और

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2 THE GAZETTE OF INDIA : EXTRAORDINARY [PART II—SEC. 3(ii)]

(v) प्रत्येक संघ राज्य क्षेत्र का प्रतिनिधित्व करने वाला चिकित्सा शिक्षा से संबंधित प्रमुख सचिव या उनके द्वारा नामित व्यक्ति - सदस्य।

[फा. सं. जेड-28016/42/2024-एएचएस]
विनोद कोतवाल, अपर सचिव

MINISTRY OF HEALTH AND FAMILY WELFARE

NOTIFICATION

New Delhi, the 23rd May, 2025

S.O. 2310(E).—In pursuance of the provisions of sub-sections (1) and (2) of section 12 of the National Commission for Allied and Healthcare Professions Act, 2021 (14 of 2021), the Central Government hereby constitutes the National Allied and Healthcare Advisory Council to advise the National Commission for Allied and Healthcare Profession, consisting of the following persons, namely: —

(i) Chairperson of the Commission — Chairperson;

(ii) all Members of the Commission — member, ex officio;

(iii) Principal Secretary dealing with medical education or his nominee from each State — member;

(iv) Chairperson of each State Council— member; and

(v) Principal Secretary dealing with medical education or his nominee representing each Union territory — member.

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KASTURBA MEDICAL COLLEGE
MANGALORE
(A constituent unit of MAHE, Manipal)

23RD NATIONAL CONFERENCE OF SOCIETY OF INDIAN RADIOGRAPHERS

IMAGINE

in association with

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

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

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

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

WELCOME Message

Namaskara from Mangaluru,

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

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

The theme, ***"Advancing Frontiers: Ushering in a New Era of Medical Imaging,"*** the conference will spotlight cutting-edge technologies, transformative ideas, and emerging trends shaping the future of healthcare. It's an opportunity to engage in thought-provoking discussions, attend insightful keynote sessions, and participate in interactive workshops.

Whether you are an academic, healthcare professional, student, or industry partner, IMAGINE 2025 offers a platform to connect, learn, and inspire innovation.

kmicon2025.com

We welcome you to Mangalore – the coastal city, the educational hub and famous for its cuisine, beaches and temples. Join us as we push the boundaries of medical imaging technology and drive progress in healthcare.

Organizing Committee...

Registration details (fees in rupees)

#	Category	Till 31st May 2025	From 1st June 2025 to 30th September 2025	Spot Registration
1	Students (BSc, MSc)	Rs. 2,360/-	Rs. 2,950/-	Rs. 5,900/-
2	Members of SIR (Faculty & PhD)	Rs. 2,950/-	Rs. 3,540/-	Rs. 5,900/-
3	Non-Members of SIR (Faculty & PhD)	Rs. 3,540/-	Rs. 4,130/-	Rs. 5,900/-
4	Radiology Faculty	Rs. 4,130/-	Rs. 4,720/-	Rs. 5,900/-
5	Radiology PG's	Rs. 3,540/-	Rs. 4,130/-	Rs. 5,900/-
6	Accompany	Rs. 2,950/-	Rs. 3,540/-	Rs. 5,900/-
7	Retired Technologist	Rs. 3,540/-	Rs. 4,130/-	Rs. 5,900/-
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IMAGINE

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Virtual and Augmented Reality in Medical Training and Patient Care

Sanchita Gupta, Wilson Hrangkhawl, Sikkim Manipal Institute of Medical College, Sikkim Manipal University.

Introduction

Virtual Reality (VR) and Augmented Reality (AR) represent transformative immersive technologies that have transcended their origins in entertainment to revolutionize healthcare. By creating simulated environments (VR) or enhancing real-world settings with digital overlays (AR), these tools are redefining medical training, diagnostics, and patient care. Their ability to bridge theoretical knowledge and practical application through realistic, interactive simulations has positioned them as critical innovations in modern medicine. As of April 2025, advancements in hardware, software, and artificial intelligence (AI) integration have accelerated their adoption, promising improved clinical outcomes, enhanced training methodologies, and elevated patient experiences.

Virtual Reality (VR) in Healthcare

VR immerses users in a fully digital environment via head-mounted displays (HMDs), obscuring the physical world and enabling interaction through controllers or motion-tracking systems. In medical training, VR provides a risk-free platform for practicing complex procedures, such as laparoscopic surgeries or cardiac interventions, with haptic feedback simulating real-world tactile sensations (1). For patient care, VR has emerged as a powerful tool for pain management and mental health therapy, immersing patients in calming virtual scenarios to reduce anxiety and support conditions like post-traumatic stress disorder (PTSD) (2).

Recent developments include the integration of VR with AI-driven simulations, enabling adaptive learning environments that respond to a trainee's performance in real time. In 2024, companies like Osso VR introduced platforms with enhanced realism, incorporating eye-tracking and biometric feedback to refine surgical precision (3).

Augmented Reality (AR) in Healthcare

AR overlays digital content onto the physical world, accessible via smartphones, tablets, or smart glasses. Unlike VR, AR enhances rather than replaces reality, making it ideal for real-time applications. In surgery, AR projects patient-specific data such as MRI or CT scans onto the operative field, improving accuracy during procedures like spinal fusion or tumor resection (4). In training, AR offers interactive visualizations, guiding students through anatomical dissections or procedural steps with real-time annotations.

By 2025, AR has advanced with lightweight, high-resolution smart glasses, such as the Microsoft HoloLens 3, which integrate seamlessly into clinical workflows. These devices now support multi-user collaboration, allowing teams to interact with 3D holograms during surgical planning (5).

Applications of VR in Medical Training and Patient Care

Surgical Training and Simulations: VR enables trainees to rehearse intricate surgeries in virtual operating rooms, reducing the learning curve for techniques like robotic-assisted surgery. Systems with haptic feedback mimic tissue resistance, enhancing realism (1). A 2023 study demonstrated that VR-trained surgeons outperformed traditionally trained peers in precision and speed during simulated procedures (6).

Patient Interaction and Diagnosis: VR simulations of patient encounters hone diagnostic and communication skills. Virtual patients exhibit realistic symptoms, allowing students to practice history-taking and decision-making, with immediate feedback improving clinical judgment (7).

Emergency Medicine and Mental Health: VR recreates high-stakes scenarios, such as mass casualty events, training teams in triage and coordination under pressure. In psychiatry, VR exposure therapy has proven effective for phobia treatment, with 2024 trials showing significant reductions in patient anxiety scores (2).

Medical Equipment Training: Professionals can master devices like ventilators or ultrasound machines in VR, minimizing errors in real-world applications (8).

Applications of AR in Medical Training and Patient Care

Enhanced Surgical Navigation: AR overlays critical imaging data during surgery, reducing reliance on external monitors. A 2024 trial in neurosurgery reported a 15% decrease in operative time using AR-guided tumor resection (9).

Patient Rehabilitation and Education: AR supports physical therapy with visual cues and gamified exercises, improving adherence rates. It also enhances patient understanding by overlaying 3D models of their conditions during consultations (10).

Remote Assistance and Telemedicine: AR empowers remote specialists to guide procedures via live annotations. During the 2023-2024 pandemic resurgence, AR-enabled rural clinicians to perform ultrasounds with expert oversight, reducing travel and exposure risks (11).

VR and AR in Telemedicine and Medical Imaging: VR telemedicine immerses patients and providers in shared virtual spaces, enhancing remote consultations. AR complements this by overlaying diagnostic data during video calls, improving assessment accuracy (12). In imaging, VR and AR transform 2D scans into interactive 3D models, aiding early detection of conditions like cancer. A

2025 study highlighted AR's role in improving radiologist accuracy by 20% through real-time anatomical overlays (13).

Challenges and Limitations

Despite their potential, VR and AR face hurdles. High costs often exceeding $50,000 for advanced systems limit adoption in low-resource settings (14). Technical issues, including latency and motion sickness, persist, though 2025 hardware updates have mitigated some concerns (15). Ethical challenges, such as ensuring patient data privacy in cloud-based VR/AR platforms, remain unresolved. Additionally, the lack of standardized protocols and long-term clinical validation hinders widespread acceptance (16).

Future Prospects

By 2030, VR and AR are expected to integrate fully with AI and 5G networks, enabling real-time, hyper-realistic simulations and global collaboration. Advances in wearable technology will reduce costs and improve ergonomics, while AI-driven analytics will personalize training and treatment plans (17). Emerging applications, such as VR-assisted gene therapy visualization and AR-guided robotic surgery, signal a future where these technologies are indispensable (18).

Conclusion

VR and AR are reshaping healthcare by enhancing training, diagnostics, and patient care through immersive, data-rich experiences. While challenges remain, ongoing innovations in hardware, AI, and telecommunications are poised to overcome these barriers. As clinical evidence mounts and costs decline, VR and AR will cement their roles as cornerstones of a more precise, accessible, and patient-centered healthcare system.

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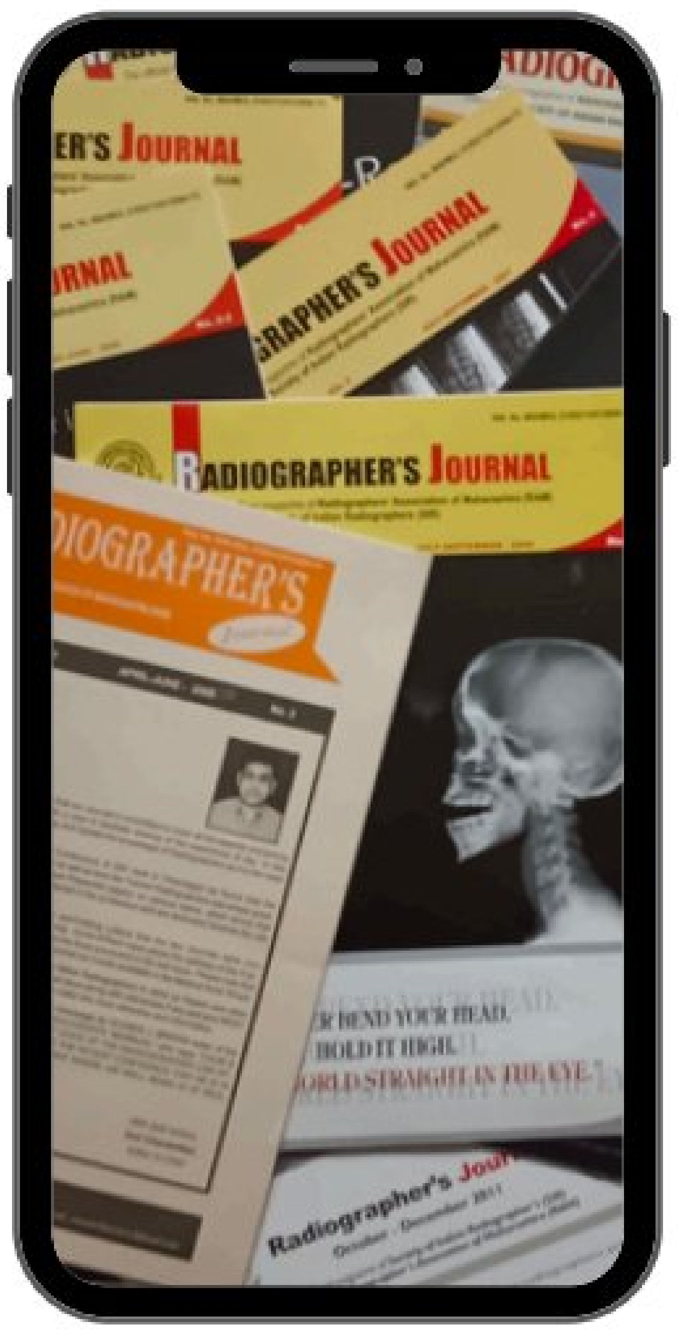


Ethics in Radiology: Incidental Findings, AI Bias, and Informed Consent

Firdous Nazir, Radiographic Technologist, Govt Medical College, Anantnag, Jammu & Kashmir

Introduction

Radiology has become one of the most powerful tools in modern medicine. It helps diagnose diseases early, guides treatment, and improves outcomes. But with this immense power comes ethical responsibility. In the rush to embrace technology — from high-resolution CT scans to artificial intelligence (AI) — radiologists are increasingly confronted with ethical dilemmas that were rare just a few decades ago.

How should incidental findings be handled? Is the use of AI in radiology free from bias? Are patients truly giving informed consent when they undergo scans that might reveal more than they expect? These are not hypothetical questions — they impact real patients every day.

Incidental Findings when to reveal and when not?

What Are Incidental Findings?

An incidental finding (also known as an "incidentaloma") is something unexpected that turns up on a scan — something unrelated to the reason the test was ordered. For example, a patient undergoing a CT scan for abdominal pain might be found to have a small lung nodule or a benign kidney cyst. These findings may be harmless, or they could indicate serious disease.

The Ethical Dilemma

Incidental findings put radiologists in a tough spot. On one hand, there's an obligation to report everything visible on a scan. On the other hand, sharing every minor abnormality can lead to unnecessary anxiety, further testing, and even harmful procedures.

Ethical Approach

A balanced and patient-centered approach is essential:

1. **Risk stratification:** Use guidelines (such as ACR white papers) to classify findings by risk level.
2. **Clear communication:** Radiologists should frame findings in terms that clinicians and patients can understand.
3. **Shared decision-making:** Engage patients in discussions about follow-up testing, especially when the risk is low.

AI Bias in Radiology: Technology's Double-Edged Sword

The Promise and Peril of AI

Artificial intelligence is rapidly transforming radiology. Algorithms can now detect lung nodules, analyze mammograms, predict stroke, and even prioritize critical scans. These tools offer speed, accuracy, and a potential reduction in diagnostic errors.

Where Does AI Bias Come From?

AI systems learn from data. If that data is incomplete, unbalanced, or unrepresentative, the algorithm may make skewed decisions. In radiology, this can lead to:

1. Under-diagnosis in underrepresented populations.
2. Overreliance on AI by clinicians.
3. Propagation of historical biases.

Ethical Response

To counter AI bias in radiology, professionals must take proactive steps:

1. Train algorithms on diverse data sets.
2. Ensure AI is used as a support tool, not a replacement.
3. Disclose training data sources and known limitations.
4. Establish clear accountability guidelines.

Informed Consent in Radiology: More Than Just a Signature

What Is Informed Consent?

Informed consent means that a patient agrees to a procedure or test after understanding its purpose, risks, benefits, and alternatives. In radiology, this is especially important when scans involve radiation, contrast, or potential incidental findings.

The Ethical Problem

In practice, informed consent in radiology is often rushed or superficial. Patients may sign forms without fully grasping what they're agreeing to. Ethical practice demands that we treat consent as a dialogue, not a formality.

How to Do It Right

1. Tailor consent to the procedure.
2. Explain incidental risks.
3. Use plain language.
4. Allow time for questions.

The Radiologist's Ethical Role: More Than a Technologist

Radiologists now play an active role in:

1. Patient communication.
2. Multidisciplinary decision-making.
3. AI oversight and validation.
4. Education and guideline development.

Institutional and Legal Considerations

Institutions must create clear protocols for incidental findings, validate AI tools before deployment, provide legally sound consent templates, and train staff on ethical practices. Legal regulations around privacy and data use are evolving and must be monitored closely.

Conclusion: Ethics as the Backbone of Trust

Radiology is at the cutting edge of medicine, but it must also lead in ethics. Whether it's handling unexpected findings, managing AI responsibly, or ensuring genuine informed consent, ethics forms the backbone of trust. Technology will keep advancing — but the essential human questions remain. Ethical practice isn't always easy, but it's what defines excellent care in radiology.

QUIZ to Recapitulate

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

1. For a patient with trauma head - the skull and cervical spine Lateral radiographs are done in which position ?

2. Which side of patient is raised for Left SI joint supine oblique view?

3. Stryker's view is recommended for patients with ?

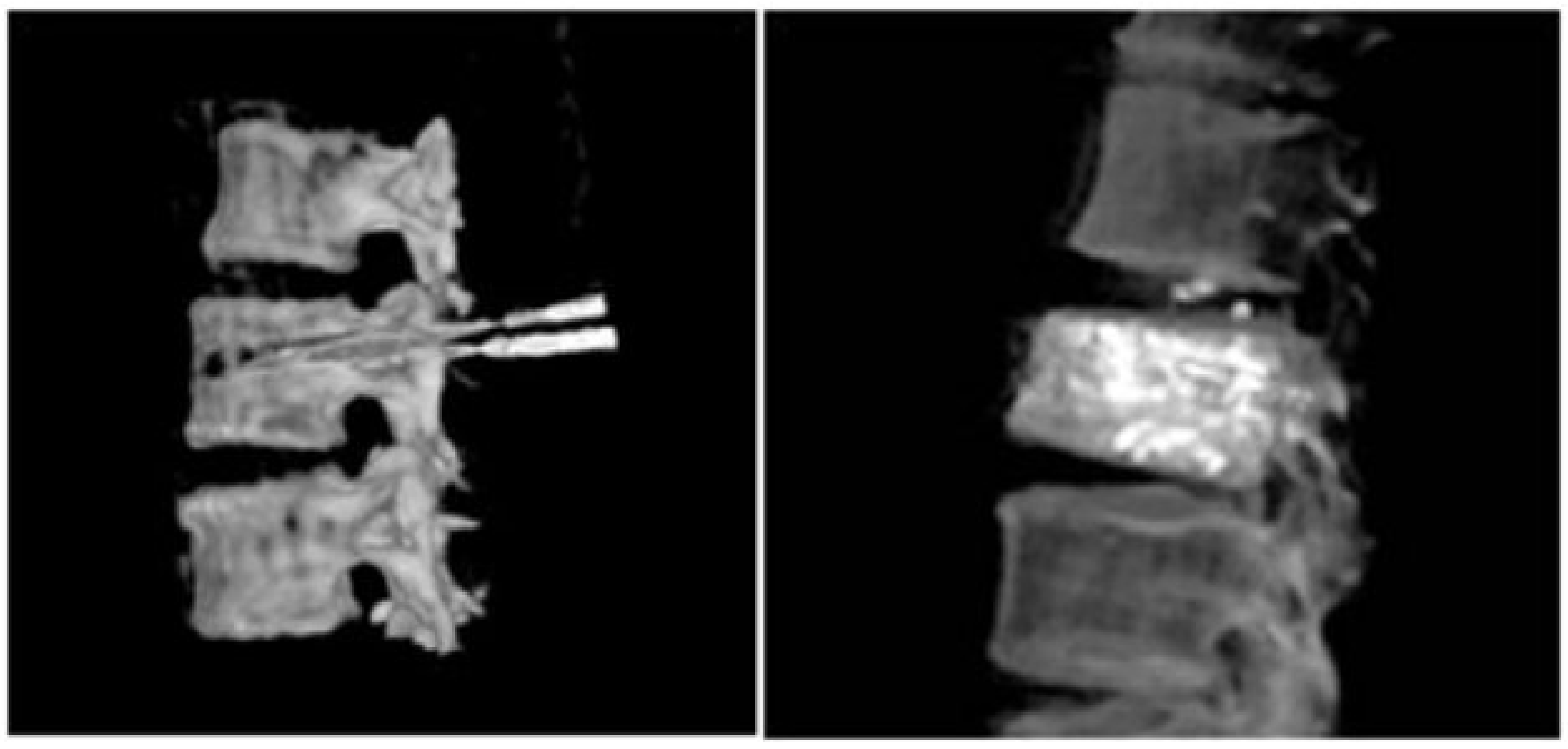
4. Macro radiography is done to obtain what ?

5. Out of CR and DR which system you will prefer for pediatric radiography ?

6. Which contrast medium is used for patient for CT head with recent (one Hour old) head injury ?

7. Where do we use Dysprosium-doped calcium sulfate ($CaSO_4:Dy$) ?

8. Identify the procedure:



9. Identify the technique and it's done for ?

10. Identify the object and its use

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

Answers for the Quiz - April 2025 issue

1. Picture Archiving and Communication System.
2. Films sensitive to particular color or wave length of light.
3. Telepaque was used as contrast medium for Oral Cholecystography (OCG).
4. Merchant view to look for articulation between patella and femur.
5. PA ulner deviation view for scaphoid (Fracure).
6. Retrograde urethrogram (RGU) to evaluate anterior urethra.
7. Lenior Transducer.
8. Recommended MPD for radiation worker as per ICRP is 50 mSv and as per AERB its 30 mSv.
9. Thermoluminescent Dosimeters (TLDs) are used for monitoring personnel radiation exposure.
10. Mass Miniature Radiography was primarily used for screening of Pulmonary Tuberculosis.

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

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Fundamentals of AI in Radiology – Part 3

Ramesh Sharma, Chief Technical Officer (Rtd.) NCI- AIIMS, Delhi.

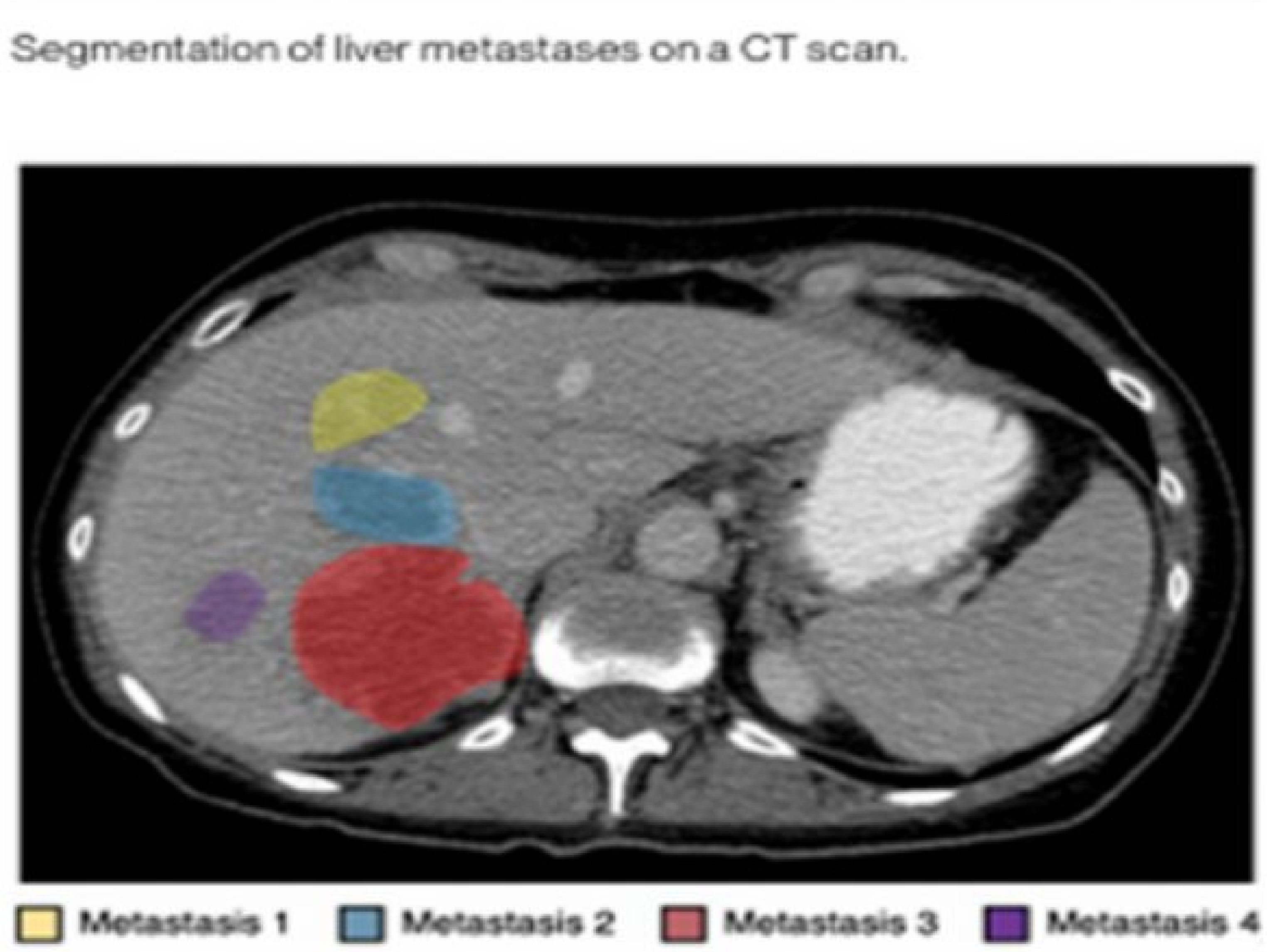
Deep Learning Applications: Many examples can be found on algorithms developed for different imaging modalities (MR, CT, X-ray, ultrasound).

Classification: train a model that is able to categorise images.

1. Binary classification: Normal vs abnormal chest X-ray without specification of a pathology.
2. Positive for a specific disease vs negative (e.g., classification of brain MRs in positive or negative for Alzheimer's Disease).
3. Anatomical planes (multi-class) classification: axial vs coronal vs sagittal.

Detection: the goal of these algorithms is to identify anatomical or pathological 'objects' within an image. Often the detected object can be highlighted with the use of bounding boxes (see image).

Examples include: Landmark detection for spinal surgery planning on X-rays / Lung nodule detection on CT scans / Kidney stone detection on CT scans / Liver lesion detection on CT scans.



Segmentation: task of dividing the pixels of an image into multiple regions or segments, where each segment corresponds to a particular object or class (eg. an organ pathology)

Examples: Prostate segmentation on MR / Liver segmentation on CT / Brain tumour segmentation on MR / Cardiac segmentation on CTA / Pulmonary tumour segmentation on CT / Stroke segmentation on CT/MR.
Image enhancement: deep learning models can be trained to perform tasks that improve image quality (or maintain image quality with lower dose) on medical images.

Applications:

1. Denoising: DL algorithms can learn to distinguish noise from the underlying signal. Noise can then be removed, while preserving the most important imaging features.

2. Super-resolution: DL models can learn to increase the spatial resolution (i.e., create high-resolution images from low-resolution images)

3. Artifact removal: removal of artifacts that impact image quality (such as motion artifacts, beam hardening).

4. Virtual contrast enhanced scans: DL models can be trained to simulate contrast-enhanced images based on a non-contrast study.

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Role of Robotics in Medical Imaging and Surgery

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Introduction

The advent of robotics in medicine marks a pivotal evolution in healthcare delivery. By addressing limitations inherent in traditional surgical and imaging techniques, robotic systems enhance precision, reduce human error, and streamline procedures (1). Today, robotics is integral to fields such as surgery, radiology, and interventional medicine, proving indispensable in both routine and complex scenarios.

The Role of Robotics in Medical Surgery

Robotic-assisted surgery represents a cornerstone of technological progress in operative care. Systems like the da Vinci Surgical System enable minimally invasive procedures with unparalleled dexterity and accuracy (2). Equipped with robotic arms and high-definition, three-dimensional visualization, these systems allow surgeons to perform complex operations with reduced trauma, minimal blood loss, and accelerated patient recovery (3).

Unlike human hands, robotic instruments offer an extended range of motion and eliminate hand tremors, making them ideal for delicate procedures. Their application spans multiple specialties, including gastrointestinal, gynecologic, cardiac, and neurological surgeries (4). Enhanced visualization and control have demonstrably improved clinical outcomes and lowered postoperative complications (5).

The Role of Robotics in Medical Imaging

In medical imaging, robotics enhances both diagnostic and interventional capabilities by improving image acquisition and analysis. Automated robotic systems produce high-resolution, three-dimensional reconstructions of anatomical structures, boosting diagnostic accuracy and aiding in precise lesion localization (6). These systems assist technologists by automating tasks requiring pinpoint accuracy, such as positioning equipment for computed tomography (CT) or magnetic resonance imaging (MRI), thus minimizing errors. Additionally, artificial intelligence (AI)-integrated robotic platforms support radiologists by interpreting intricate imaging datasets and flagging anomalies for review (7).

Robotics in Interventional Radiology

Robotics has profoundly impacted interventional radiology, enhancing safety and efficacy. In procedures like biopsies, fine needle aspiration cytology (FNAC), and endovascular interventions, robotic systems reduce radiation exposure for healthcare providers while improving needle placement accuracy via real-time 3D imaging guidance (8). Advanced platforms, such as the ANT-C system and IR-Robotics, excel in navigating guidewires and catheters through complex vascular anatomies. This precision enhances outcomes in procedures like stent placement and tumor ablation, reducing complication rates (9).

Benefits of Robotics in Medical Practice

Robotic systems deliver multiple advantages:

- **Enhanced Precision and Control:** Microscale accuracy exceeds human capabilities.
- **Reduced Invasiveness:** Minimally invasive techniques decrease patient recovery time and infection risk.
- **Improved Ergonomics:** Surgeons experience less physical strain during lengthy procedures.
- **Standardization:** Consistent procedural execution improves reliability and outcomes.

Challenges and Limitations

Despite their benefits, robotic systems face adoption barriers:

- **High Costs:** Acquisition, maintenance, and training expenses remain significant (10).
- **Learning Curve:** Proficiency requires extensive training for healthcare professionals.
- **Ethical and Regulatory Issues:** Autonomous systems raise concerns about accountability and oversight.
- **Integration Challenges:** Compatibility with existing hospital infrastructure can be problematic.

Future of Robotics in Medicine

The future of medical robotics promises further innovation, driven by AI, machine learning, and cloud computing. AI-enhanced systems are poised to enable autonomous decision-making, real-time diagnostics, and predictive surgical planning (11). Beyond current applications, robotics is expanding into pharmaceutical production, rehabilitation, telemedicine, and nanomedicine. Emerging technologies, such as robotic capsule endoscopy and microsurgical systems, are under development, alongside robotics for elderly care and physiotherapy (12). As these systems become more compact, cost-effective, and widely available, they are expected to transform healthcare delivery in both urban and rural settings.

Conclusion

Robotics has redefined medical imaging and surgery, delivering unprecedented accuracy, safety, and efficiency. While challenges like cost and implementation persist, advancements in AI, imaging technology, and interventional robotics signal a bright future for patient care. Sustained research and innovation will be critical to unlocking the full potential of robotics across medical domains.

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How Machine Learning is Changing the Medical Radiology Doctor's Role

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Introduction

In today's healthcare system "Radiology is been acting as a backbone" by offering better understanding in this field with the help of technologies like X-Rays, C-T scans, MRI, USG. After the introduction of advance technologies like Machine Language (ML) and Artificial Intelligence (AI) in this field, it is profoundly impacting the radiology, resulting in more in-depth studies and as a decision support to make the diagnosis and treatment planning more efficient and effective.

AI like deep learning (utilizes neural network), is really good at picking up useful information from medical images with higher accuracy and more efficiently, since these computer programme learns from tons of data and can classify complicated patterns and features that even doctors might miss. They can even give us a fresh idea of what image features are important for making good decisions. The conjugation of this technologies with the radiology is playing important role in complementing professional competence, making improvement in diagnosis, optimizing workflows, and enhancing patient care. In this article we will discuss how these technologies are playing important role in the advancement of the radiology by making things automatic by reducing the subtle errors by training the ML with thousands of datasets, the challenges which are associated with the conjugation of radiology with ML and also what are the future aspects of it and how the things will work in the future with better version of what it is today.

AI as a Catalyst for Change in Diagnostics

The Impact of Machine Learning in Image Analysis

With the integration of ML in radiology, it has resulted in more accurate analysis of medical images compared to radiology at its own. The sheer volume of images radiologist analyse daily makes it challenging for even a most skilled professionals to avoid overlooking subtle abnormalities due to fatigue or human limitation. However, AI algorithms, trained on vast datasets, can identify patterns and abnormalities in imaging scans more precisely. These systems are particularly effective in detecting early signs of diseases such as cancer, stroke, and fractures. For example, tools which are based on AI like deep learning networks are being used to analyse mammograms for early breast cancer detection. Studies have shown that with the use of AI in diagnosis of tumours, it has resulted in more accurate identification of malignant tumour compared to, or sometimes exceeding, radiologist. Similarly, AI-based CT scan analysis is being used to detect lung nodules, which can be indicative of lung cancer.

Furthermore, during image acquisition, AI-powered imaging systems have the potential to reduce unnecessary scans, optimize patient positioning, and improve how we understand what we see in the images. To illustrate, an AI-equipped MRI could identify a lesion and suggest adjustment to the scan sequence for the clearest possible view.

By implementation of Machine Language as an additional layer of verification it helps reduce diagnostic errors, minimizes false positives and negatives, and improves overall patient outcomes.

Decision Support and improved diagnosis leading to quality care

By application of AI-driven systems to support clinical decisions, we could see better quality care, imaging that runs more smoothly, and it does reduce the chances of accidents or mistakes in how examinations are planned. It acts as a powerful decision-support tool by comparing patient imaging data with large-scale databases of historical cases. AI-based decision support systems provide recommendations based on similar patterns, helping radiologists make more informed and data-driven decisions. For instance, AI-integrated platforms which have been design with an algorithm to analyse millions of medical images and provide insights into rare diseases that might otherwise be overlooked. This capability of AI model is very effective in diagnosing various conditions where early intervention is crucial, such as congenital disease, cardiovascular disorder, and neurological disorders (Alzheimer's disease).

Addressing Radiologist Burnout

The demand for radiology services has surged in recent years, leading to a significant workload for radiologists. Teaching new radiologists is satisfying for experienced doctors, but it can make them work bit slower. However, trainees are a big help: they look at scans, write drafts, get feedback, and send it for signing. This lets senior doctors focus on the important conclusions. Soon, AI assistants will give this same help to all radiologists. Using programs that see images and write text, the AI will spot findings (can find more than 60 different things in one single scan) and draft reports. The radiologist will then just review and sign. The AI can even learn from the changes doctors make to improve. Machine learning helps alleviate this burden by handling tedious and repetitive tasks, allowing radiologists to focus on the cognitive aspects of diagnosis and treatment planning. Which results in increasing job satisfaction for radiologists and come up with quality care.

Workflow Optimization and Efficiency

Radiologist often deals with large number and variety of cases daily, which may lead to fatigue and can also increase chances of errors.

ML- equipped architecture can optimize the workflow by automating the repetitive tasks which includes:

Virtual assistance: AI is becoming noticeable in healthcare through virtual assistants and chatbots. These tools, powered by AI, are helping with things like patient check-in, scheduling appointments, and even initial talks with patients. Virtual assistants can answer queries, give information about health issues, and make it simpler for people to use the healthcare system.

Image Triaging: AI can analyse all the cases that have been appointed and can prioritize the cases based on the severity i.e. it will prioritize the most severe case requiring immediate intervention, to ensure the safety of the patient.

Quantitative Analysis: The measurement of tumour sizes, organ anomalies, and disease progression can be more precisely assessed with the use of Machine Language (ML).

AI based report making: Since Machine Learning algorithm is trained with the tons of data set, so it can help in drafting initial reports with more accuracy, resulting in optimization of workload and speeds up diagnosis of cases that needs more attention.

Machine learning and AI are making radiology departments much more efficient by cutting down on mistakes, making diagnoses faster, and streamlining how things work. This lets radiologists spend more time on complicated cases that really need their skills, while AI handles the routine tasks. Since there will be enhancement in efficiency of the service due to optimized workflow, it results in cost reduction for the services, which can make good radiology care easier and cheaper for patients.

Ethical and Practical Challenges in AI Integration

Although integration of ML in medicine brings many benefits, it also comes with various challenges which complicates in equipping this technology, some of the challenges are:

Data Privacy and Security: Ensuring that the patient data is protected and being used ethically remains a major concern. Using AI in healthcare needs access to lot of personal data, so keeping it safe is the most important. So, to protect this data, institution have to use strong cybersecurity to protect these sensitive data from breaches and hackers. Also, AI systems need to follow rules like HIPAA in the US, which controls how personal health info is handled.

Need of supervision: Although AI assists in diagnosis, it is essential to validate the findings given by the AI, and handling of complex cases.

Algorithmic bias: AI models can inherit biases from training data, potentially leading to disparities in diagnosis and treatment recommendations. For instance, AI trained mostly on data from one race might not work as well for people of other races. It's really important to fix this bias in AI so that everyone gets fair and equal treatment in healthcare.

Regulatory and Legal Hurdles: In order to use the AI model in medical imaging, it requires strict validation and regulatory approvals for ensuring patient safety. So, to use the AI in healthcare and to protect patients right, clear standards and regulations need to be established.

Future Prospects of AI in Radiology

Till today, it is just the beginning of AI era. The future of ML in radiology has a great potential in the advancement of this technology. Some of the advancements of this technology are listed below:

AI-integrated Predictive Analytics: Future AI models show potential for predicting disease progression and treatment outcomes, allowing for more proactive healthcare interventions. This is a new area, but early research is promising. For example, machine learning can accurately estimate how brain tumours will respond to treatment. Also, researchers have used features in chest CT scans to predict how long patients might live by finding signs of their overall health in those scans.

AI based Telemedicine: AI equipped radiology could facilitate remote monitoring, to improve the availability of medical imaging services in areas where this service is still not available.

For Example, AI is also making care better in nursing homes and long-term care places. AI sensors can watch how older patients move, notice if they fall, and tell caregivers if someone needs help. By keeping an eye on patients all the time, AI helps make sure they get help quickly, which lowers the chance of serious problems.

Application of Radiomics and AI in Precision Medicine: Using machine learning to analyse lots of different kinds of patient information (like their background, scans, health history, lab results, and genes) could make healthcare much more personalized than just using images alone. To really make personalized medicine work, we need new computer methods to handle all the data needed to figure out what makes diseases unique to each person and how to best treat them.

Radiomics is a method used to pull out a lot of measurable details from radiology images. It's a new area in machine learning that turns these images into data that can be analysed for insights.

Prompt AI assistance: In future the AI system may work with the radiologist in real time, providing instant response and helps in decision making in small time limit. This results in efficient diagnostic.

Personalized interventions: AI could personalize the imaging protocol and treatment plans based on individual data, resulting in effective care.
As these advancements unfold, the role of radiologists will continue to evolve, with AI serving as a crucial partner in medical imaging and diagnosis.

Conclusion

Machine Learning is really bringing transformation in radiology, resulting in more accurate diagnosis, optimizing workflow, and making contribution in quality care. Think of AI not as a replacement for doctors, but as a super helpful assistant that makes their expertise even better. As tech keeps getting better, radiologists who jump on board with AI will be in a great position to give patients top-notch, fast, and personalized care. Not only thinking about the advantages of this technology. We've got to think about the ethical consideration. So, the rules should be strictly followed to avoid critical circumstances. Now, it's not smooth sailing. It's also worth considering how radiologists are trained to work effectively with the new skill set achieved with the integration of AI. But it is just a beginning, there are lot of ongoing researches, and development of technologies going on, so the teamwork between the field of radiology and AI is definitely going to keep evolving, resulting in it to be more precise and efficient.

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Hospital

Swoop Portable MR Imaging System: Brain Imaging for Efficient Clinical Decisions

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Abstract
A revolutionary development in brain imaging technology, the Swoop Portable MR Imaging System is intended to provide quick, easily accessible, and high-quality magnetic resonance imaging (MRI) at the point of care. Because the Swoop system is small, portable, and easy to use, it can be used in a variety of clinical settings, including emergency rooms, intensive care units, and rural or resource-constrained locations, in contrast to traditional MRI systems that need sophisticated infrastructure and specialised facilities. Clinicians may quickly make clinical judgements by using the system's rapid imaging capabilities and user-friendly interface to obtain diagnostic-quality brain images in a matter of minutes. This invention could help patients by speeding up diagnosis and treatment, especially for neurological disorders that require immediate attention, such stroke and traumatic brain damage. The Swoop system's distinctive blend of mobility, affordability, and user-friendliness makes it a revolutionary tool in contemporary neuroimaging, extending the application of MRI technologies and facilitating more effective, patient-cantered care.

Keywords: Portable MRI brain imaging, Swoop system, neuroimaging, patient care, stroke detection, traumatic brain injury, accessible imaging.

Introduction

The development of magnetic resonance imaging (MRI) in 1977 revolutionised medical diagnoses, however not everyone has benefited from it. Nowadays, large areas as well as the world lack easy access to MRI machines, creating huge gaps in the benefits of modern imaging. Cement barriers, specialised personnel, and significant costs surround magnetic resonance imaging (MRI) systems, which are generally restricted to specific hospitals or only accessible during certain hours of the day. When it is accessible, the technology usually necessitates a significant investment of resources and extended wait times for both patients and their physicians.

Brain imaging is now accessible to clinicians with the Swoop system, the only FDA-approved portable MR brain imaging system in the world that can provide imaging at numerous points of care in a range of professional healthcare settings. The Swoop system potentially allows for earlier treatment decisions, quicker discharges, and more effective use of hospital staff and resources by combining artificial intelligence with safe, ultra-low-field magnetic resonance, which does not have the siting and shielding requirements of conventional MRI systems. The Swoop system lowers the possibility of unfavourable events occurring during transportation by allowing patients to stay in a secure and comfortable environment with family and caregivers by their sides. The Swoop system can navigate through busy healthcare environments to a patient's bedside at many stages of care since it is made to fit into lifts and through entrances. The system is ready to scan in a matter of minutes after plugging it into a regular electrical socket and controlling it with an Apple iPad Pro mobile digital device.

In medical settings, the Swoop portable ultra-low-field MR brain imaging device is almost always portable. The Swoop system is small and very portable, making it perfect for brain imaging in paediatric hospitals, intensive care units, and other clinical settings (Fig 1). The magnet in the Swoop system is **64 mT.** The system weighs about **1,400 pounds** and is **33 inches** broad and **59 inches** tall. **T1, T2, FLAIR,** and **DWI** (with ADC map) are among the imaging sequences that are controlled by an Apple iPad Pro user interface.

Fig 1. Hyperfine swoop portable MR imaging

Simple to operate, the Swoop system allows:

Serial imaging: Track patients throughout time.

An accelerated learning curve: Because the system is easy to use, navigate, and provide safety training, more users can access it.

Portability: The Swoop system's powered drive wheels let it to pass through a typical door and move between patients with ease.

Location flexibility: A Swoop system operates on less than 900W of power and may be powered by a regular electrical socket, negating the need for a shielded room.

Cost-effective ownership: Purchasing and maintaining the Swoop system is substantially less expensive than a stationary conventional MRI equipment.

Secure image upload: To the HIPAA-compliant Hyperfine, Inc. Image Viewer or the facility PACS.

How does a portable magnetic resonance imaging device look like?

AI-powered software- The Swoop system enhances overall image quality and supports diagnostic confidence through the application of artificial intelligence algorithms (Fig 2 A-B).

1. Tablet controller. Exam setup, scan start, and image export are made easy with the use of a 12.9-inch Apple iPad Pro mobile digital device (included).

2. Power supply. After plugging into a standard wall outlet, the Swoop system can begin scanning in less than two minutes. The device is remarkably energy-efficient, consuming only 900 watts, or roughly the same amount as a coffee machine.

3. Gauss guard. An easy-to-use 5-gauss-line guard that rapidly extends and contracts ensures system security.
4. Transfer bridge. For simple patient loading at the bedside, the transfer bridge unfolds. To transfer the system to your subsequent patient, fold the bridge back up.
5. Shield door and sensors. Because of our shield door's unique design and continual "noise cancellation" of electromagnetic interference, operation doesn't require additional shielding.
6. Head coil. The multi-channel replaceable head coil is housed in a polycarbonate plastic that is clear, strong, and simple to clean.
7. Casters and Joystick. Thanks to its powered drive wheels and joystick, the Swoop system makes moving between patients simple.

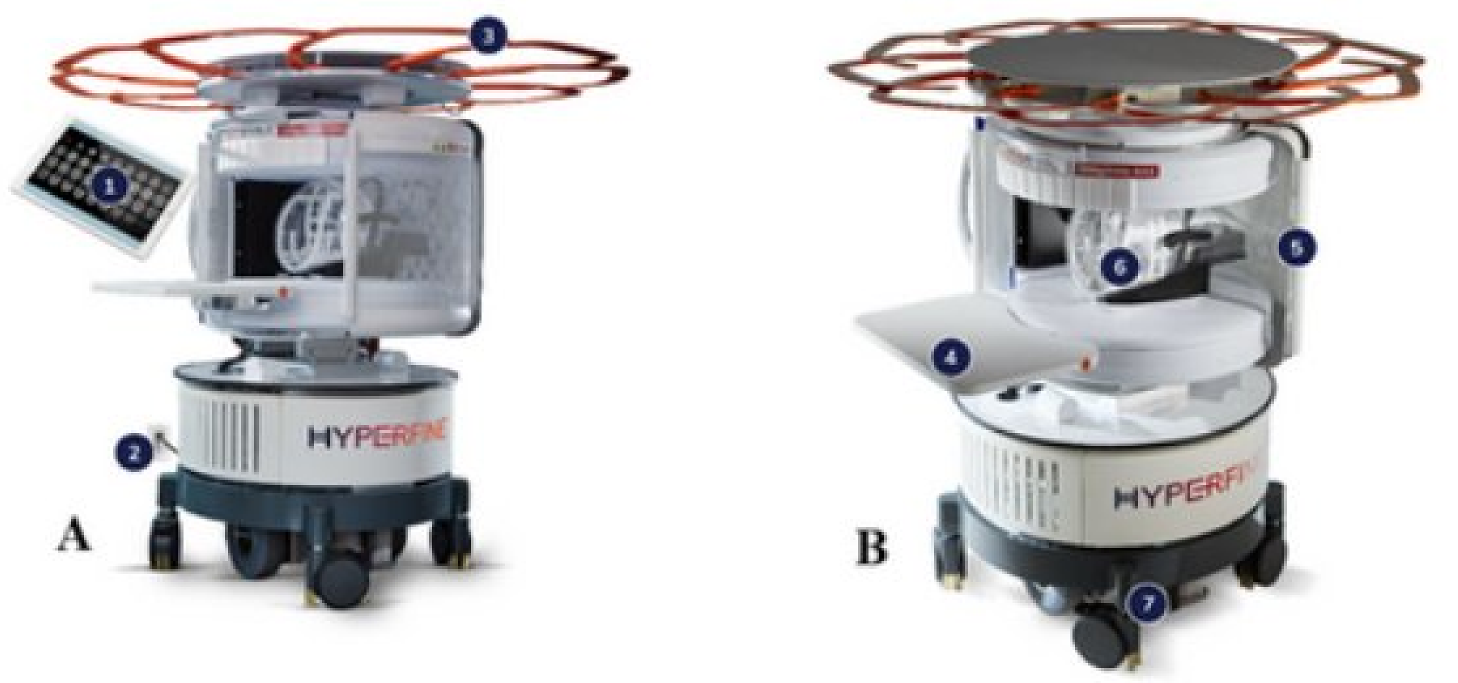

Figure 2A-B Components of portable MR imaging system.

Sequences

1. T1 (Standard) / T1 (Gray/White)
2. T2 / Fast T2
3. Fluid-Attenuated Inversion Recovery (FLAIR)
4. Diffusion-Weighted Imaging (DWI) and Apparent Diffusion Coefficient (ADC)[4] Maps

Your child will remain in bed the entire time once the Swoop system is configured, with their head resting in the clear "helmet" that is part of the apparatus. Harmonious tones will be generated by vibrations while the system gathers images for the scan. The duration of the scan may vary from thirty minutes to an hour, depending on the scan sequences that the doctor chooses. Clinicians might take the Swoop system out of your child's room after the examination. A physician will go over the results after examining the images.

Advantages of the Swoop system for treating paediatric hydrocephalus

Clinicians can bring the advantages of MRI for paediatric hydrocephalus treatment to your kid's bedside if they require brain imaging and the hospital has a Swoop system. This will spare your child from the ionising radiation of a CT scan and let you to stay by their side. Moreover, if your child struggles with stillness, the Swoop system's Fast T2 sequence (which takes less than three minutes) may lessen the need to sedate them for brain imaging.

Conclusion

With the Swoop system, physicians may now use brain imaging to support their clinical decision-making in a range of healthcare settings, addressing the accessibility challenges associated with traditional MRIs. The Swoop system is the only FDA-approved portable magnetic resonance imaging (MR) brain imaging technology that blends unique artificial intelligence with safe, ultra-low-field magnetic resonance. By reducing adverse events connected to intra hospital travel, the Swoop system may facilitate earlier treatment decisions, speedier discharges, and more effective use of staff and hospital resources.

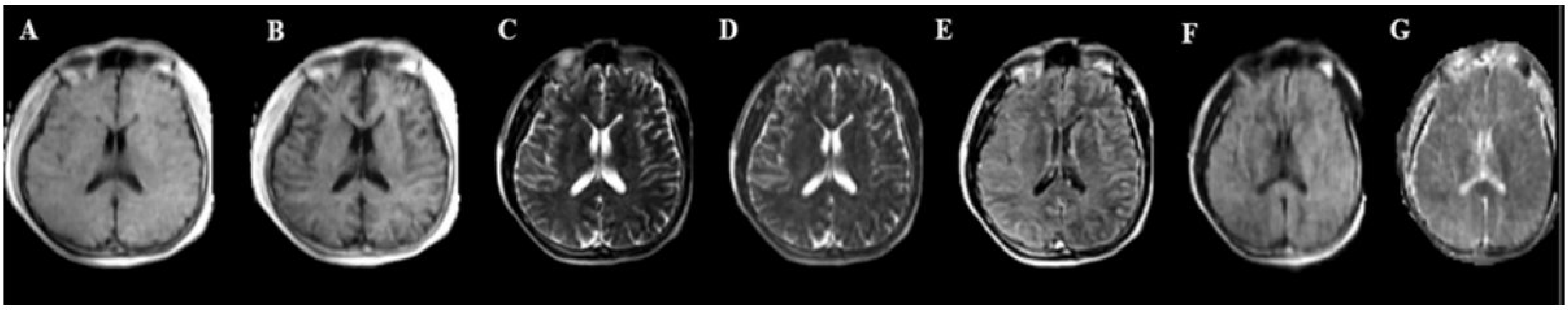

Figure 3 Sequences of portable MR imaging system. (A) T1 (Standard), (B) T1 (Gray/White), (C) T2, (D) Fast T2, (E) Fluid-Attenuated Inversion Recovery (FLAIR), (F) Diffusion-Weighted Imaging (DWI), (G) Apparent Diffusion Coefficient (ADC) Map

The Swoop Portable MR Imaging System and children: Expectations for the scan of your child.

Using the Swoop portable MR imaging equipment, an MR examination is completely non-invasive. All that your youngster needs to do is take anything off of their head and neck. The Swoop system's acoustic noise is far less than that of a traditional MRI system. It is also optional to wear hearing protection due to the low noise levels. You can also remain at your child's bedside and even hold their hand thanks to the Swoop system's open design and minimal magnetic field.

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AI as a New Frontier in Contrast Media

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Abstract

Medical imaging is undergoing a revolution thanks to artificial intelligence (AI), especially in the area of contrast media. With an emphasis on three main areas—dose optimization, contrast-free imaging, and improved image analysis—this paper examines AI as a revolutionary force in the use of contrast media. Although contrast chemicals have long been necessary to increase diagnostic precision, exposure must be kept to a minimum because to worries about negative reactions and patient discomfort. AI presents encouraging answers to these problems. AI-driven dose optimization predicts the optimal contrast dose for diagnostic-quality images by using patient-specific information such as demographics, body composition, and previous imaging. By minimizing contrast exposure while preserving or increasing diagnostic yield, this individualized approach lowers the risk of contrast-induced nephropathy and other negative outcomes. Additionally, AI is facilitating the advancement of contrast-free imaging methods. Convolutional neural networks (CNNs) and generative adversarial networks (GANs) are two examples of deep learning models that are trained to produce artificially improved contrasted images from non-contrast scans. In certain therapeutic situations, this novel method may be able to do away with the requirement for contrast agents, which would be advantageous for patients who have contraindications or a high risk of negative reactions. Additionally, AI improves contrast-enhanced image analysis. Artificial intelligence (AI) systems may identify tiny patterns and features in images that human viewers might overlook, improving the sensitivity and specificity of pathology detection. Additionally, by quantifying contrast enhancement patterns, these algorithms can offer important insights regarding the properties of tissues and the course of disease. Recent developments in AI-driven contrast media research are summarized in this study, along with the possible advantages and drawbacks of each strategy. It also discusses the difficulties of applying AI solutions in clinical settings, such as data collection, model verification, and legal issues. This article offers a thorough summary of how AI is changing medical imaging and enhancing patient care by examining AI as a new frontier in contrast media.

Introduction

Contrast chemicals are now essential components of contemporary medical imaging, greatly increasing the accuracy of diagnosis through better tissue distinction and anatomical structure visualization. Nevertheless, there are several restrictions on using these agents. Patient discomfort from intravenous injection and worries about possible negative effects, such as allergic reactions and contrast-induced nephropathy, have prompted efforts to reduce contrast exposure and investigate alternate imaging methods. Medical imaging is only one of the many scientific fields where artificial intelligence (AI) is becoming a game-changer. Artificial Intelligence provides creative answers to the problems outlined above in the context of contrast media. The three main areas of dosage optimization, contrast-free imaging, and improved image processing are the subject of this review, which examines AI as a new frontier in contrast media. AI-driven dose optimization uses patient-specific data to forecast the lowest effective dose needed to produce diagnostic-quality pictures, thereby personalizing the administration of contrast. This strategy could preserve or even increase diagnostic yield while lowering the chance of unfavourable outcomes. Additionally, by using deep learning models to create artificially enhanced contrast images from non-contrast scans, AI is facilitating the development of contrast-free imaging tools. For patients who cannot use contrast chemicals, this novel method presents a possible substitute. Lastly, By identifying subtle visual features and measuring contrast enhancement trends, artificial intelligence (AI) improves the interpretation of contrast-enhanced images, improving diagnostic precision and providing insights into the course of disease. This review summarizes current developments in these fields and emphasizes how AI has the potential to change how contrast media are used in medical imaging in the future.

Current AI utilization in radiology

Even though there are a number of widely used systems, the current state of AI use in radiology varies by institution. Many of the present AI systems are being used in limited ways as tools to improve the workflow of radiologists, which is in line with the more recent idea of "working with radiologists." A large number of these AI systems are classified as "micro-optimizations." Rather than completely automating the radiologic process, the main objective of micro-optimization algorithms is to support the radiologist in his or her everyday duties. Pixel-based optimizations and nonpixel-based optimizations are the two types of micro-optimizations. Radiologists can more effectively devote their time and energy to image interpretation, consulting, and patient care by employing AI to standardize and expedite time-consuming, repetitive, or non-interpretive duties.

AI for contrast dose optimization

AI-driven contrast dosage optimization seeks to minimize patient risk while optimizing diagnostic information through personalized contrast administration. Conventional contrast dosing frequently uses standardized procedures based on body surface area or

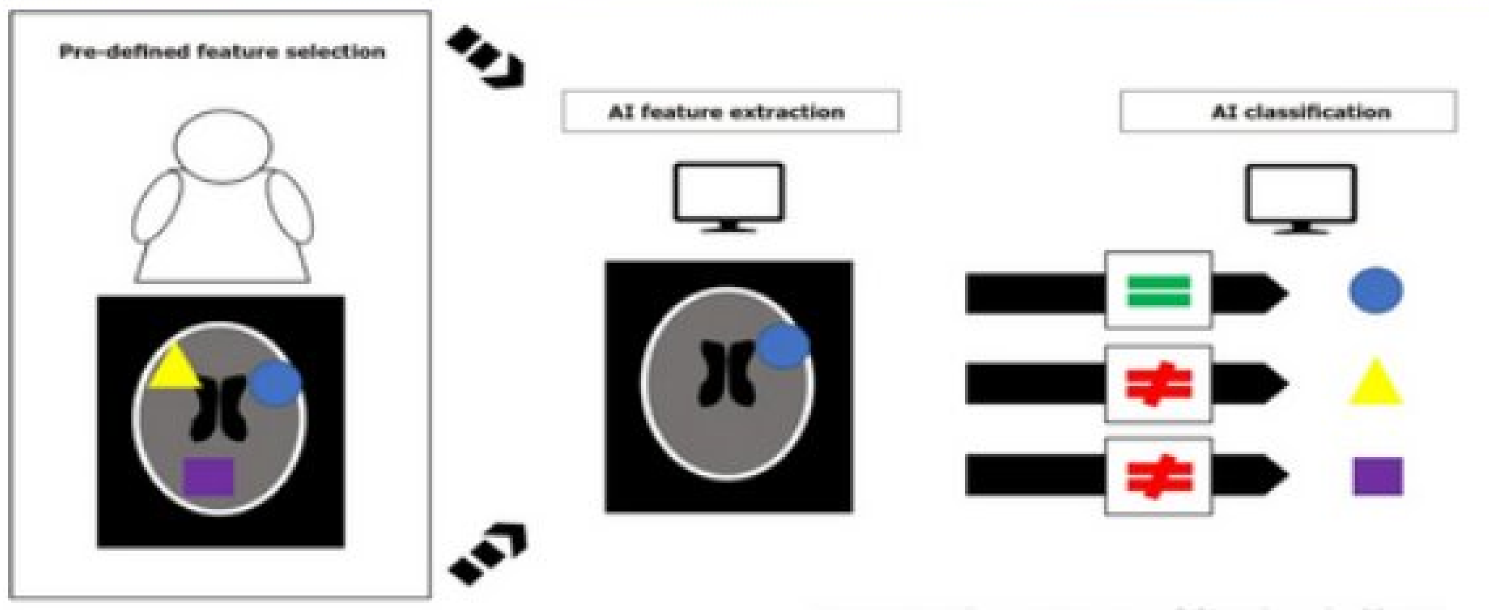

Figure 1Machine-learning requires pre-defined feature inputs which are then extracted in order to classify target image characteristics.

patient weight, which might not take into consideration individual differences in physiology, renal function, or particular therapeutic indications. By utilizing patient-specific data, such as demographics, body composition, medical history, and previous imaging examinations, AI provides a more sophisticated approach.

Large databases of patient data and related imaging results are used to train AI algorithms, which frequently use machine learning models. These models learn to forecast the ideal contrast dosage needed for each person to obtain images of diagnostic quality. By drastically lowering contrast exposure, this individualized strategy can lower the chance of negative outcomes like contrast-induced nephropathy and allergic responses.

In order to estimate pre-procedural dose modifications and possibly even real-time dose adjustments during the imaging operation based on image quality feedback, a number of methodologies are used, including predictive modelling. By lowering the needless use of contrast agents, this improves patient safety while also increasing cost-effectiveness. The effectiveness and safety of AI-driven contrast dose optimization across a range of imaging modalities and therapeutic applications are being further validated by ongoing research and clinical trials.

AI for contrast-free imaging

Synthetic contrast-enhanced images can be created from non-contrast scans thanks to AI, which is transforming the potential for contrast-free imaging. Specifically, generative adversarial networks (GANs) and convolutional neural networks (CNNs) are deep learning models that have been trained on paired datasets of contrast and non-contrast images. These models can forecast how tissues might appear with contrast enhancement because they understand the intricate links between the two image kinds. For patients who cannot use contrast chemicals, such as those with allergies or renal impairment, this approach has enormous promise. Patients who are undergoing repeated imaging treatments and those who are at high risk of adverse responses can benefit from it. AI-powered contrast-free imaging is still a developing subject, but it has showed promise in a number of applications, including as abdominal, brain, and cardiovascular imaging. The goals of ongoing research are to increase these models' robustness and accuracy, broaden their therapeutic usefulness, and solve any potential drawbacks.

AI for enhanced image analysis with contrast

AI greatly improves contrast-enhanced image analysis by automating difficult processes and offering insights that are not possible with human intelligence. Diagnoses can be made early and with greater accuracy thanks to deep learning models' exceptional ability to identify small lesions and describe them using texture, contrast enhancement patterns, and other picture attributes. For identifying tiny cancers or minute variations in tissue perfusion, this is especially useful. AI makes it possible to precisely quantify contrast enhancement as well. Tissue perfusion, vascularity, and other physiological characteristics can be objectively measured by AI algorithms that analyse dynamic changes in signal intensity over time. The prognosis, treatment response, and illness severity are all aided by this quantitative data.

Image analysis is further improved by the integration of AI and radiomics. Many quantitative features are extracted from photos using Radiomics and then fed into AI algorithms. This method improves diagnostic precision and tailored therapy by applying extensive information about tissue properties and disease processes to contrast-enhanced pictures.

AI also improves the consistency and dependability of diagnostic evaluations by lowering intra- and inter-reader variability. AI tools reduce subjective interpretation by offering objective analysis, which results in more consistent diagnosis from various radiologists. By incorporating these AI technologies into clinical processes, image analysis is streamlined, productivity is increased, and patient care is eventually improved.

Broader consideration:

Regulatory Landscape for AI in Medical Imaging

With important organizations like the FDA in the US and the EU leading the pace with their AI Act and MDR, the regulatory environment for AI in medical imaging is changing quickly. The special features of AI-based software as a medical device (SaMD) are covered by these rules. Clinical validation is one of the main priorities. To demonstrate safety and efficacy for their intended purpose, AI algorithms must pass stringent testing, which frequently calls for comprehensive clinical trials and empirical data. Regulators stress the importance of broad and representative training datasets to guarantee generalizability and prevent biased results because data bias is a serious risk. Transparency and explain ability are also becoming more significant. It is essential for regulators and medics to comprehend how AI makes its decisions. AI applications are categorized by the FDA using a risk-based methodology, which places more stringent criteria on devices that pose a greater danger. Predetermined Change Control Plans (PCCPs), which specify how modifications will be handled and verified, are crucial for adaptive AI that learns continuously. After deployment, real-world performance monitoring is advised to gauge AI efficacy. Data privacy and cybersecurity are critical. There are still issues with addressing ethical issues, establishing assessment metrics, and keeping up with the quick changes in technology. The regulatory environment is becoming clearer in spite of these obstacles, offering a framework for the ethical development and application of AI in medical imaging.

Ethical consideration and bias in AI algorithm

When using AI for medical imaging, ethical issues are crucial, especially when it comes to algorithmic prejudice. Although bias can originate from a number of sources, it mostly occurs in the training data. An AI model may perform differently across subgroups, resulting in differences in diagnosis and treatment, if the data used to train it is not representative of the target population (for example, overrepresentation of particular demographics or illness severities). This may exacerbate already-existing health disparities or possibly lead to the development of new ones. When applied to photographs from a different ethnic group, for instance, an AI algorithm that was trained largely on images from that group may perform less accurately. Careful data curation is necessary to address bias and guarantee representative and diverse datasets. Furthermore, in order to detect and lessen any biases, continuous monitoring and assessment of AI performance across various subgroups is essential. Building confidence and guaranteeing the moral application of AI in medical imaging also depend on transparency in algorithm development and implementation.

Cost-Effectiveness and Implementation Challenges

AI in medical imaging offers both considerable implementation hurdles and cost-effectiveness opportunities. Regarding cost-effectiveness, AI has the potential to lower healthcare expenses in a number of ways. By minimizing the use of contrast agents, AI-driven dose optimization lowers material costs. By increasing diagnostic accuracy, enhanced image analysis might lessen the necessity for invasive procedures or follow-up exams. In the long term, streamlined processes made possible by AI automation can help save workforce expenses and increase efficiency. Better patient outcomes and more efficient therapies can result from earlier and more precise diagnosis, which also lowers costs.

Nonetheless, there are a number of implementation issues that must be resolved. AI hardware and software might come with a hefty upfront cost. AI tool integration into current clinical workflows can be challenging and necessitate major improvements to IT infrastructure. It can be costly and time-consuming to gather and curate data for AI model training. Additionally, for deployment to be successful, staff training on the usage and interpretation of AI outputs is essential. The complexity and expense are further increased by regulatory obstacles and the requirement for continuous validation and monitoring. A comprehensive cost-benefit analysis that considers both immediate expenditures and long-term savings is necessary for the effective application of AI in medical imaging.

Future directions and emerging trends

In contrast to media, artificial intelligence has a dynamic future, with a number of new trends influencing its course. The creation of increasingly complex AI models that can incorporate multi-modal input is one such avenue. More comprehensive and individualized diagnostic evaluations will be possible by integrating imaging data with clinical data, genetics, and patient history. The move toward more explainable AI (XAI) is another trend. Building trust and guaranteeing appropriate clinical usage of AI requires a knowledge of how these algorithms arrive at their results as it becomes more integrated into clinical decision-making. The goal of XAI approaches is to increase the transparency and interpretability of AI decision-making processes. Another fascinating area of exploration is real-time AI analysis during imaging operations. AI systems that can give real-time feedback during scans may be able to optimize image capture parameters, allow for dynamic dosage modifications, and even direct interventional treatments. Furthermore, without exchanging private patient information, federated learning techniques will enable AI models to be trained on a variety of datasets from various institutions. This method can solve privacy issues while enhancing the robustness and generalizability of AI models.

Lastly, it is anticipated that AI will be included into larger healthcare ecosystems. To offer smooth and all-encompassing assistance for clinical decision-making, AI technologies will be progressively integrated with radiology information systems (RIS), electronic health records (EHRs), and other healthcare IT systems.

Conclusion

The use of contrast media in medical imaging is about to undergo a revolution thanks to artificial intelligence, which will provide creative answers to persistent problems and open the door to more individualized and efficient patient care. The three main topics of dosage optimization, contrast-free imaging, and improved image analysis have been the emphasis of this review's exploration of AI as a new frontier in contrast media.

By using patient-specific data to reduce contrast exposure while preserving or enhancing diagnostic quality, AI-driven dose optimization provides a customized method of administering contrast. This approach could lower the chance of unfavourable outcomes, enhance patient comfort, and save money. A paradigm change has occurred with the introduction of AI-powered contrast-free imaging methods, which provide a good substitute for individuals who are allergic to contrast agents or who are at high risk of negative reactions. AI increases access to diagnostic imaging for a larger population by producing artificial contrast-enhanced pictures from non-contrast scans, hence removing the requirement for contrast administration in some clinical circumstances. The interpretation of contrast-enhanced pictures is also greatly improved by AI, which makes it possible to quantify contrast enhancement patterns, identify minor anomalies, and provide objective measurements of tissue properties. These developments enhance the precision of diagnoses, enable individualized treatment planning, and enhance patient outcomes. Even while there has been a lot of development, there are still a number of obstacles. To fully utilize AI in contrast media, it is imperative to address potential biases in AI algorithms, ensure regulatory compliance, and overcome implementation challenges. The goal of ongoing research and development is to enhance AI models' generalizability, accuracy, and robustness while also facilitating their smooth integration into clinical workflows. To sum up, artificial intelligence is changing the way contrast media are used in medical imaging. AI is ushering in a new era of individualized, effective, and efficient patient care by improving image processing, enabling contrast-free imaging, and optimizing dosage. To fully realize AI's disruptive potential in this subject, further research, teamwork, and responsible application are required.

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AI-Powered Image Stitching in Digital Radiography

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Abstract

Digital radiography's AI-powered image stitching technique uses AI algorithms to flawlessly merge several overlapping X-ray images into a single, bigger image. Compared to conventional approaches, this cutting-edge methodology has several advantages. AI-powered stitching algorithms can precisely recognize and align anatomical features, reduce distortions, and enhance image quality by leveraging machine learning. As a result, the workflow becomes more efficient, the radiation dose is decreased, and the diagnostic accuracy is improved. AI can also be used to tailor imaging techniques, aid in diagnosis, and enable 3D reconstruction. AI-powered image stitching has enormous potential to transform digital radiography and enhance patient care, even though there are still obstacles to overcome, such as the requirement for huge datasets and guaranteeing the explainability of AI algorithms. AI-powered stitching is becoming more and more common in clinical practice in fields including whole-body imaging, scoliosis assessment, and orthopaedic imaging. It is transforming the collection and interpretation of radiographic images, improving patient outcomes and enabling more precise diagnosis.

Introduction

AI-powered stitching in digital radiography is revolutionizing medical imaging by improving the accuracy and efficiency of producing detailed radiography images. Large anatomical regions, such the complete spine or full-length limbs, can be captured with this technology's ability to seamlessly merge numerous overlapping radiography images into a single, coherent image. Image artifacts or misalignment may arise from the lengthy and error-prone process of traditional manual image stitching. By employing complex algorithms that identify and align shared characteristics across numerous images, AI-powered stitching gets around these issues. Higher quality and more dependable images can result from these algorithms' ability to recognize anatomical markers like bones and joints and guarantee exact alignment. The ability of AI-powered stitching to lower radiation doses for patients is one of its main benefits. The technology can reduce the number of exposures required by optimizing image acquisition protocols, as opposed to needing multiple exposures to cover a large area. This not only improves patient safety but also streamlines the imaging process. Additionally, stitching driven by AI improves workflow efficiency of radiologists and technologist. Radiologists can concentrate more on diagnosing and analyzing the pictures since it lessens the amount of manual labour needed for image stitching. Additionally, the technology aids in standardizing the stitching procedure, guaranteeing uniform image quality in various scenarios. Overall, AI-powered stitching in digital radiography represents an important development in health care imaging, offering improved image quality, improved patient safety, and improved accuracy in radiographic procedures.

The Radiology Concept of Image Stitching:

Slicing or segmenting images is a common practice in medical imaging, especially with modalities like CT, MRI, or ultrasound. To gain a complete picture of the organ or bodily area, these slices or pictures must be joined or "stitched" together. Manual intervention or simple software algorithms may be used in traditional stitching approaches, which can be laborious, prone to mistakes, or have limited capacity to handle intricate variations in image quality, alignment, or artifacts.

The Process of Image Stitching

The two primary phases in image stitching are usually registration and blending.

1. Registration: Several images taken at multiple points or positions are aligned using registration. To guarantee that overlapping sections match precisely, this step is essential. There are several algorithms used for registration:

a. Featured methods: These techniques locate important elements in pictures (such as corners and edges) and utilize them to align pictures. Common methods include:

1. Harris Corner Detection
2. Scale-Invariant Feature Transform (SIFT)
3. Speeded-Up Robust Features (SURF)

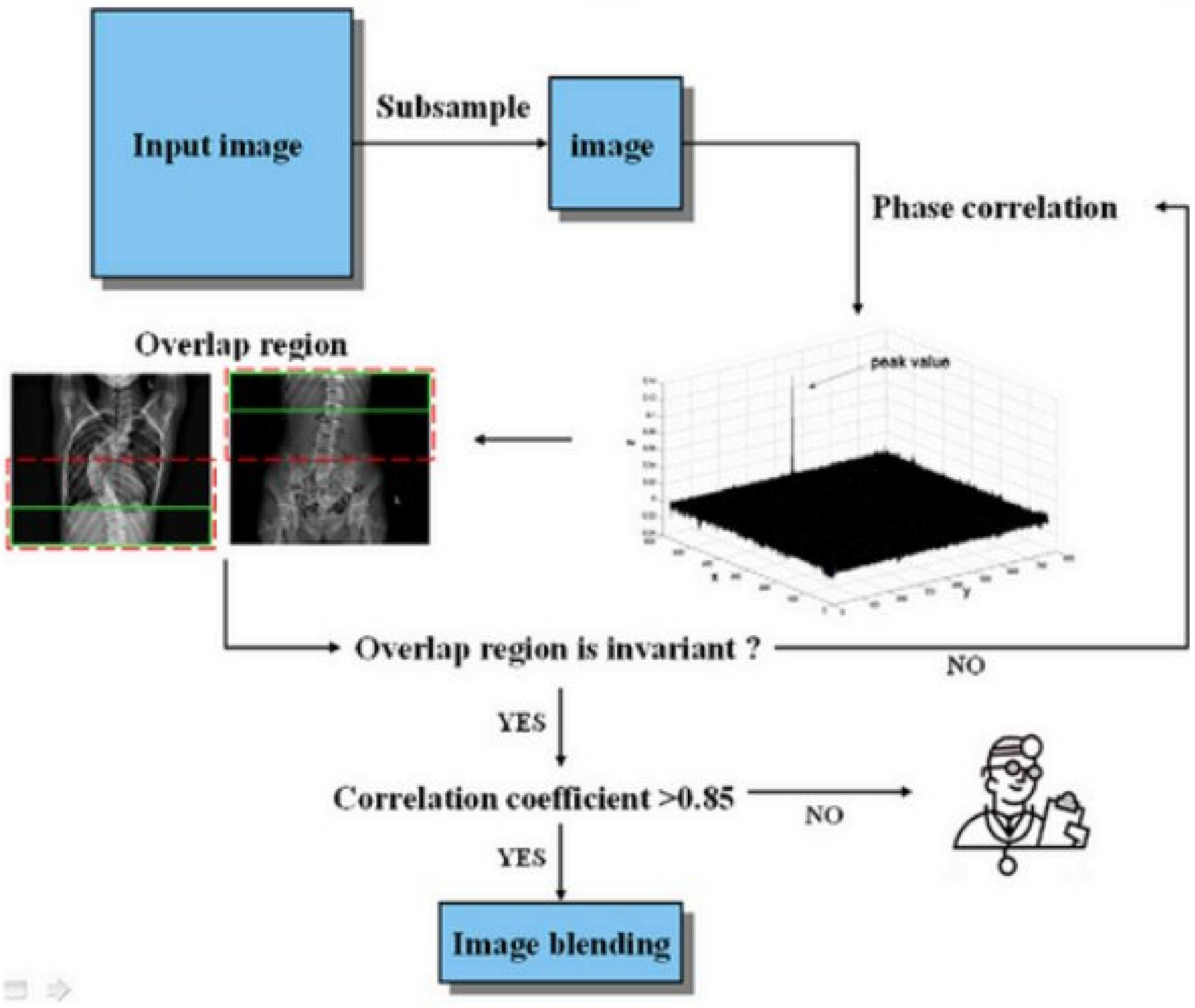
By examining how image intensity varies in various directions, the Harris Corner Detector can locate corners in an image. Finding unique features in a picture that are resistant to changes in rotation and scale is possible with SIFT (Scale-Invariant Feature Transform).For real-time applications, SURF (Speeded-Up Robust Features) is a quicker SIFT variant.

b. Direct Method: Pixel-to-pixel matching is used in direct methods to increase image similarity. They can be computationally demanding even if they are frequently more accurate.

2. Blending: Images are combined into a seamless final image through blending once they have been registered. In order to remove obvious seams and provide a seamless transition between images, this procedure entails modifying pixel intensities along the borders.

AI and Machine Learning in Image Stitching

Digital radiography's AI-powered image stitching technique uses machine learning algorithms to flawlessly merge several overlapping X-ray images into a single, bigger image. By using advanced AI algorithms, this



Figure; Process of Image stitching

solution outperforms conventional approaches. AI algorithms are highly skilled at feature extraction, accurately recognizing and aligning anatomical landmarks. By enabling accurate picture registration, this strong feature matching reduces distortions and artifacts brought on by patient movement or equipment constraints. In addition, artificial intelligence improves image quality through noise reduction, contrast optimization, and the reduction of stitching artifacts like seams. As a result, anatomical features may be seen more clearly, which helps identify minute anomalies and increases diagnostic precision. AI reduces human interference and increases efficiency by automating the entire stitching process. This reduces the possibility of human error while simultaneously streamlining process, producing more dependable and consistent outcomes.

Applications in Radiology

1.Panoramic Stitching in Cone Beam Computed Tomography (CBCT): Despite offering 3D imaging, CBCT frequently has field of view constraints. Multiple CBCT scans taken from various angles can be seamlessly combined using AI-powered stitching techniques, thereby increasing the field of view. For intricate surgical planning and the evaluation of major lesions, this enables thorough view of extensive anatomical regions, such as the complete craniofacial skeleton. By reducing artifacts and improving spatial resolution in the stitched volume, AI systems can maximize image quality. Visualizing minute anatomical details, such the complicated anatomy of the nose and sinus cavities or the delicate components of the temporomandibular joint, might be very helpful with this.

2.Hand X-Ray Image Stitching: AI-powered image stitching improves hand X-ray collection and interpretation. It gets beyond the drawbacks of single-view radiography by merging several overlapping images, giving a more thorough picture of the hand's anatomy.

Even with slight patient movements or differences in picture acquisition, AI algorithms are highly skilled at recognizing and matching important anatomical landmarks (such as bone borders and joints) across the overlapping images, guaranteeing precise registration.

3.Chest Radiography: Larger anatomical areas, such the entire thorax, can be acquired through stitching and combined into a single composite image. This is essential for ailments that might not be fully visible on a single ordinary chest X-ray, such as pneumothorax, pleural effusions, and specific lung disorders. Stitching can enhance the visibility of modest abnormalities that may be obscured by individual images, such as tiny nodules, faint fractures, and fine lung marks, by integrating numerous images.

4.Scoliosis Diagnosis: Medical practitioners can make more precise diagnoses of disorders like scoliosis by stitching together several X-ray pictures of the spine.

Advantages of AI in Stitching

1.Efficiency and Speed: AI systems can process vast amounts of pictures and stitch them together far more quickly than conventional techniques, saving radiologists time when stitching by hand.

2.Improved Accuracy: AI models are able to align and stitch images with more precision, reducing the possibility of errors that may arise from hand stitching or more conventional software-based techniques. Improved diagnosis accuracy results from this, especially in complex cases.

3.Handling Complex Data: AI-powered systems can handle increasingly complicated datasets, such multi-modal or multi-planar pictures, which are images from several orientations or modalities, such as CT and MRI, and stitch them together seamlessly.

4.Reduction of Human Error: When working with large datasets, manual stitching might cause errors. AI technologies increase the image's overall quality and dependability by lowering the possibility of misalignment or improper stitching.

Main challenges in medical image stitching

The primary difficulties in medical picture stitching include a range of operational and technical problems that may impact the precision and usefulness of the final images. The following are the main issues noted:

1. Parallax-errors

When images are taken from several angles, parallax errors occur, which results in things appearing in various locations throughout the images. In surgical settings, where equipment and organs may move and cause ghosting or misalignment in the stitched output, this is especially problematic.

2. Variations in Illumination

Inconsistencies in brightness and hue can result from variations in the lighting conditions used to capture the photographs. It may be challenging to produce a smooth final image free of obvious seams or artifacts as a result of these variances, which might complicate the blending process.

3. Geometric Deformations

Accurate image registration may be hampered by geometric modifications, such as those brought on by patient movement or anatomical changes during treatments. To properly align photos due to these deformations, complex techniques are required, which might be computationally demanding.

4. Problems with Image Quality

Low contrast, excessive noise levels, and poor resolution are common problems with medical images. These elements may cause the stitched image's quality to deteriorate, making it more difficult to spot important anatomical details. Longer acquisition times are usually needed to improve image quality, which raises the possibility of motion artifacts.

5. Complexity of Computation

Stitching high-resolution medical radiographs can have enormous processing needs, necessitating sophisticated hardware and algorithms. This intricacy may restrict real-time applications in healthcare contexts and result in lengthier processing times.

6. Insufficient Standardization

Medical image stitching currently lacks a well-recognized procedure, which causes variations in methods and results amongst various institutions. It may be difficult to compare outcomes or successfully integrate systems due to this lack of uniformity.

7. Challenges in Data Management

Effective processing and storage solutions are needed for the massive datasets produced by medical imaging. Effectively managing these datasets presents logistical issues but is essential for prompt diagnosis and treatment planning.

8. Combining Different Modalities

Due to variations in imaging principles and resolutions, stitching pictures from several modalities (such as CT and MRI) adds further registration and alignment challenges.

Conclusion

AI-powered image stitching is a major development in medical imaging technology. AI improves the precision and effectiveness of diagnostic processes by automating the process of merging many images, enabling medical practitioners to acquire thorough views of intricate anatomical systems with little manual intervention. This technology has a wide range of uses, from preoperative planning to diagnosing diseases like scoliosis, which eventually improves patient outcomes. We should expect even more advancements in feature identification, real-time processing, and blending approaches as AI algorithms develop further, which will significantly increase the quality of stitched photos.

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Dark Field Computed Tomography

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Introduction:
X-ray computed tomography (CT) is one of the most used three-dimensional medical imaging modalities today. It has been refined over several decades, with the most recent innovations including dual-energy and spectral photon-counting technologies.

It has been discovered that wave optical contrast mechanisms beyond the presently used X-ray attenuation offer the potential of complementary information, particularly on otherwise unresolved tissue microstructure, one such approach is "Dark-Field Imaging."

"Dark Field Computed Tomography" is a form of computed tomography imaging technique which uses small angle scattering x-ray photons and wave properties of x-rays to form dark field images.

Principle:
In dark field imaging we apply Talbot – Lau Interferometry principle.

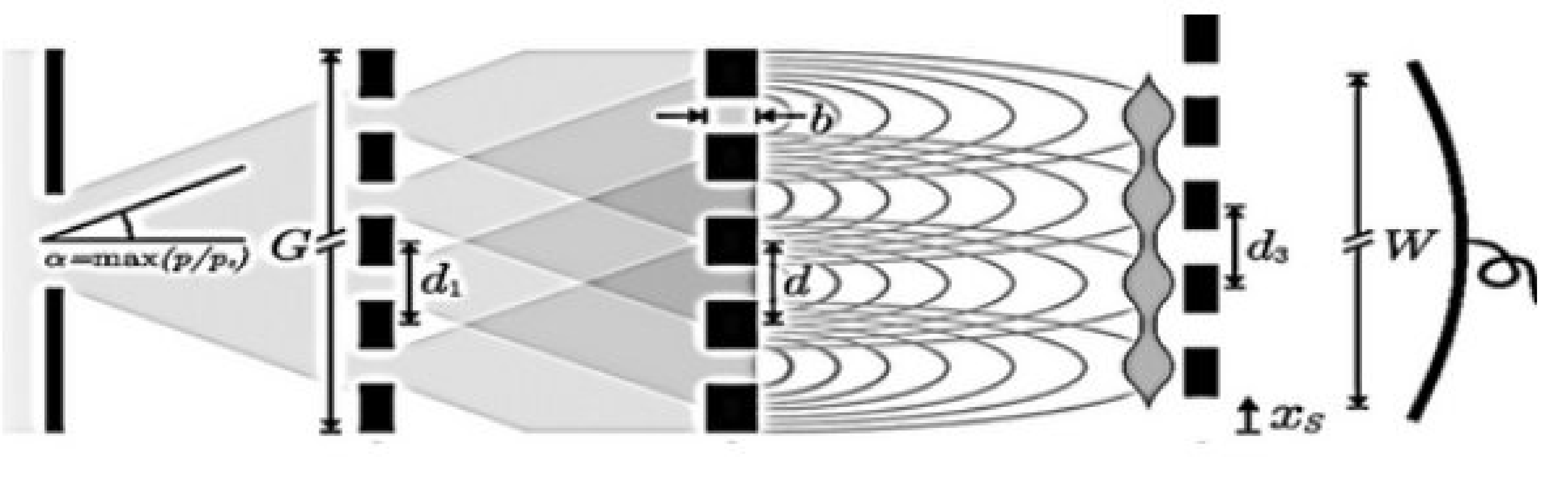
"Talbot-Lau interferometry" generates fringe patterns the period of which is largely unaffected by the de Broglie wavelength.

Talbot-lau interferometry Works on "wave optics mechanism"; The wave nature of light propagation depends on the medium through which it travels.

Objective:
Based on Talbot-Lau Interoferometry x-ray diffraction takes place and results in the formation of darkfield images.

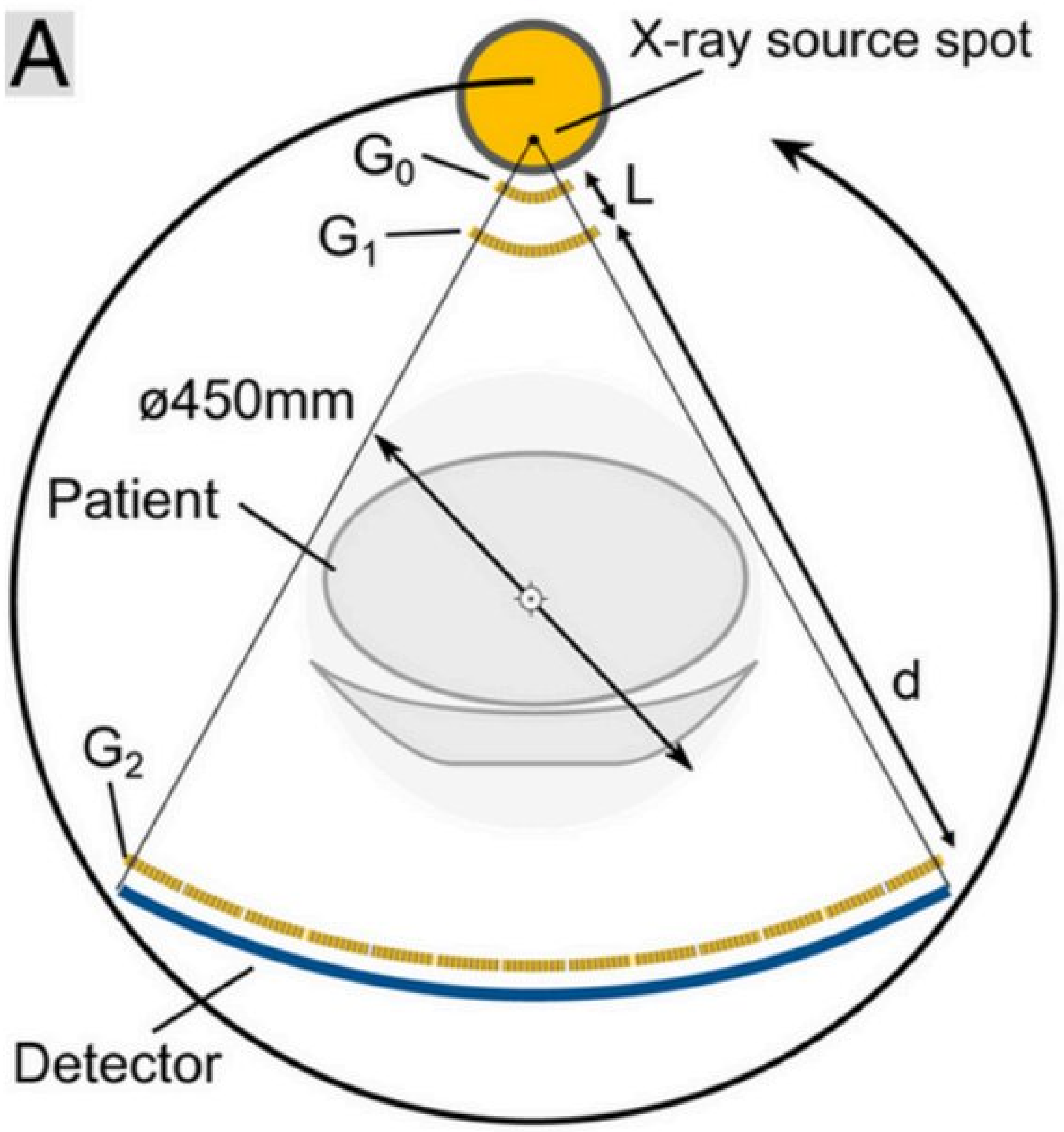
Considering the wave nature of X-rays, complementary contrast can be achieved by further measuring their small-angle scattering (dark-field) properties.

This provides additional valuable diagnostic information of unresolved tissue microstructure.

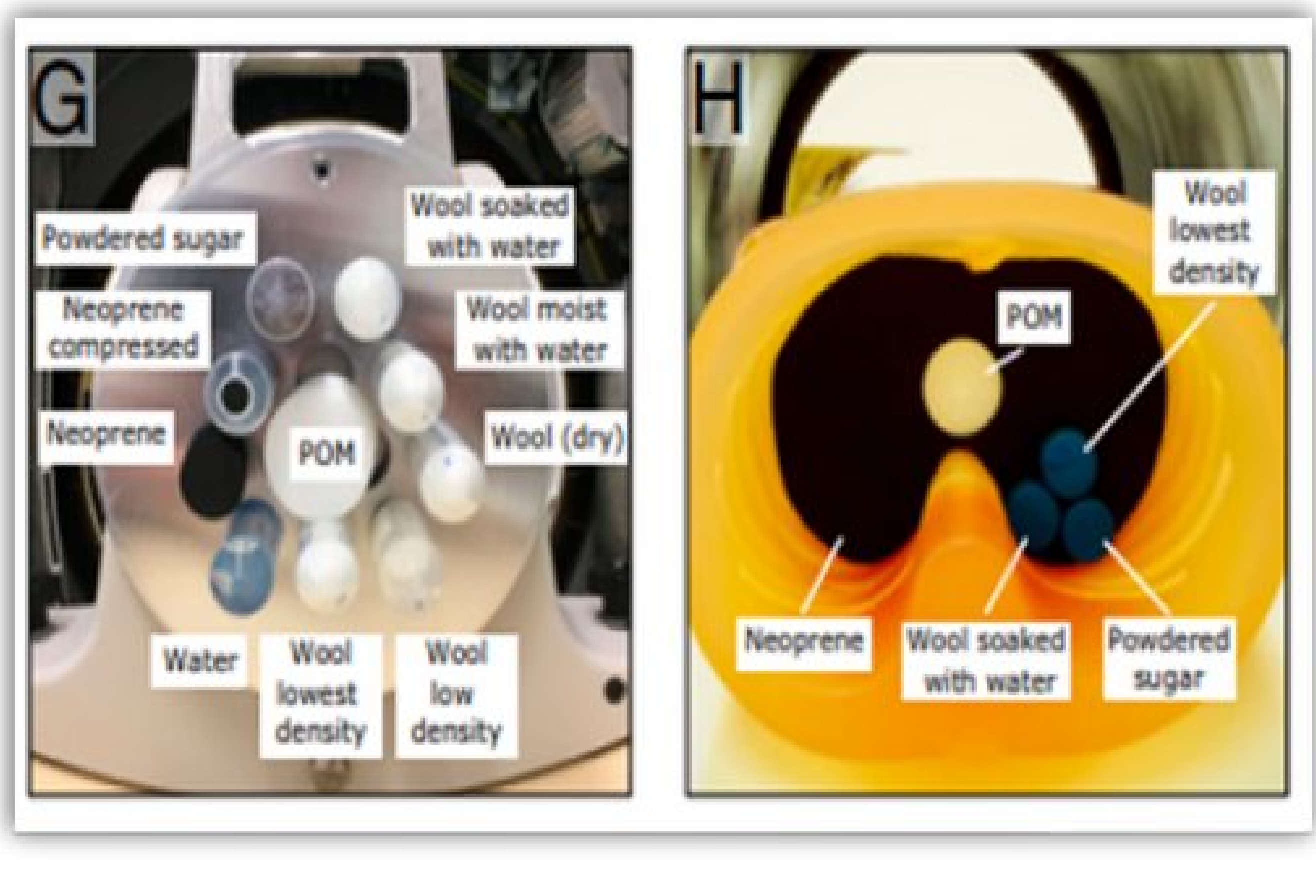


Materials & methods

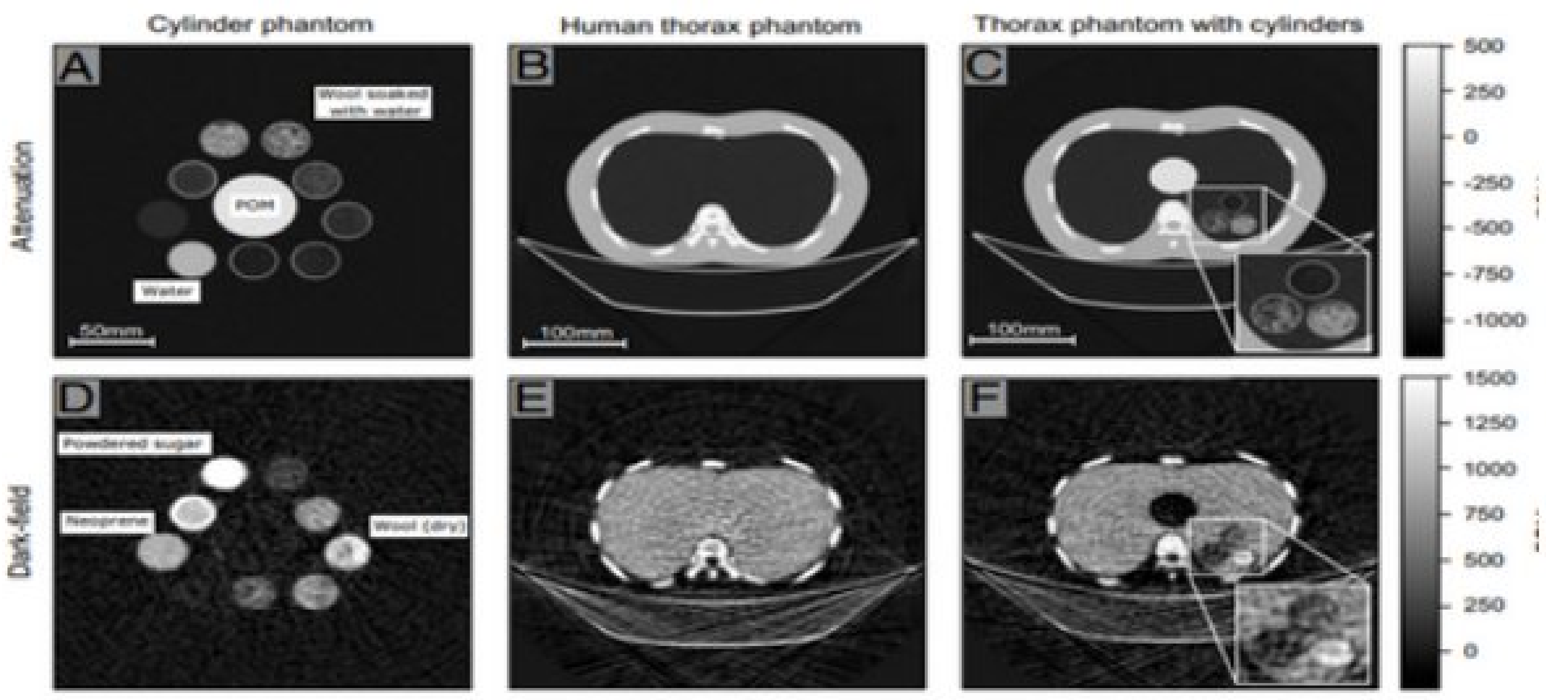
- To measure perturbations of the x-ray wave, front other than the mere attenuation and to subsequently extract the dark-field and phase-contrast signals, it is necessary to place optical elements, grating structures in the x-ray beam path (i.e. between the source and detector)



- The role of X-ray grating interferometer is to measure X-ray attenuation, refraction, and small angle scattering simultaneously.
- The gratings are patterns composed of many parallel absorbing lines at a fixed periodicity.
- The three gratings are attached namely G0, G1 & G2 made from X-ray lithography electroplated (GOLD) material.
- Grating G0 splits the radiation from an incoherent X-ray source into many slit sources, which fulfils the coherence requirement for darkfield imaging.
- Grating G1 introduces a fine intensity modulation on the incident radiation with a periodicity in the range of a few micrometres.
- To resolve this line pattern, a highly absorbing analyser grating G2 is positioned in front of the detector.
- Attenuation of the radiation by the sample causes a decrease of intensity, while refraction and small-angle scattering induce small distortions and contrast changes of the generated fringe patterns.



- The conventional signal extraction method involves the recording of the so-called stepping curve, the gratings are precisely moved in multiple steps over a period.
- A comparison of two stepping curves acquired with a sample in the beam path allows extracting the attenuating, scattering, and phase-shifting properties of the measured object.
- To assess the quantitative performance of this first human-scale prototype dark-field CT system, a phantom composed of different materials in plastic tubes are used.
- The dark-field image (D,E,F) channel allows us to differentiate foams, powders, and cotton wool compositions since the dark-field signal picks up information on fine structures and porosities.



Result:

- Micro and nano structures are clearly seen in darkfield CT as seen in phantom study.
- Radiation dose is comparatively lesser than HRCT scans.
- Dark field images is formed by the small angle scattering signals which are very valuable in diagnosis and staging of lung diseases.
- Currently Darkfield CT is under clinical research, but it has shown very good significance in X-ray imaging hence this grating-based technique is implicated into CT.

Conclusion:

- By this progress in current CT will be helpful in diagnosis of lung diseases. Hence this innovation in future CT will give complimentary information on micro/ nano structural properties in lung parenchyma are detected clearly than HRCT scans.
- Darkfield CT provides information on the lung's underlining microstructures and in view of alveolar structure and the functional condition of the lung which helps in better understanding of pulmonary disorders and early detection of COPD.
- Since this technique is applied in X-ray imaging has had a great impact in clinical significance, grating based imaging is implied in CT for better resolution and for good diagnosis.

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Dual-exposure Technique for extending the Dynamic Range of X-ray Flat Panel Detectors

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Abstract
This work proposes a method to combine two acquisitions of the same sample with two different x-ray photon flux levels and the same beam spectral configuration in order to increase the dynamic range of x-ray flat panel detectors. A linear model was used to model the detector pixel response in terms of mean and variance in order to merge the two datasets. To account for the impact of pixel saturation, the model was expanded. We assumed that each dataset's had an independent Gaussian distribution, and we calculated a joint probability density function (JPDF) of the pixel values. Using a maximum likelihood approach, the final pixel value of the high-dynamic-range dataset's was estimated using this PDF. Experimental data from a small-animal cone-beam micro-CT scanner with a flat panel detector was used to evaluate the pixel model's adequacy for representing the detector signal. We used analytical formulas and simulations to study the possible extension of our technology in dynamic range for generic flat panel detectors. Using experimental data from two distinct phantoms, the effectiveness of the suggested dual-exposure strategy was contrasted with that of a standard single-exposure technique in realistic imaging situations. Signal-to-noise ratio, contrast, and profile analysis were used to evaluate the quality of the photos. Our solution enhanced the dynamic range from 76.9 to 166.7, which is defined as the ratio of the exposure for saturation to the exposure corresponding to instrumentation noise. Compared to single-exposure collections, dual-exposure results demonstrated a better contrast-to-noise ratio and contrast resolution for the same x-ray dose. In the combined dataset, image artifacts were also lessened. This method of extending the detector's dynamic range without raising the dosage is especially appropriate for picture samples that have both high and low attenuation regions.

1. Introduction

Digital detectors are increasingly being used in preclinical and clinical settings to obtain X-ray images (Kalender and Kyriakou 2007). Flat panel indirect (FP) detectors are increasingly the preferred option for cone-beam CT (CBCT) or digital imaging in two dimensions (2D) radiography. These days, FP-based x-ray systems are employed in many different fields, including digital radiography (Korner et al., 2007), C-arm systems, CBCT (Siewerdsen et al., 2005), interventional fluoroscopy (Siewerdsen et al., 2007), musculoskeletal CBCT imaging (Zbijewski et al., 2011), breast CBCT systems (Boone et al., 2002), kVp CBCT systems connected to linear accelerators for image-guided radiation therapy (Jaffray et al., 2002), or small animal micro-CT (CBμCT) imaging (Badea et al., 2008, Vaquero et al., 2008).

However, when a sample contains both low- and high-density materials, the image quality may be compromised due to the restricted dynamic range (DR) of FP detectors. The ratio of saturation charge to noise floor is a standard way to quantify DR levels. According to the makers, typical values can be 4000 for the Shad-o-Box (Rad-icon Imaging Corp, Santa Clara, CA) or 2000 for a Hamamatsu C7940DK-02 (Hamamatsu Photonics K.K., Hamamatsu, Japan).

Because of this restricted DR, if the exposure is changed to better view the soft tissue architecture, dense areas may become obscured in 2D imaging. This problem is more significant in CBCT because widely used analytical reconstruction algorithms, like FDK (Feldkamp et al., 1984), result in significant artifacts in the reconstructed slices when the object being examined is truncated by the field of view (FOV) covered by the acquired projections (Feldkamp et al., 1984, Yu et al., 2006). The FOV of the scanner should therefore exceed the sample size. Without overloading the detector components in the object-free region, it is impossible to get a high enough signal-to-noise ratio (SNR) inside the subject's high attenuation region. Any CT scanner may experience this issue if the subject's DR is higher than the detector's.

A number of strategies have been put out to deal with this problem. The majority of them are based on hardware changes or unique detector designs and were first created for optical imaging (i.e., photography and video). Some approaches include spatially variable pixel sensitivity (Nayar and Mitsunaga, 2000), using a non-conventional pixel design (Lule et al., 1999), combining unique scintillator and pixel designs (Nittoh et al., 2003), or using numerous sensors inside a single pixel (Fox et al., 2005). A few software-based techniques have also been put forth in addition to these strategies. Clinthorne and Strobel (1998) provide an example, where they used the low dynamic range (DR) image to mathematically predict a high dynamic range (HDR) dataset.

Several of the most popular software-based methods for increasing the DR of optical image detectors (such as those used in photography and video) rely on taking multiple pictures, each with a unique radiation exposure (Mann and Picard 1995). A new HDR image is then created by combining the collected data. To determine the value of a pixel in an HDR image, the combination algorithm can be as straightforward as choosing the best sample from the two original datasets (Madden 1993) or it can be more complex, utilizing all of the information in the collected data (Dromigny and Zhu 1997, Robertson et al 2003). based approaches. Sukovic and Clinthorne (2001) suggested combining two datasets obtained with varying exposures (mAs) in order to boost the DR of projection data. Nevertheless, discontinuities were apparent in the HDR data, and the DR of the generated data was not contrasted with that obtained using traditional scanning techniques.

To increase the DR of FP detectors, we provide a brand-new dual-exposure method. The technique uses a maximum likelihood estimation based on prior knowledge of the detector's reaction to incoming radiation to integrate two projection datasets. An analytical model for pixel mean and variance (Yang et al., 2010) that was expanded to incorporate the effect of saturation is used to characterize the detector response. We acquired the model parameters for an actual detector, and we used experimental data to evaluate the model's correctness. Using simulated data and realistic imaging settings with experimental 2D projection images and CBCT data from a commercial CBμCT scanner, we assessed the effectiveness of our approach to expand the DR and its possible limitations.

There have been prior reports on the extension of the DR of FP detectors in CBµCT by the use of multi-exposure-

2. Materials and methods

We present our DR extension method's theoretical underpinnings in the sections that follow, outlining the data's altered acquisition and mathematical processing. In order to achieve this, we provide a detector pixel model which serves as the foundation for the ensuing maximum likelihood estimation of the HDR data and offers an estimate of the pixel signal and variance as a function of exposure.

We explain how to use experimental data obtained using a real FP detector to generate a parametric description of the detector pixel model. We also assess the degree of agreement between the detector experimental data and the pixel model.

The collection of parameters is then used for the theoretical assessment of the DR extension capability in ideal settings. , the approach is ultimately assessed using experimental data.

3. Results

3.1. Estimation of parameters for the detector model

For the three image integration durations (125, 500, and 1000 ms) used in the study, displays the detector's gain curve and the corresponding pixel variance as a function of exposure. When some of the pixels reach saturation and the analytical model for variance fails, the linear trend in detector pixel variance, as averaged across the detector area, is interrupted.

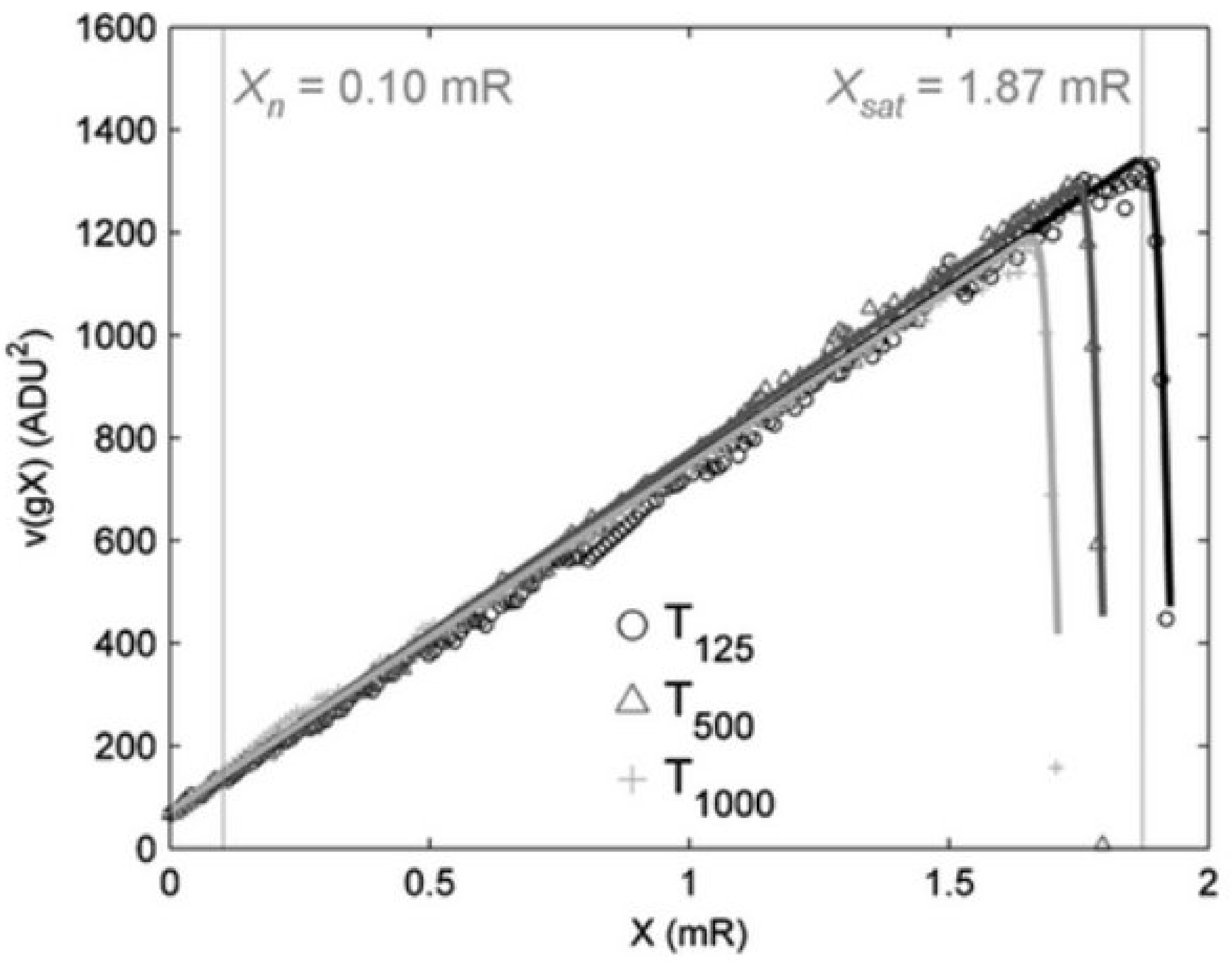

Figure 1. After subtracting the dark signal, the pixel variance as a function of exposure exhibits a linear relationship until the detector reaches saturation. Solid curves display the theoretical value for pixel variance, while markers reveal the experimental data because the pixel signal is clipped. The upper limit for the exposure setting was defined as the point at which the variance reached its highest value. Figure 4(A)'s variance curves demonstrate how extending the integration period reduces the maximum exposure value. Figure 4(B) illustrates how the dark signal increases with integration time, which explains this result. The dark signal's variance appears to be independent of integration time, indicating that Xn remains constant during integration. Figure 4 shows a constant gain (g = 2026 ADU/mR) and level of INEE (Xn = 0.102 mR), as well as a slope relating signal mean and variance of h = 0.33. The parameters for the linear gain (g) and noise model (Xn and h) generated from the data were determined to be constant across different integration times. Thus, gXn = 206.7 is the value of the total instrumentation noise in detector ADUs. For integration times of 125, 500, and 1000 ms, respectively, the theoretical variance curve computed using the censored Gaussian model (see figure 5) has relative mean absolute errors of 0.041, 0.032, and 0.039, indicating strong agreement with actual data. The dynamic ranges for integration times of 125, 500, and 1000 ms, respectively, are DR = 427.18, DR = 398.32, and DR = 378.34 for unity SNR. For integration times of 125, 500, and 1000 ms, respectively, the dynamic ranges for quantum noise-limited imaging were DRQ = 18.73, DRQ = 17.46, and DRQ = 16.59.

3.2. Theoretical performance of the HDR method for generic detectors

The outcomes of the simulated data. Frame averaging offers no advantage in terms of SNR when the beam attenuation is high enough since there are not enough photons reaching the detector. When the beam is attenuated by more than 17 cm of water,

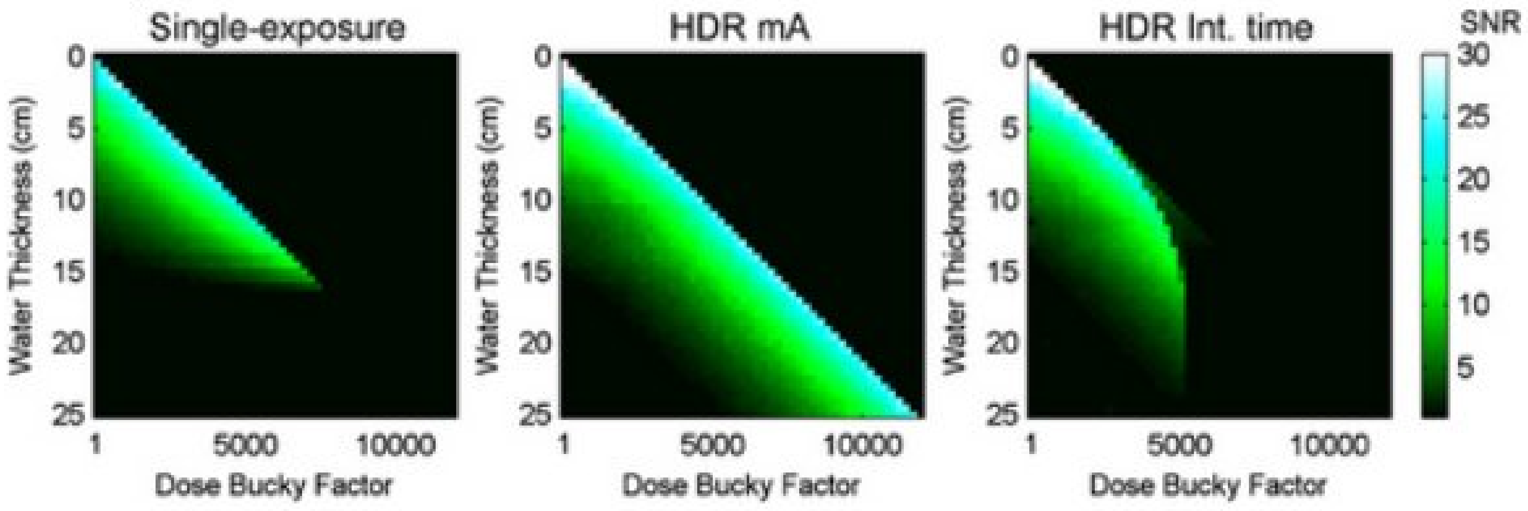

Figure 2. SNR of the collected data for frame averaging (A), the HDR data generated by increasing the anode current (B), and the detector integration time (C) as a function of attenuation and Bucky factor.

Figure 2b. demonstrates how the HDR technique allows for the extension of the DR of the obtained data since, by increasing the exposure by the proper factor, the data's SNR can be kept constant during attenuation. If the Bucky factor is high enough to generate a viable signal, the increase in exposure is converted into a recovery of SNR instead of frame averaging. The HDR approach works similarly to frame averaging when the Bucky factor is less than that value The HDR method's performance noticeably deteriorates when the overexposed dataset is acquired with a longer integration period. The advantages of the HDR technique are negated when the dark signal increases and narrows the DR of the overexposed image.

3.3. Experimental results on (2D) planar projection data

A planar image of the copper pattern phantom for both single- and dual-exposure data obtained using protocol 1 in table 1 (30 kVp). After the raw data has been logarithmically transformed, both images are shown. Plotting the profile data over the bar pattern for both acquisitions in how noise masks the signal for high attenuation values, hiding the change from one copper thickness value to the next. Frame averaging is unable to increase SNR in these regions, as predicted by the theoretical findings above. However, when the HDR approach is used, the steps become obvious. SNR readings in the ROI as a function of attenuation. While single-exposure data do not yield a viable signal for large thickness values, the detector's DR obtained using the HDR approach offers a useful signal over a wider range of attenuation values. The DR of the recorded attenuation data is DRQ = 166.7 because, when utilizing the HDR approach, attenuation factors above 0.006 fall within the quantum noise-limited portion of the detector's response curve. The minimum signal above the INEE increases to about 0.013 when frame averaging is used, indicating that the DR is DRQ = 76.9.

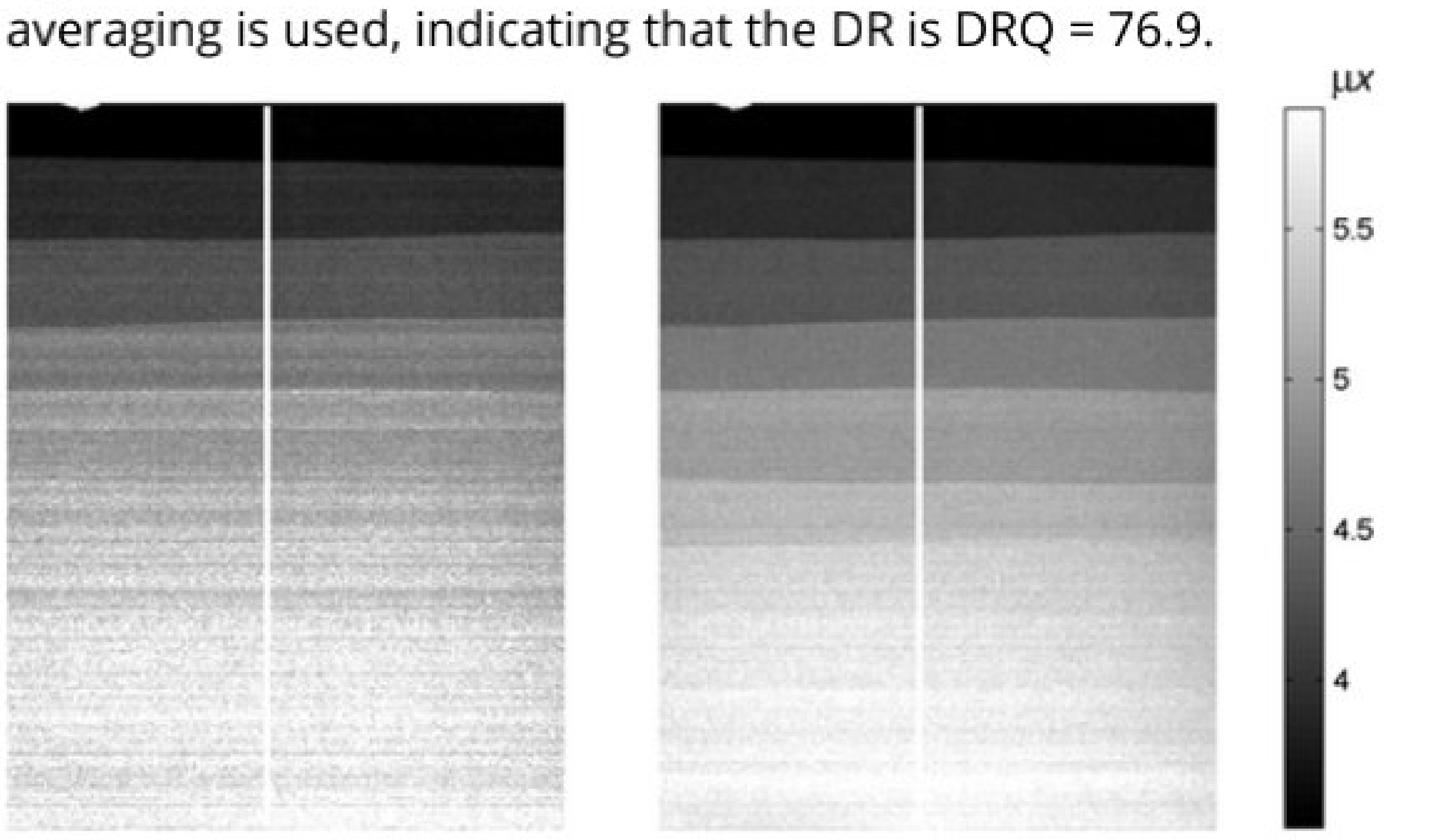

Figure 3. Single-exposure protocol (A) and dual-exposure protocol (B) were used to acquire the copper stair phantom for acquisition protocol 1 (30 kVp). The image does not display the lead frame. The location of the profile data measurement is indicated by the white line. The sample received the same radiation exposure throughout the gathering of both datasets.

3.4. Experimental results on (3D) tomographic data

A portion of the reconstructed volume for both the single-exposure and dual-exposure images . The contrast resolution of the single-exposure image is lower, and the majority of Noise and artifacts obscure the inserts (see figure 10's zoomed-in window). A noticeable decrease in the amount of noise and ring artifacts in the data may be seen when using the HDR approach. When using the HDR approach, the mean CNR value inside the 1.5 mm inserts rises from 0.58 for the single-exposure data to 1.71. one of the many projections used to produce the tomographic data for the various acquisition techniques. In the low exposure dataset, that a sizable portion of the pixels (39%) were below the instrumentation noise threshold (Xn). However, under the high current, these pixels were in the detector's quantum noise zone.

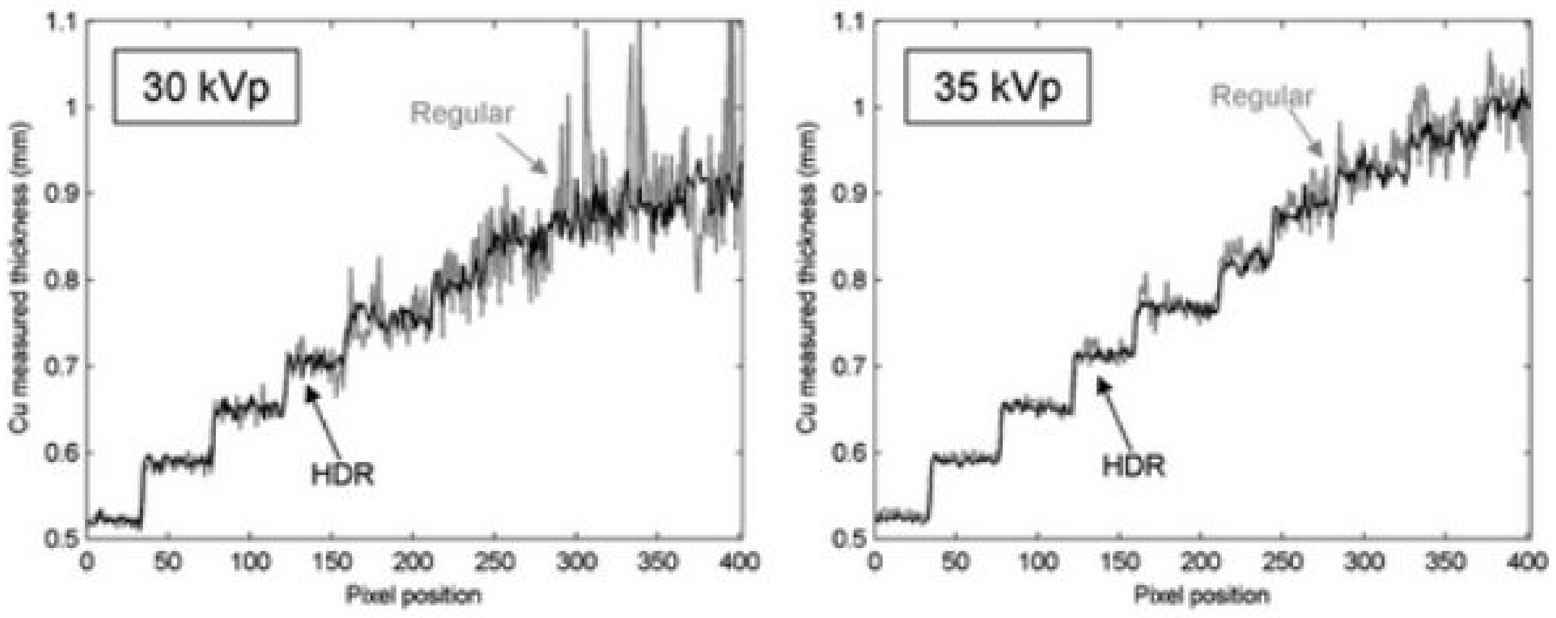

Figure 4. Profile plots for the single-exposure protocol (gray curves) and the dual-exposure protocol (black curves) for 30 kVp (left) and 35 kVp (right), or protocols 1 and 2, respectively, are displayed across the bar pattern phantom projection. To display the estimated thickness of copper, image log values have been normalized by the copper attenuation factor at the beam's mean energy. At both energy levels, HDR results indicate a reduced noise level for big thickness values.

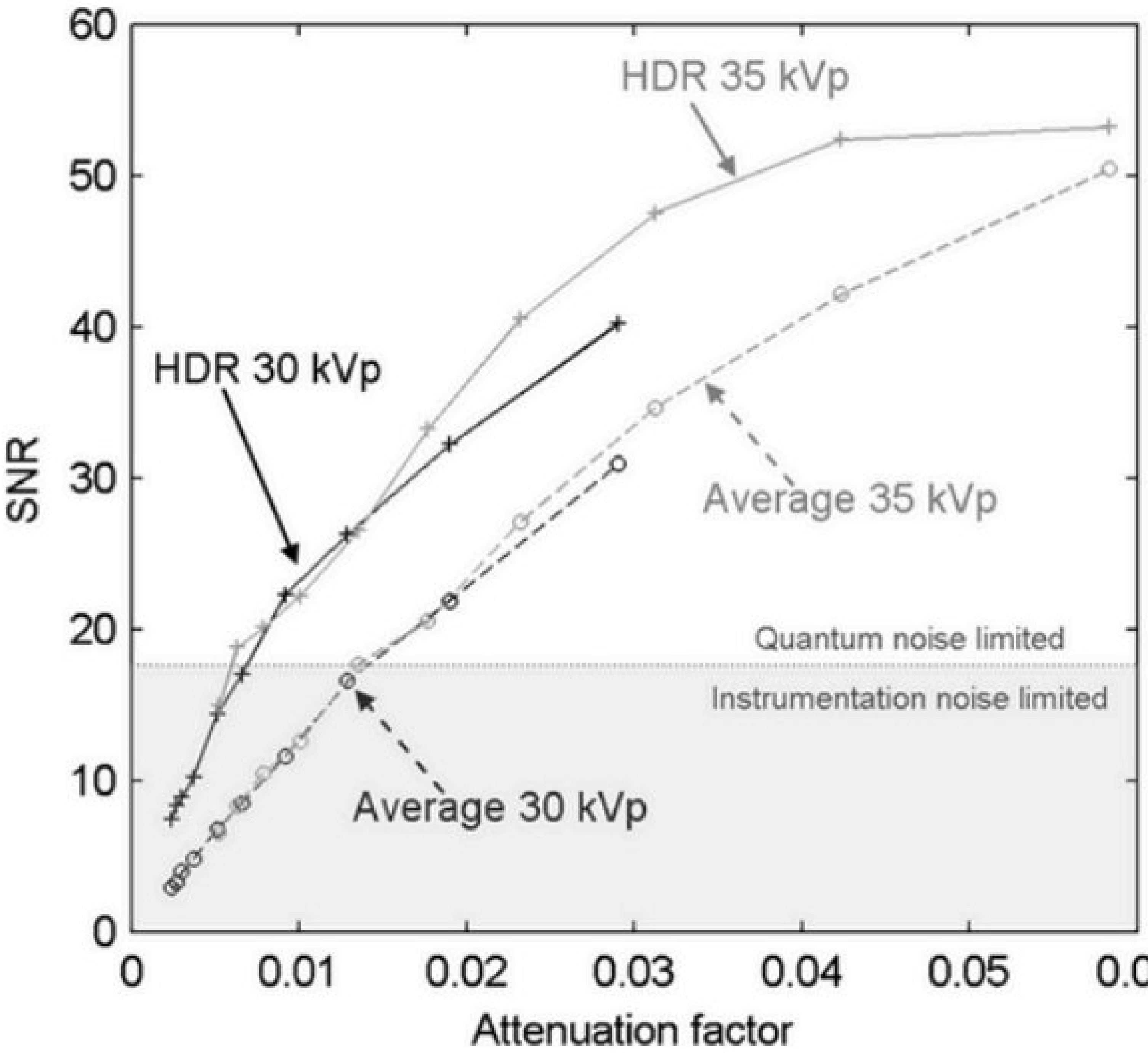

Figure 5. For the HDR and frame averaged data, SNR was calculated inside the ROIs for each thickness as a function of attenuation factor. The portion of the SNR curves where the instrumentation noise exceeds the quantum noise is indicated by the gray shaded area.

SNR measurements demonstrate that, for the same administered dose, employing the HDR technique results in higher SNR than frame averaging. Because of the symmetry of the phantom, results for this specific angular point can be extrapolated to any projection.

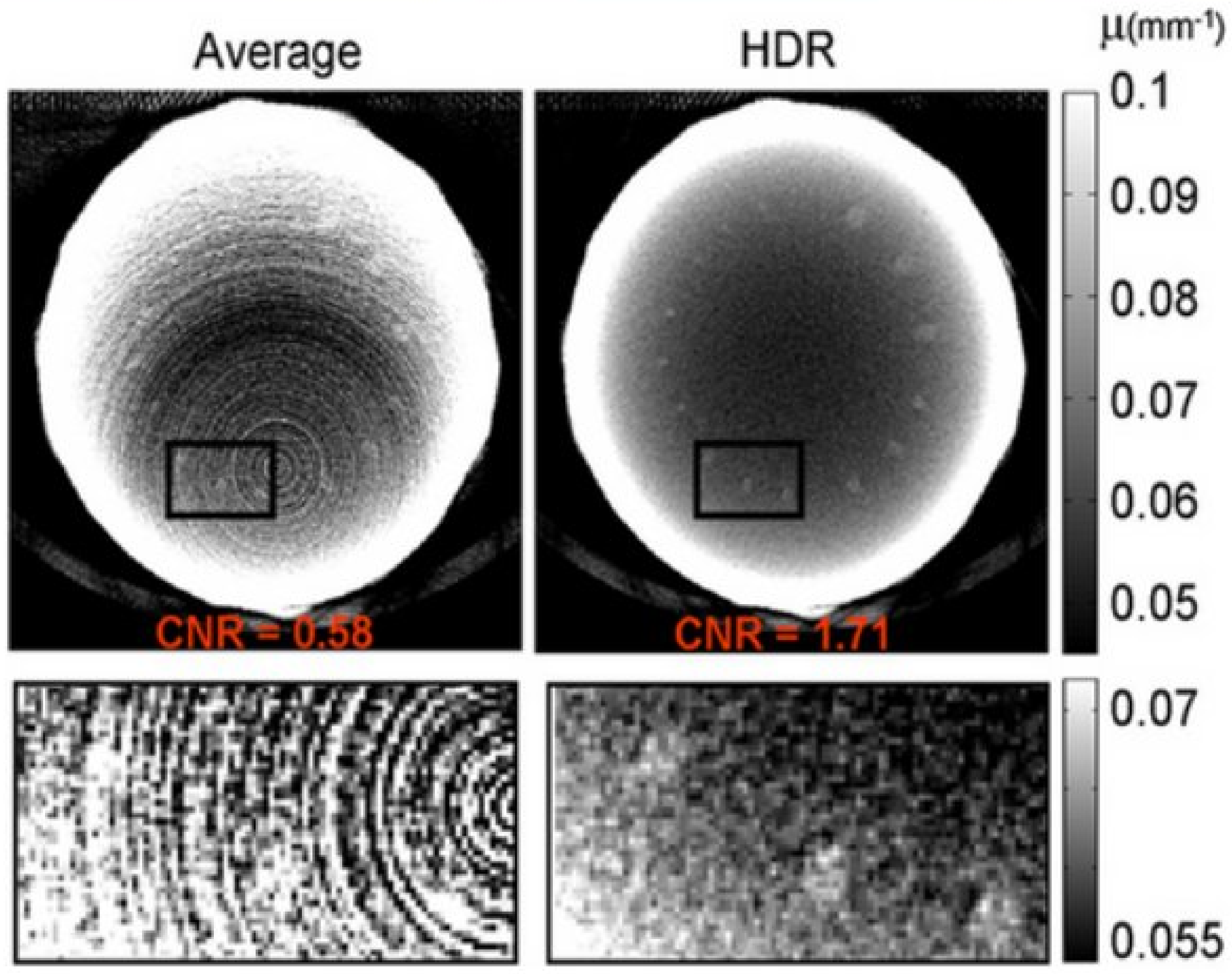

Figure 6. A slice of the contrast resolution phantom obtained with the dual-exposure methodology created for this study (right column) versus a standard single-exposure protocol (left column). It is challenging to separate the inserts from the backdrop due to the high amount of noise and artifacts.

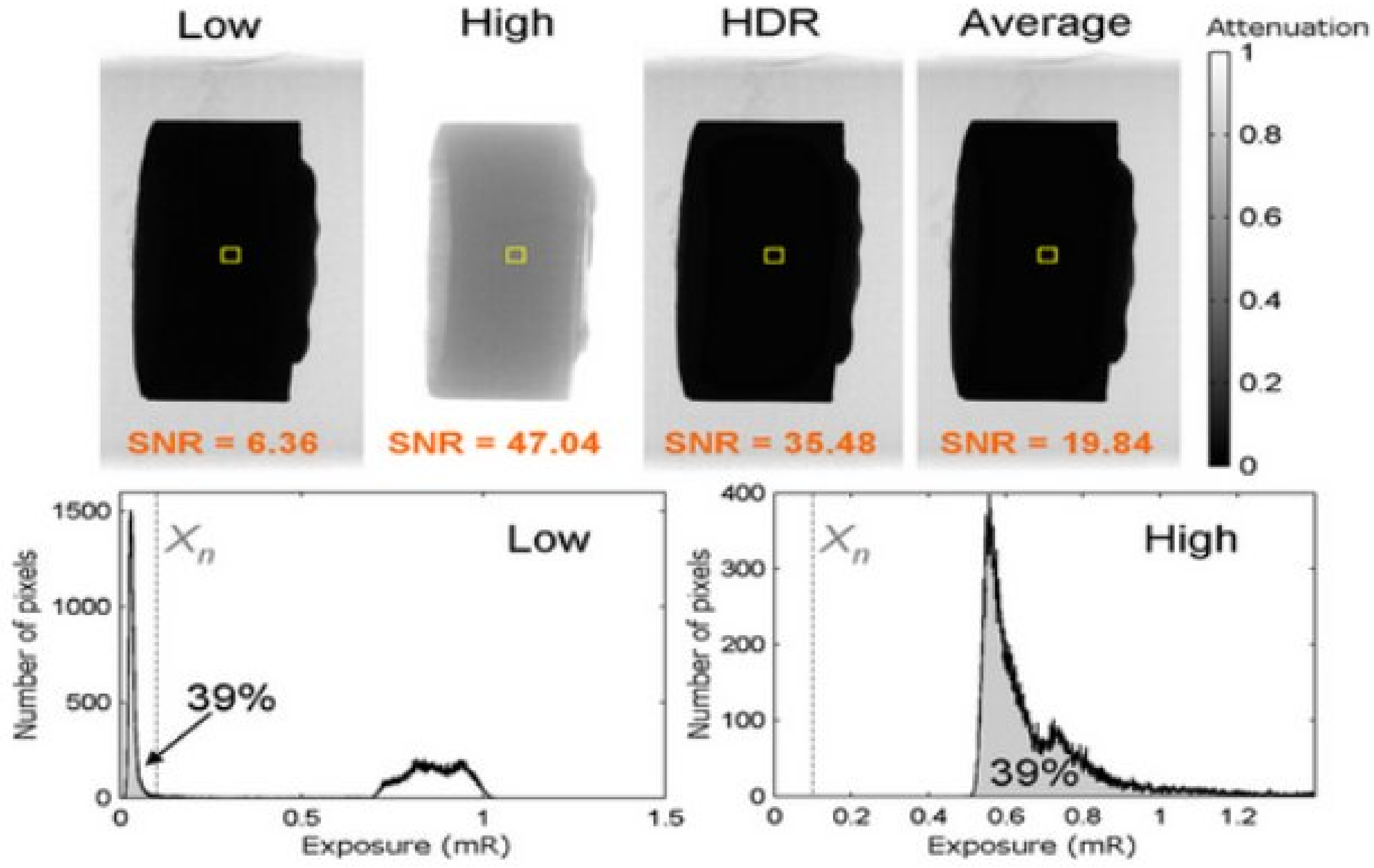

Figure 7. For one of the projection pictures utilized for the CT reconstruction, the projection data and related SNR are displayed in the upper row of the figure. The ROIs shown in the projection images had their SNR values assessed. Take note of how the HDR method's increased dynamic range is accompanied by an increase in SNR. The instrumentation noise level and the histograms for the low and high current datasets are displayed in the bottom row. The low current data plot's shaded area displays pixels with values below the instrumentation noise level, whereas the high current dataset's shaded area displays pixels that are not saturated..

4. Discussion

This study's approach expands the DR of x-ray FP detectors, like those frequently seen in CBCT. This enhancement avoids the requirement for hardware changes that could be costly and challenging to implement in commercial devices by employing a modified collecting procedure and an extra processing step using the collected data.

We suggest combining two datasets using maximum likelihood estimation, which is based on a theoretical model for the mean and variance of pixel signal that has already been published, in order to produce the HDR image. The model was expanded to include the impact of saturation on the pixel signal's variance. The validity of the detector response model for the realistic simulation of FP detectors was demonstrated by its strong agreement with experimental data.

For longer integration times, the detector displayed a decrease in DR and a linear response that broke at the saturation point.

The decrease in DR resulted exclusively from the rise in dark signal with integration time, while additive noise and variance slope were shown to be constant over integration time 435Phys. Med. Biol. 59 (2014) 421 A Sisniega et al.

According to simulated data, if the anode current of the x-ray source could be increased indefinitely, the HDR approach might possibly extend the detector's DR to infinity. Because the dark signal increased with a longer integration period, the detector's DR decreased. Therefore, increasing the detector exposure via prolonging the picture integration time rather than the anode current resulted in a degradation of the HDR method's performance.

In samples with regions of high attenuation, experimental results demonstrated improved image quality for both projection and tomographic data. SNR graphs for the same dose given to the sample indicated that this improvement came from an increase in the detector's DR rather than just a decrease in the noise in the data. Because there was no legitimate signal inside the area in any of the frames that were taken, the results for the copper staircase phantom demonstrated that noise in the single-exposure data concealed the signal inside high attenuation zones.

Due to the absence of signal, frame averaging was unable to improve the phantom structure's visibility. The overexposed image yielded a valid signal in some of the heavily attenuated sections after the dual-exposure approach was applied. This revealed the portion of the structure that was not visible with the single-exposure data, extending the detector's DR. The benefit is greater in heavily attenuated locations since our method expands the DR of the detected signal. The form of SNR curves for HDR data, which exhibit asymptotic behavior at decreasing attenuation, reflects this phenomenon. A desirable feature for later data processing steps, this finding suggests that the noise properties are homogenized across high and low attenuation zones. When applied to samples with high attenuation materials that surpass the detector's DR, the contrast and noise acquired using the method described here were superior to those obtained with single-exposure methods in terms of tomographic data. For heavily attenuated regions, photons do not reach the detector, which explains the low contrast resolution in the single-exposure data.

In severely attenuated locations, the signal level was low and more uniform due to the absence of photons. The greater impact of ring artifacts is caused by small variations in the gain calibration point, which become much more noticeable for such low signal quantities. In the rebuilt volume, the stronger rings hide information inside regions encircled by high attenuation material. In addition to increasing ring artifacts, low signal levels resulted in reduced CNR because additive noise's relative contribution increased, deteriorating the reconstructed dataset's noise characteristics. There were no discontinuities in the rebuilt slices because the combination method employed all of the collected data. Previous suggestions that combined the obtained datasets using a simpler method showed discontinuities (Sukovic and Clinthorne 2001). As long as the image lag is sufficiently small and does not contaminate the following data frames particularly when a pixel transitions from saturation to linear response from one frame to the next—our technique might be used with any FP detector, independent of the underlying technology. The method's performance will suffer if the recovery time following saturation is excessively long. Determining the maximum amount of mage lag that is tolerable while still producing outcomes that are acceptable would require additional research that is outside the purview of this publication. Since just one dataset is obtained, we were unable to compare the effectiveness of our method with that of hardware-based approaches, which would undoubtedly be more effective, particularly in terms of acquisition time.

Regardless of the specific hardware implementation, our method is significantly less costly and may be incorporated as a small adjustment to the image processing chain of any system based on an FP detector. 421 A. 436Phys. Med. Biol. 59 (2014) Sisniega and associates Other methods, which assume prior knowledge of the sample structure, pre-equalize the radiation field to compensate for the detector's restricted DR. The most popular method is bow-tie filtering, which aims to get a more uniform radiation distribution at the detector surface by altering the beam's spatial characteristics prior to the sample attenuating it (Mail et al., 2009). Notably, the effect of bow-tie filters is diminished when the acquisition settings deviate from the anticipated situation when contrasted with DR extension approaches, like the one described here. For example, the DR of the attenuated beam may still be too high for the FP detector if the sample's size or shape deviates greatly from what is predicted or if there are unexpectedly high attenuation objects.

However, regardless of the attenuation distribution of the imaged sample, the suggested HDR approach has the same capability for accommodating a subject with a greater DR without imposing any prior conditions on the sample attributes. To achieve a comparable SNR across the projection image, the dual-exposure method suggested here could be expanded to a multi-exposure strategy based on several exposure levels. However, the highest DR that can be achieved with a multi-exposure approach is limited by the maximum mA that the x-ray tube can achieve. Future research will examine alternatives to the combination algorithm that has been described. Additionally, new probability density function models are being investigated.

5. Conclusion

To increase the DR of x-ray FP detectors, we suggest a brand-new dual-exposure method. Our findings demonstrate that the technique successfully extends the detector's DR and improves performance in comparison to traditional methods, especially in cases when the sample contains high attenuation zones.

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Spectral Mammography

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Abstract: Spectral mammography is an advanced breast imaging method that combines contrast enhancement and dual-energy X-ray imaging to enhance lesion detection, particularly in dense breast tissue. In certain clinical contexts, it provides a useful substitute for MRI and boosts diagnostic confidence in difficult cases.

Key Words: Dual energy X ray, Contrast enhanced mammography, Breast Imaging, Breast cancer detection, Digital Breast Tomosynthesis.

Introduction

In 1913, mammography was created, and over the following 60 years, the method was refined. Early-stage cancer detection began to soar in the 1970s and 1980s when all women were getting mammograms. Breast cancer is one of the most prevalent cancers in women globally, so early and precise detection is essential. Despite being the most widely used screening technique, standard mammograms do have limitations with regard to tissue contrast, especially in dense breast patterns. However, by using dual-energy imaging for anatomical and functional input, spectral mammography, also known as contrast-enhanced spectral mammography (CESM), has offered a ground-breaking platform that increases the confidence of diagnosis. Thus, promising developments have been offered as a potential supplement or substitute for traditional MRI and mammography.

Methodology – Working Principle

Spectral mammography is based on the principle of dual-energy subtraction imaging. Essentially, it involves taking X ray images at two different energy levels: low energy (similar to standard mammography) and high energy (just beyond the iodine K-edge). By varying the X-ray energies, the high- and low-energy images of the breast are combined to emphasize areas where the contrast agent has pooled.

The technique combines an iodinated contrast agent with standard mammography to enhance the diagnostic ability in patients who have denser parenchymal background patterns. A 100 mL of a 1.5 mL/kg low-osmolar non-ionic monomeric iodine-based contrast agent is injected into a vein of the arm. After the contrast is allowed to flow into the breast, the breast is compressed to immobilize it. Two pictures are taken using low and high energy X rays, the low energy image being a standard full-field digital mammography (FFDM) image.

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Figure 1 : Modern mammography machine

In a high energy image, the iodine absorbs more of the higher energy X-rays, enhancing areas with higher contrast agent concentrations. The non-enhanced areas are eliminated by the system's software after processing the two images. The trainer or radiologist interpreting the image will identify potential cancer by using the areas enhanced by abnormal blood vessels.

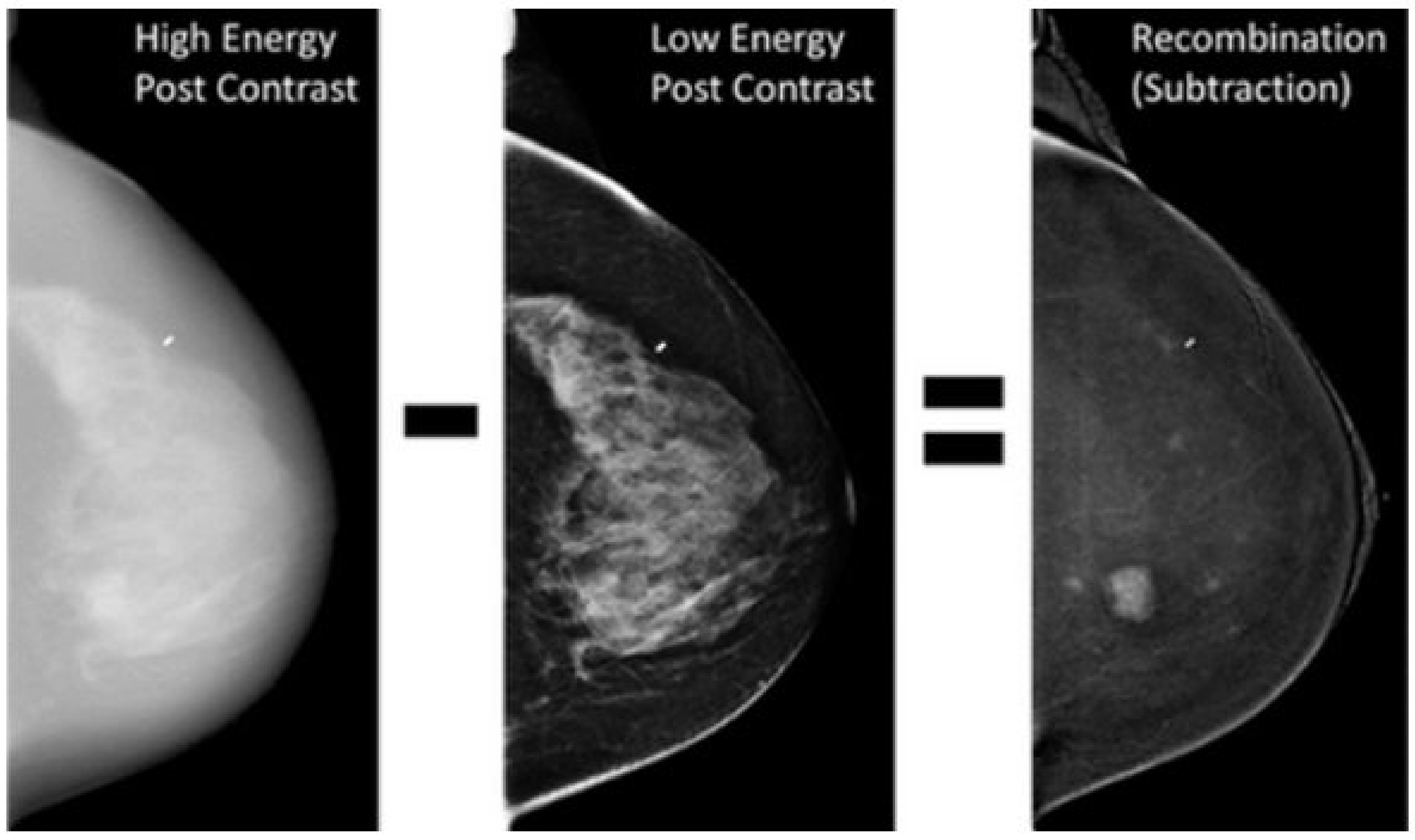

Figure 2 : Subtraction of the lower energy image from the high energy image results in the recombination image. It is imperative to have no motion involved to avoid any misregistration artifact between the acquisitions of the high energy and lower energy images.

Uses

1. Assessment of Inconclusive Findings from Standard Mammography

Spectral mammography, when using contrast enhancement, increases the conspicuity of a lesion by marking areas of high vascularity (malignant). This dual-energy technique assists radiologists in differentiating benign from suspicious lesions, thus reducing unnecessary biopsies for lesions that truly need to be observed .

2. Screening High-Risk Patients who are unable to Undergo MRI

The gold standard for screening high-risk women is magnetic resonance imaging (MRI). However, some patients may be unable to have an MRI because of claustrophobia, implants, renal insufficiency, or financial limitations. In such cases, spectral mammography offers a more approachable and patient friendly option which offers high sensitivity functional imaging through contrast enhancement for the early detection of lesions in the dense breasts.

3. Finding Recurrence in Breasts After Surgery or Radiation

Scarring, architectural distortion, and oedema are some of the ways that post-operative and post-radiation changes in the breast can mimic or conceal recurrence on routine mammograms.

By displaying aberrant vascular activity, a defining feature of recurrent or residual disease, spectral mammography facilitates more precise differentiation from benign post-treatment alterations.

4.Monitoring of Treated Breast Cancers

Regular follow-ups are common for patients with a history of breast cancer. By early detection of small recurrent or new lesions, spectral mammography can improve surveillance, particularly in surgically altered breasts where standard mammography has limitations.

Advantages :

- Increased visibility of lesions in dense breast tissue
- less expensive and less time-consuming than a breast MRI
- Improved accessibility and comfort for patients
- MRI-like functional imaging that is quicker and simpler to understand

Disadvantages :-

- Ionising radiation exposure (but within permissible bounds)
- Iodinated contrast use , which carries the risk of nephrotoxicity or any allergic reactions
- In certain clinical settings , limited availability
- Not yet widely recognised or completely standardised for screening

Digital Breast Tomosynthesis (DOT) in Radiology

Digital Optical Tomosynthesis (DOT) and spectral mammography both seek to get around the challenges of traditional 2D imaging, though they are not interchangeable. By obtaining several low-dose projections across an arc and reassembling them into thin slices, DOT produces pseudo-3D images. DOT improves diagnostic accuracy when used in conjunction with spectral imaging, especially in complex cases. In order to provide multiparametric breast imaging, some sophisticated systems combine structural and functional data for a thorough assessment.

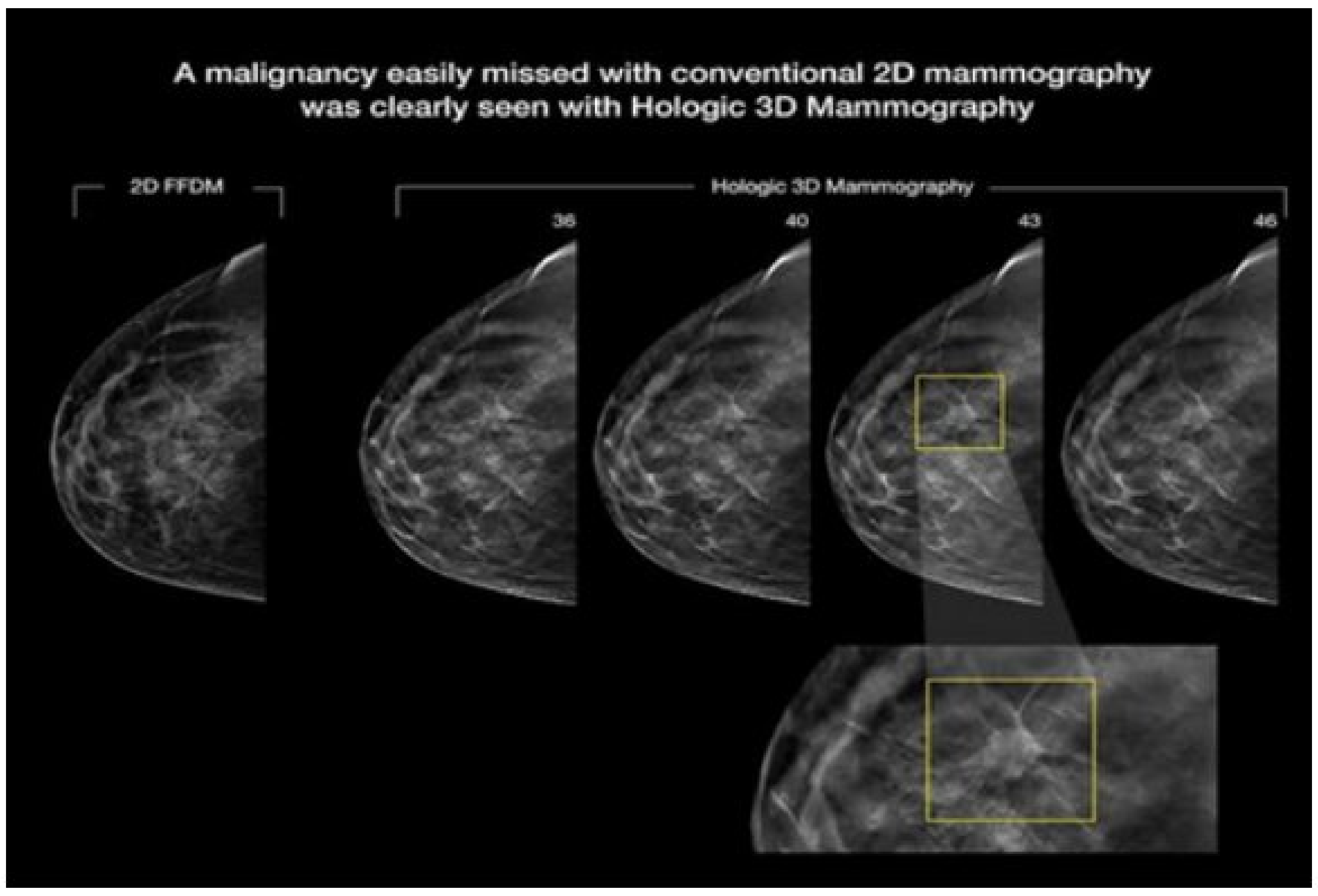

Figure 3 : It shows a series of thin-slice breast images reconstruction into a 3D view , helping the radiologist detect small lesions or abnormalities that may be hidden in the traditional 2D mammograms .

Conclusion

A major development in breast imaging is spectral mammography, which uses dual-energy contrast-enhanced imaging to provide both anatomical and functional information. It is a useful substitute for patients who are unable to have an MRI and addresses some of the main drawbacks of conventional mammography, especially in cases of dense breast tissue. It is becoming a potent tool in the treatment of breast cancer nowadays because of its capacity to enhance lesion detection, track treatment response, and evaluate high-risk or post-treatment cases. It has the potential to become a standard component of thorough breast imaging procedures as access and technology advance.

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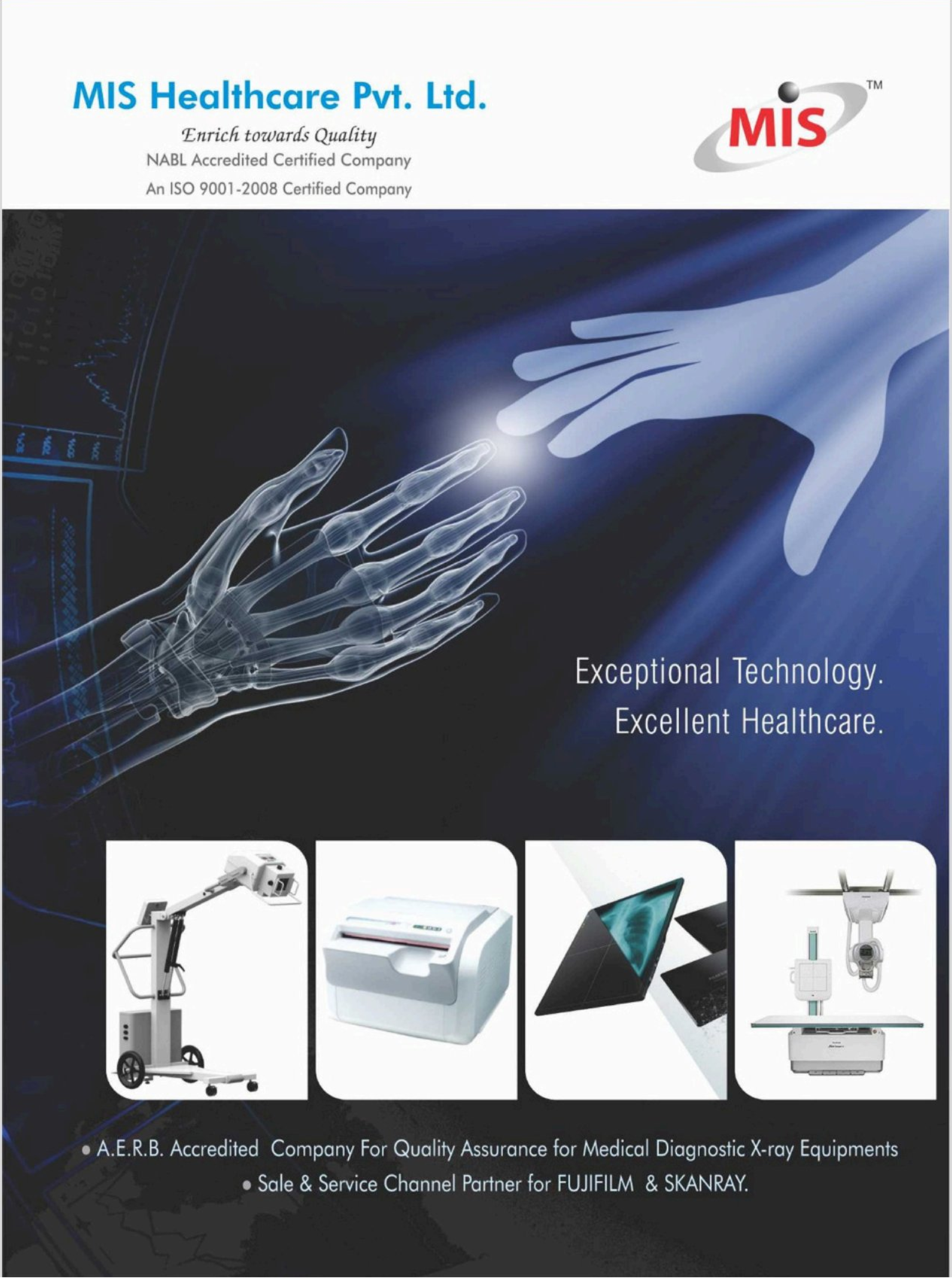
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Excellent Healthcare.
• A.E.R.B. Accredited Company For Quality Assurance for Medical Diagnostic X-ray Equipments
• Sale & Service Channel Partner for FUJIFILM & SKANRAY.

Diffuse Optical Tomography

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Abstract: Diffuse Optical Tomography (DOT) is a new non-invasive imaging technique that uses near-infrared light to create three-dimensional models of tissue physiology. DOT, unlike traditional radiological techniques that focus on anatomical features, provides functional and metabolic insights by measuring hemodynamic responses and oxygenation levels in tissues. This review delves into the ideas, methodology, clinical applications, and radiological relevance of DOT, with a particular emphasis on current developments like as deep learning integration and wearable technology. Despite limitations in spatial resolution and tissue penetration, DOT is showing considerable promise in neurology, cancer, and infant care, placing itself as a complementary tool in the ever-changing medical imaging landscape.

Key Words: Diffuse Optical Tomography, Near-Infrared Imaging, Functional Imaging, Tissue Oxygenation, Medical Radiology, Breast Cancer Imaging, Neurological Monitoring, Deep Learning, Non-invasive Diagnostics

Introduction

A new non-invasive imaging method called diffuse optical tomography (DOT) makes use of near-infrared (NIR) light to produce three-dimensional maps of tissue oxygenation and haemodynamics. DOT is mostly functional, offering real-time insights into tissue physiology such as blood flow, oxygenation levels, and metabolism, in contrast to conventional radiological techniques like CT or MRI that provide structural information (Jiang, 2011). Due to its cost-effectiveness, mobility, and safety, the approach has gained popularity recently, especially for use in paediatric, cancer, and neurology (Durduran & Yodh, 2014).

Utilising the distinct absorption properties of oxy- and deoxy-hemoglobin in the near-infrared spectrum, DOT is perfect for determining tissue oxygenation and perfusion. As the study of non-ionizing diagnostic tools advances, DOT keeps showing promise as an alternative and improvement to conventional imaging techniques.

Working Principle

The basic principle of Diffuse Optical Tomography (DOT) involves projecting near-infrared (NIR) light—typically within the 650–900 nm range—into biological tissue using light sources or fiber optics. As the light propagates through the tissue, it undergoes multiple scattering and absorption events, primarily due to the presence of chromophores such as oxygenated and deoxygenated hemoglobin. This interaction alters the light's path and intensity.

Detectors placed at varying distances from the light source collect the remitted light, which carries information about the tissue's optical properties, particularly absorption and scattering coefficients (Durduran & Yodh, 2014). The recorded data is then used to reconstruct tomographic images that reflect the spatial distribution of these optical properties.

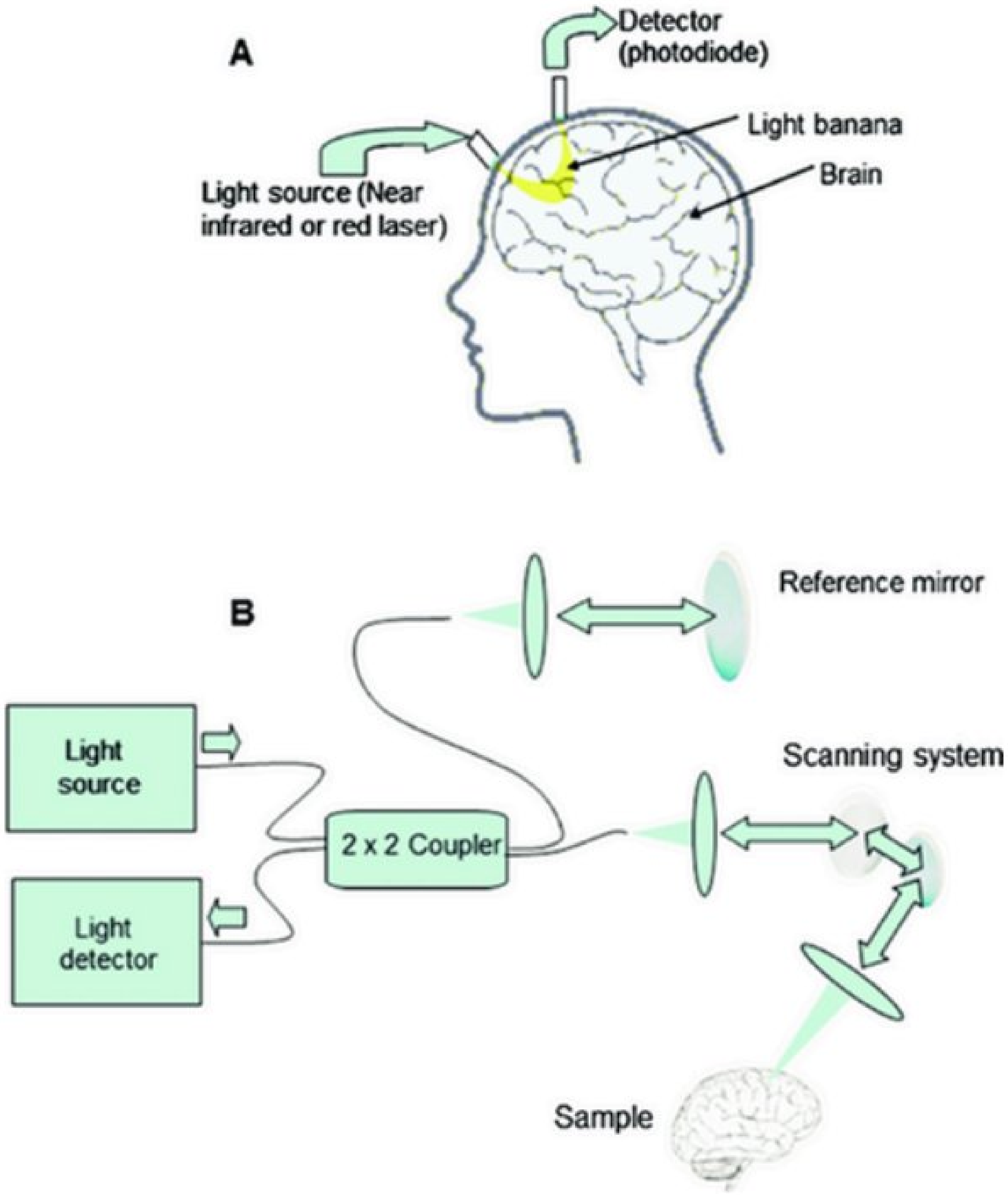

Figure 1: Principles of Diffuse Optical Tomography

Diffuse Optical Tomography (DOT) systems are generally categorized into three main types, each with distinct strengths:

Continuous Wave (CW) Systems: These measure the reduction in light intensity as it passes through tissue. CW systems are relatively simple and cost-effective but are limited in their ability to provide detailed depth information.

Frequency Domain (FD) Systems: These systems assess both the intensity and the phase shift of modulated light waves. Compared to CW systems, they offer improved depth resolution, making them suitable for more accurate tissue characterization.

Time Domain (TD) Systems: TD systems detect the precise arrival times of photons, enabling high-resolution, depth-sensitive imaging. However, they require sophisticated and expensive hardware due to the complexity of their electronics.

A notable recent advancement in DOT is the integration of frequency-domain techniques with deep learning models, particularly Convolutional Neural Networks (CNNs). This combination has significantly enhanced image reconstruction capabilities, allowing for the generation of multi-parametric images with greater speed and precision. These deep learning-driven approaches effectively address traditional challenges in resolution and computational efficiency (Dong et al., 2023).

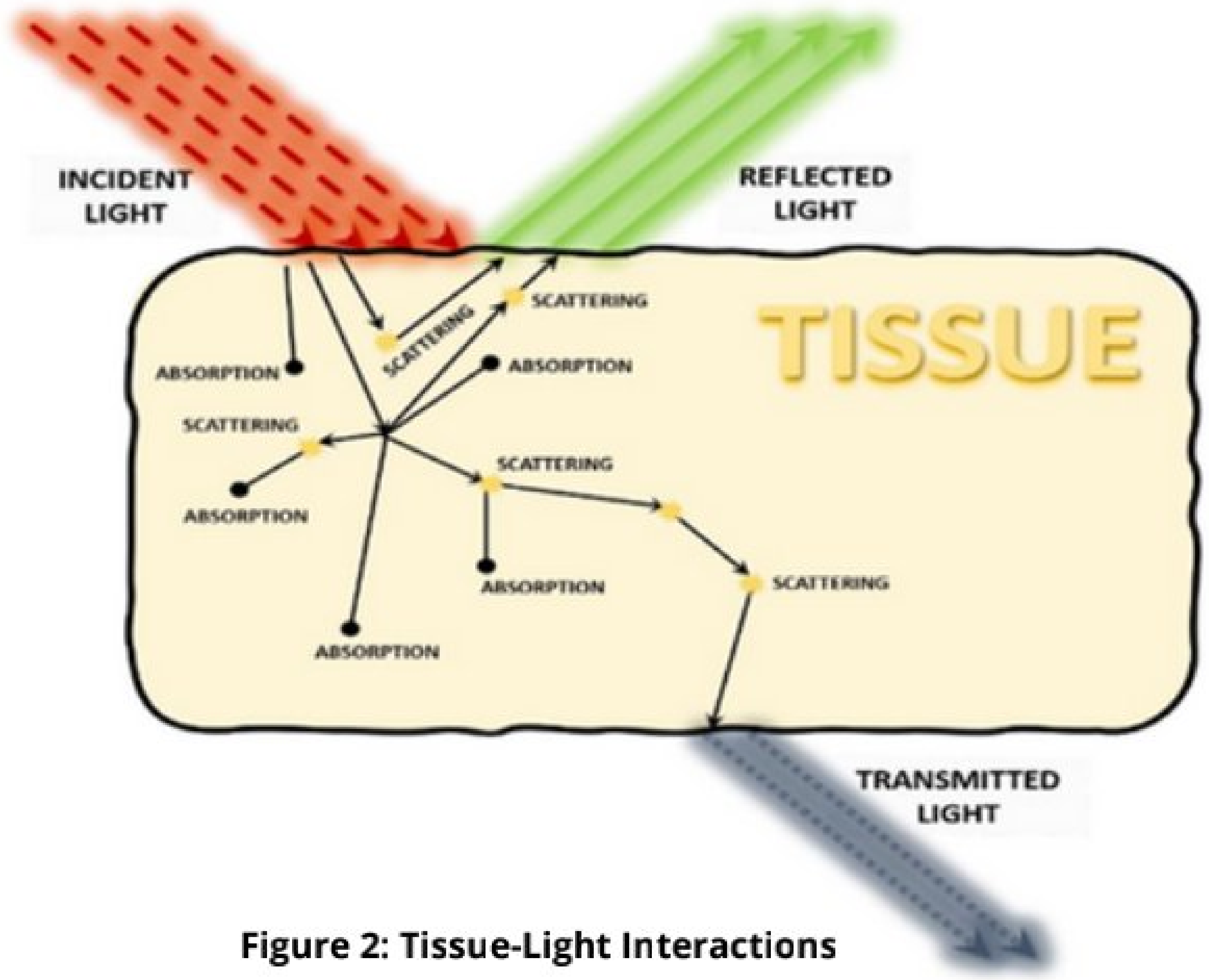

Figure 2: Tissue-Light Interactions

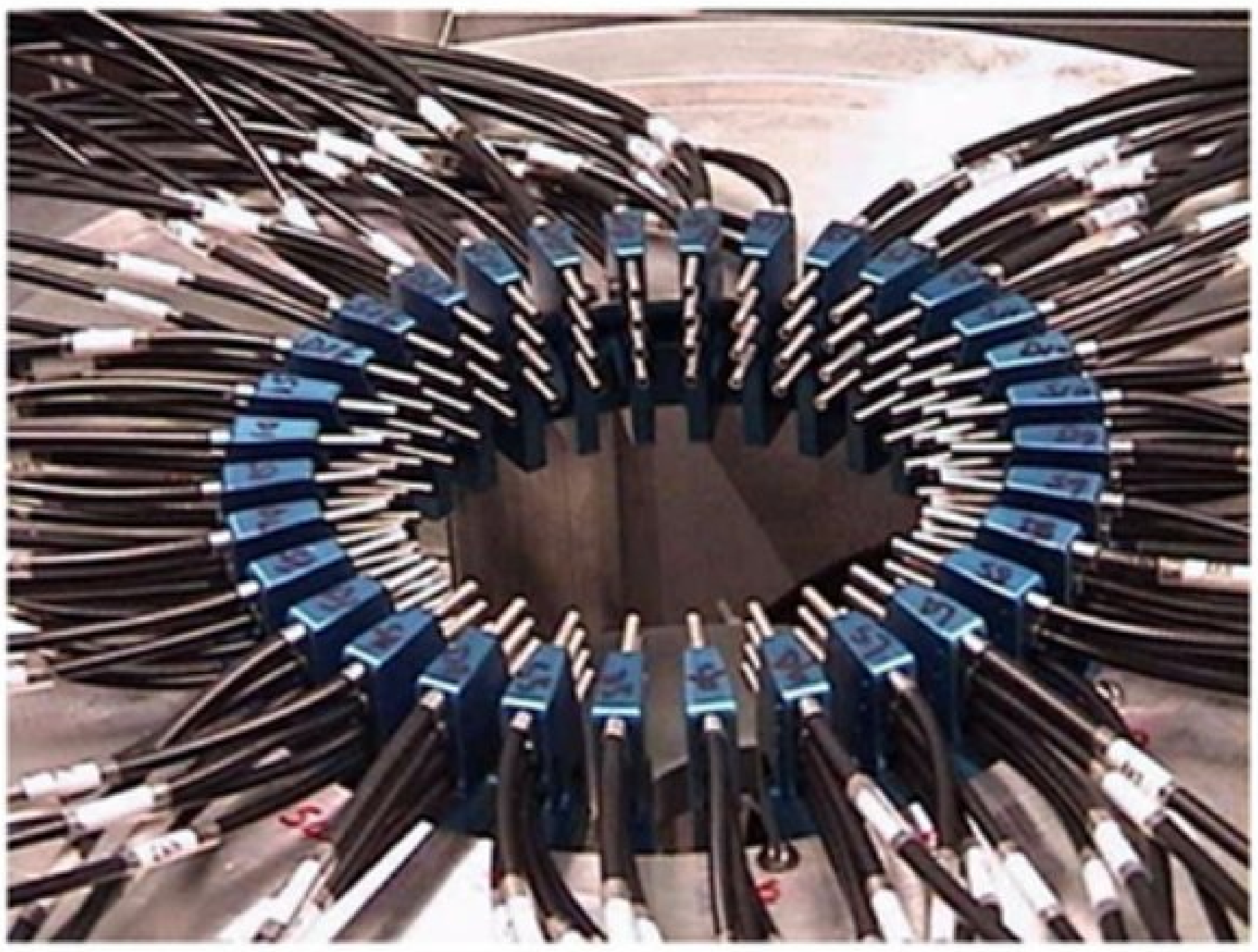

Figure 3: A fiber-optic array for breast cancer detection by way of diffuse optical tomography.

Clinical Applications

DOT has found applications across several medical fields due to its real-time functional imaging capabilities:

Neurology: DOT is widely used in functional brain imaging, especially in infants and during tasks to assess cerebral hemodynamics. It is effective in monitoring conditions like epilepsy and hypoxic-ischemic injury (University of Florida, 2023).

Oncology: In breast cancer diagnostics, DOT assists in differentiating benign and malignant tumors based on vascularization and oxygen metabolism. It is often used alongside ultrasound or mammography for greater specificity (Jiang, 2011).

Neonatology: DOT is particularly valuable for monitoring cerebral oxygenation in premature infants, where MRI and CT may pose risks or logistical challenges (Martinos Center, 2012).

Muscle Physiology: Sports science uses DOT to study muscle oxygen dynamics during exercise and recovery.

Therapy Monitoring: In oncology, DOT tracks changes in tumor blood flow and oxygenation, offering a non-invasive means of evaluating chemotherapy response (Dong et al., 2023).

Advantages:

Non-ionizing: Safer for repeated use, especially in sensitive populations.

Functional Imaging: Capable of assessing metabolic activity, not just structure.

Portability: Compact systems can be used bedside or in ambulatory settngs.

Cost-effectiveness: Lower operational costs compared to MRI or PET.

Disadvantages:

Low Spatial Resolution: Light scattering limits image sharpness compared to CT or MRI.

Limited Penetration Depth: Effective only in superficial tissues (up to ~10 cm).

Complex Reconstruction Algorithms: Requires robust computational support and expertise.

Noise Sensitivity: Susceptible to motion artifacts and signal interference.

Diffuse Optical Tommography In Radiology

While DOT is not a replacement for traditional radiological imaging, it complements existing modalities by providing dynamic physiological data. In radiology, its strength lies in functional imaging — observing how tissues behave over time or in response to stimuli or treatment. Hybrid approaches, such as DOT-MRI or DOT-CT fusion, are being explored to combine anatomical and functional insights in a single imaging session. Wearable DOT systems are also being developed for continuous monitoring of brain activity, expanding its use beyond hospital settings (Lee et al., 2023).

Radiation Type	Near-Infrared Light	Magnetic Field	Ionizing Radiation
Functional Imaging	Yes	Limited	No
Anatomical Detail	Low	High	High
Penetration Depth	Few cm	Whole Body	Whole Body
Safety	Very High	High	Moderate
Portability	High	Low	Low
Cost	Low	High	Moderate

Table 1: Comparison between Diffuse Optical Tomography and other Imaging Modalities

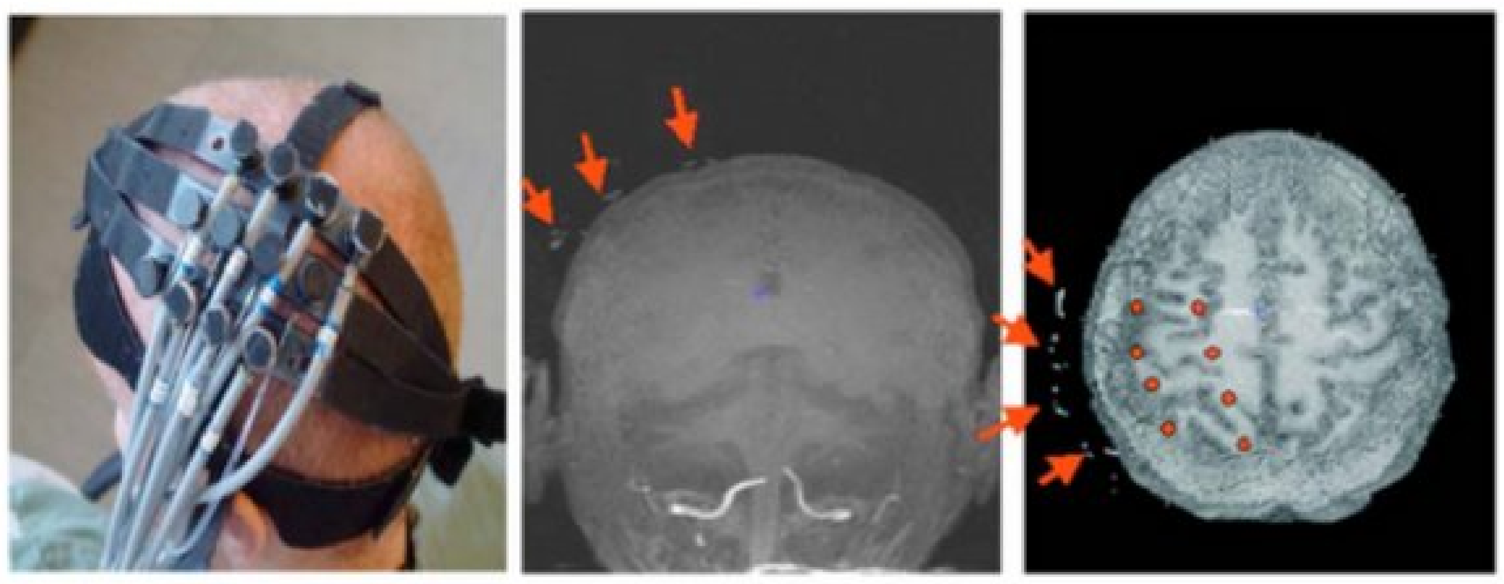

Figure 4: DOT spectroscopic measurements of optical absorption changes to record hemoglobin concentration changes

Future Implementations and Challenges

While diffuse optical tomography is gaining popularity as a powerful imaging method, some problems remain. The key constraints are limited tissue penetration and relatively low spatial resolution due to the diffusive nature of Near Infrared light. External factors such as patient movement and ambient light also influence data quality. However, advances in hardware miniaturization, computational enhancements based on artificial intelligence, and integration with other imaging systems (e.g., DOT-MRI fusion) are paving the way for wider clinical application. Future developments aim to improve DOT's accuracy, accessibility, and applicability in emergency, ambulatory, and home-care settings, expanding its reach beyond specialized clinics.

Conclusion

Diffuse Optical Tomography (DOT) stands at the forefront of a new generation of imaging modalities that prioritize functional, safe, and accessible diagnostics. By leveraging near-infrared light, DOT provides critical insights into tissue oxygenation and hemodynamics—offering a powerful complement to conventional anatomical imaging techniques. While current limitations in spatial resolution and depth penetration remain, rapid advances in computational methods, particularly deep learning, are driving substantial improvements in image quality, processing speed, and diagnostic accuracy. The emergence of wearable DOT systems and hybrid imaging approaches further signals a transformative shift in clinical practice—enabling continuous, real-time monitoring in both hospital and non-clinical settings. As research and technology continue to evolve, DOT is poised to play an increasingly vital role across diverse domains such as neurology, oncology, neonatology, and personalized medicine, ultimately contributing to more informed, timely, and patient-centered care.

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The MedFuture India Conference is set to act as a catalyst for transformative change in the healthcare industry, paving the way for a more innovative and future-ready approach to medical training.

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Association of Healthcare Providers (India) represents the vast majority of healthcare providers in India. The Association of Healthcare Providers (India)'s vision is to have a healthy India, encompassing society, community and common man at grass root. The Association of Healthcare Providers (India) envisions a healthy India, with a focus on improving the well-being of society, communities, and individuals at the grassroots level.

AHPI represents more than 20,000 hospitals and healthcare institutions across India. Its goal is to unify healthcare providers to work collaboratively with the government and society to enhance the well-being of the common man and build a healthier India.

AHPI organizes a wide range of conferences, events, and workshops focused on the healthcare sector in India bringing together healthcare professionals, policymakers, and industry leaders to address the latest developments, challenges, and opportunities in hospital management, healthcare delivery, and policy.

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  - Assessment Models for Competency-Based Education
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How Printable Organic Sensors are making X-ray Detection more precise for Cancer Care

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Introduction

Cancer continues to be one of the most pressing health challenges globally, affecting millions of lives each year. Radiation therapy is a cornerstone of cancer treatment, but traditional X-ray detection systems used in this process have significant limitations. These systems often lack precision, are costly, and can pose risks to patients due to their reliance on ionizing radiation. These challenges have driven the need for innovative solutions that can improve the accuracy, safety, and affordability of radiation therapy. Enter printable organic sensors -a groundbreaking technology that is transforming X-ray detection in cancer care. These sensors, made from carbon-based materials, offer unparalleled advantages, including high sensitivity, flexibility, and bio compatibility. With a 99.8% beam transmission rate and 2% detection accuracy, printable organic sensors enable real-time monitoring of radiation therapy, a capability that was previously unattainable with traditional systems. This article delves into the evolution of organic semiconductor sensors, their manufacturing process, technical advantages, and integration into existing medical systems, while also exploring current research that highlights their potential to revolutionize cancer care.

The Evolution of Organic Semiconductor Sensors in Medical Imaging

Traditional X-ray Detection Limitations in Cancer Treatment

Ionizing Radiation Risks:

- Traditional X-ray detectors use ionizing radiation, which can damage DNA and increase a patient's lifetime risk of developing cancer.
- **Example:** An abdominal/pelvic CT scan delivers an effective dose of 10 mSv, equivalent to 4.5 years of natural background radiation.
- **Risk:** 1:2000 risk of fatal cancer in patients aged 16-69 years, with young patients facing up to five times this risk.
- **Accuracy Issues:** Chest X-rays miss lung cancer in more than 20% of cases, leading to delayed diagnoses.
- **Rigid Structure:** Conventional detectors' rigid structure limits their use in medical settings, particularly during treatment monitoring.

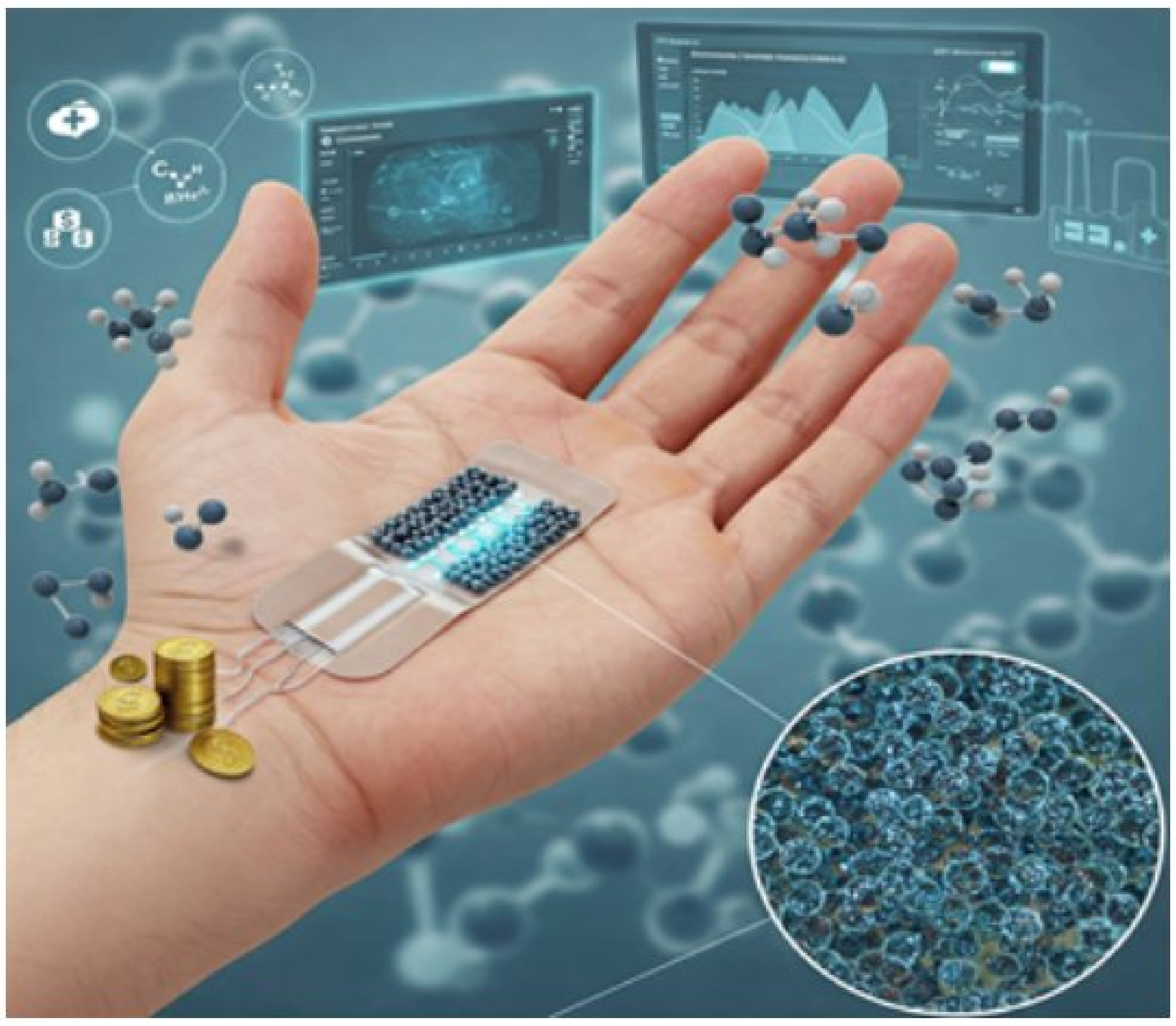

Fig: A flexible biosensor implanted in a hand, surrounded by carbon molecular structures symbolizing tun-ability.

Breakthrough Properties of Carbon-Based Sensing Materials

- **Bio compatibility:** Organic materials interact directly with biological systems without causing adverse reactions, making them ideal for implantable biosensors and in vivo monitoring.
- **Flexibility:** Unlike rigid traditional detectors, carbon-based materials can adapt to the human body, expanding their use in customized healthcare.
- **Cost-effectiveness:** Affordable production methods and solution-based fabrication techniques enable large-scale production of organic sensors.
- **Tun-ability:** Scientists can modify the electronic properties of organic materials for specific applications, enhancing their performance in medical imaging.
- **Surface Structures:** Carbon-based materials, particularly tetrahedral amorphous carbon (ta-C), create complex functionalized surface structures that improve sensitivity for analyte detection.

How Organic Materials Respond to Radiation Differently

- **Biocompatible Response:** Organic X-ray sensors provide a bio compatible response to ionizing radiation, transmitting 99.8% of the radiation beam under conventional radiotherapy conditions while detecting X-rays with 2% accuracy.

- **Charge Carrier Mobility:** Organic semiconductors exhibit exceptional charge carrier mobility, enabling electronic circuits with sharp turn-on and quick switching capabilities needed for medical imaging applications.
- **Wearable Sensors:** Wearable organic X-ray sensors represent a significant breakthrough, allowing continuous monitoring during treatment with high sensitivity suitable for advanced treatment modalities like Microbeam Radiation Therapy (MRT).

Fig: Wearable organic X-ray sensors. Show them in the form of flexible patches or wristbands, actively monitoring during treatment.

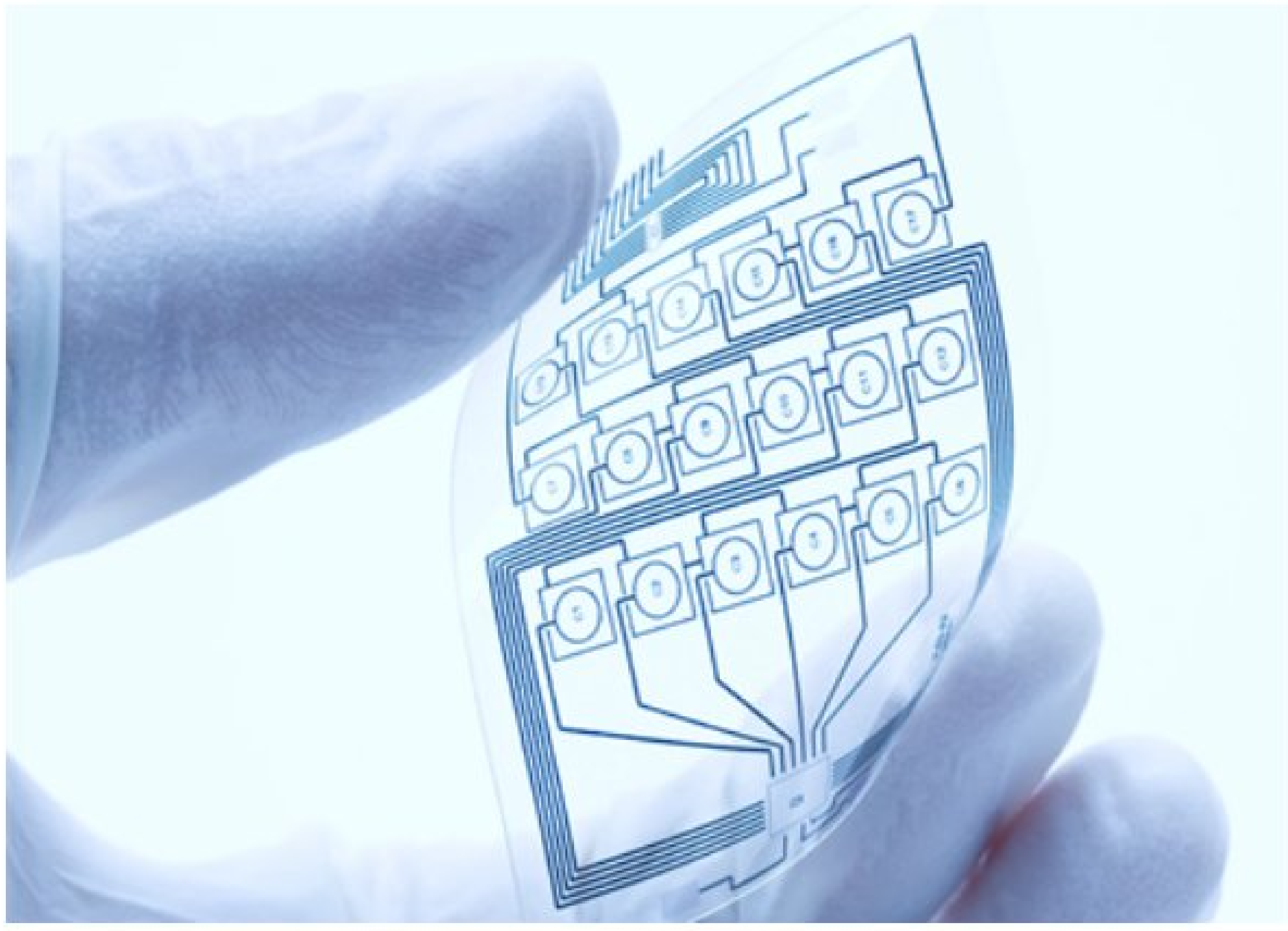

Fig: Wearable organic X-ray sensors.

Printable Fabrication Techniques for Flexible Sensors

- **Ink jet Printing:** Deposits organic semiconductors and quantum dots on various substrates, creating large-area sensor arrays that can bend easily.
- **Low-Temperature Processing:** Sensors are processed at low temperatures (usually below 150°C), compatible with heat-sensitive flexible materials like PET, polyimide, and polyethylene naphthalate.

Other Fabrication Methods:

- **Spin-coating:** Creates uniform thin films.
- Drop-casting: Suitable for thicker active layers (around 20µm).
- Vacuum evaporation: Deposits metal electrodes.
- **Roll-to-roll processing:** Enables industrial-scale production.

Cost-Effective Production Methods

- **Solution-Based Methods:** Organic sensors use solution-based methods that are more cost-effective and environmentally friendly compared to traditional detectors requiring thick crystals (1mm-1cm).
- **Material Efficiency:** Printing processes waste less material than traditional manufacturing techniques.
- **Energy Efficiency:** Room temperature processing or minimal heating reduces energy consumption during production.
- **Example:** Scientists developed budget-friendly flexible ionizing ray sensors using lead tungstate nanoparticles ($PbWO_4$ NPs) in polymer substrates, offering both economic and performance benefits.

Quality Control Challenges in Medical-Grade Sensors

- **Performance Impact:** Small manufacturing changes can significantly affect performance, requiring real-time detection systems.
- **Key Quality Control Factors:** Precision, Accuracy, Sensitivity, Repeatability, and Quantitation Range: Must be assessed without destroying or invading the sensors. Bio compatibility, Mechanical Durability, and Radiation Sensitivity: Thorough testing required for medical applications.
- **Balancing Automation and Costs:** Over-engineered solutions could price out potential users, making cost-effective quality control strategies essential.

Technical Advantages of Organic X-ray Sensors in Radiotherapy

99.8% Beam Transmission Rate for Uninterrupted Treatment

- **Near-Perfect Transmission:** Organic sensors transmit 99.8% of the radiation beam, allowing direct positioning in the beam path without disrupting the prescribed treatment dose.
- **Continuous Monitoring:** Traditional detectors often require treatment pauses or dose adjustments, but organic sensors enable continuous monitoring without interruption.

Up-to-the-Minute Data Analysis Capabilities

- **Immediate Feedback:** Organic radiation sensors provide immediate feedback on radiation exposure, enabling precise treatment adjustments.
- **Fast Response:** Certain organic field-effect transistor-based sensors (RAD-OFETs) respond in sub-microsecond time scales—the fastest ever observed for organic semiconductors.

Tissue-Equivalent Response for Accurate Dosimetry

- **Human Tissue Composition:** Organic sensors contain carbon and hydrogen, similar to human tissue, reducing correction factors needed to estimate actual dose delivery.

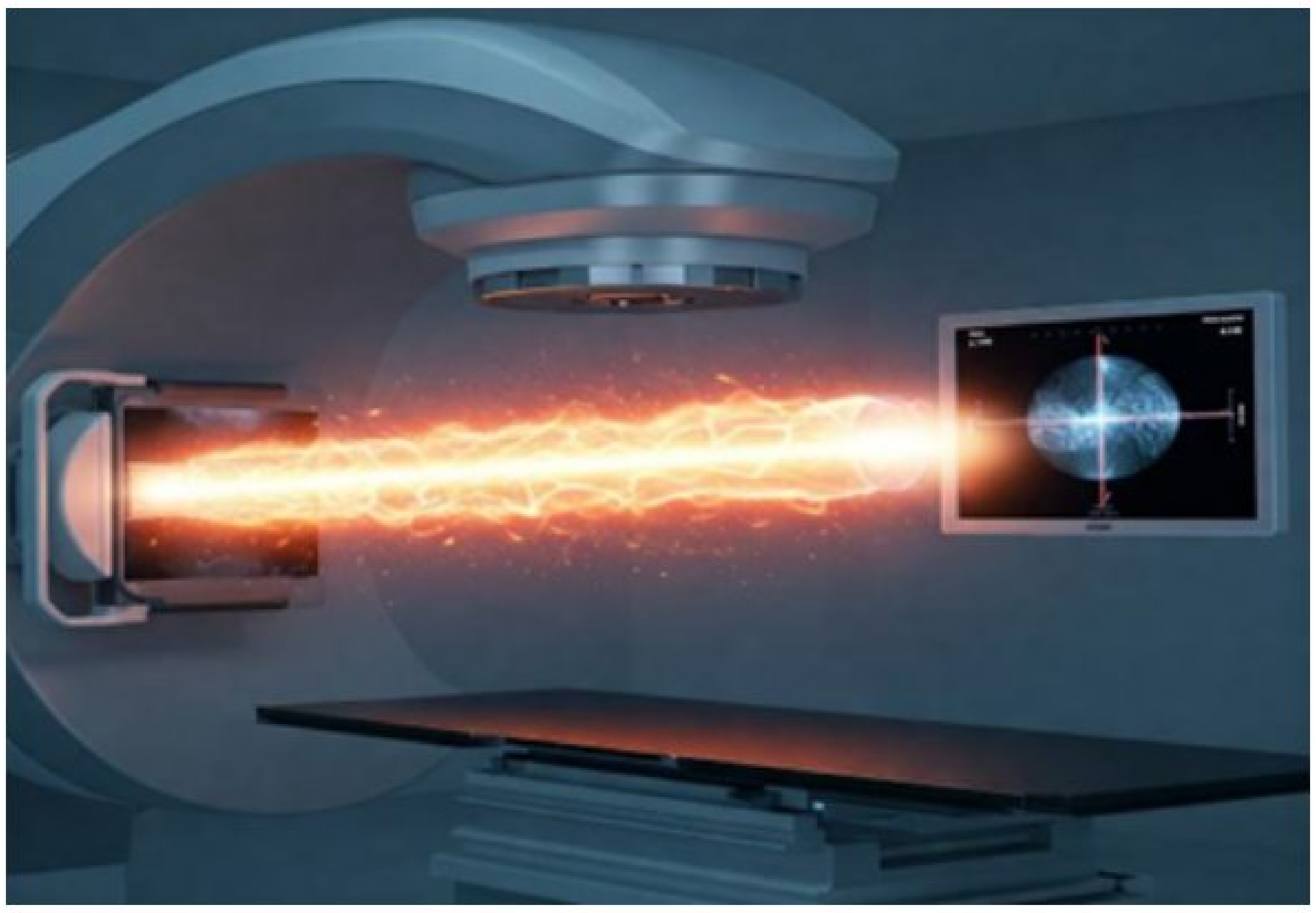

Fig: An organic X-ray sensor is integrated directly into the radiation beam path, transmitting 99.8% of the beam without interruption.

- **Mirror Human Response:** These sensors mirror the human body's response to radiation, outperforming conventional silicon detectors that show up to a 7-fold over-response compared to human tissue at lower energies.

FIG: Organic sensors integrated into a medical treatment environment, highlighting their tissue-equivalent response. Include molecular structures of carbon and hydrogen to represent their composition, alongside a human figure undergoing radiation therapy.

Microbeam Radiation Detection with 2% Precision

High Precision: Organic sensors detect microbeam X-rays with 2% precision, resolving multiple 50 µm-wide X-rays with a full-width-half-max of (51.6 ± 1.9) µm across energy ranges of 47–87.5 keV.

Advanced Treatment Techniques: This spatial resolution is crucial for advanced treatment techniques that require pinpoint accuracy.

integration with Existing Medical Systems and Workflows

Hardware Compatibility with Current Radiotherapy Equipment

- **Ultra-Thin Profile:** Printable organic sensors' ultra-thin profile and flexible construction make them highly compatible with modern radiotherapy systems.
- **Direct Placement:** These sensors can be placed directly in the beam path without altering treatment delivery, thanks to their 99.8% beam transmission rate.
- **MRI-Guided Systems:** Organic sensors provide significant benefits to MRI-guided linear accelerator systems, detecting steep dose changes in microbeam radiation therapy (MRT) with 2% precision.

Software Integration for Dose Calculation and Monitoring

- **Data Interfaces:** Organic sensors require simple data interfaces to integrate with current oncology software systems.
- **Adaptive Radiotherapy Platforms:** The data produced by organic sensors is compatible with adaptive radiotherapy platforms, enabling treatment adjustments based on dosimetric information.
- **Wireless Capabilities:** Many organic sensor systems feature wireless capabilities, connecting to Internet of Things (IoT) platforms for immediate data analysis and better clinical decisions.

Training Requirements for Radiation Oncology Teams

- **Certification Training:** Medical physicists need certification training covering quality assurance procedures for organic sensors.
- **Practical Experience:** Radiation oncologists must gain practical experience in interpreting live data from the sensors.
- **Bridging Knowledge Gaps:** Training programs must bridge the gap between radiation physics, medical electronics, and clinical oncology for successful implementation.

Current Research on Organic and Inorganic Materials Based Sensors

University of Wollongong's Breakthrough Studies Dr. Jessie Posar's Team:

- Demonstrated that organic sensors transmit 99.8% of the radiation beam while detecting effectively.
- Proved flexible organic sensors can detect microbeam X-rays with a precision of 2%, matching silicon-based detectors' performance in dangerous radiation fields.
- Potential to "revolutionize personalized radiation therapy, offering a new level of safety and effectiveness in patient care."

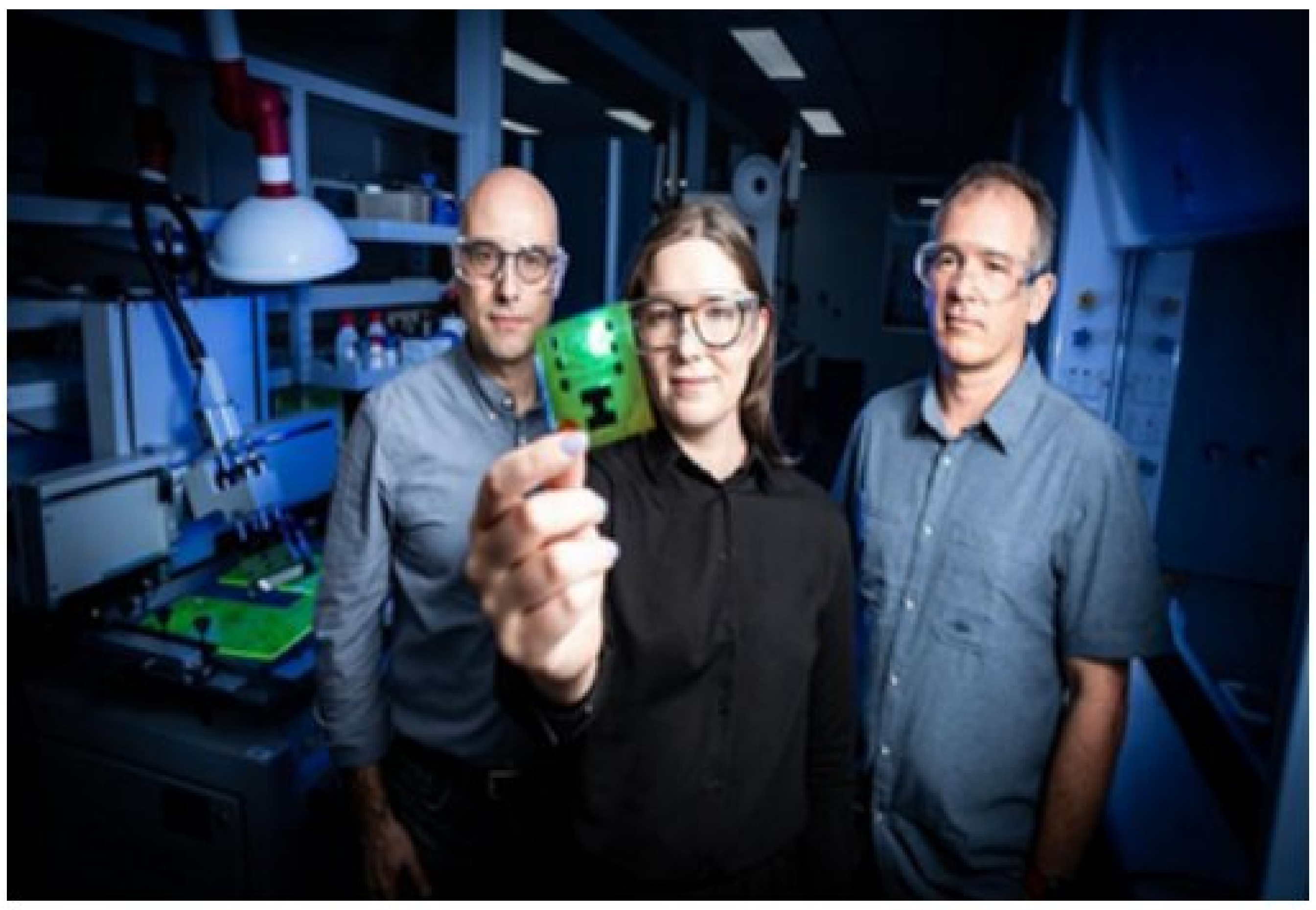

Fig: New research shows promising signs in the effort to develop safer radiotherapy protocols (Photo courtesy of University of Wollongong).

Comparison with Silicon-Based Detection Systems

- **Traditional Drawbacks:** Silicon-based detectors require thick crystals, resulting in rigid structures, high operational voltages, and high costs.

Organic Advantages:

- Organic semiconductor sensors offer remarkable sensitivity values under both soft and hard X-rays.
- Adding bromine atoms to carbazolyl-type organic molecules improves X-ray absorption, with four bromine atoms per molecule yielding the best results.

Metal Organic Framework Materials as Alternative Chemical Sensors

- **MOFs(Metal-organic frameworks):** MOFs combine metal nodes with organic linkers to create highly porous structures.

Advantages:

- High sensitivity, quick response times, strong absorption coefficients, and radiation stability.
- Excellent candidates for future sensing technologies due to their adjustable pore environments and molecular sieving capabilities.

Conclusion

Printable organic sensors represent a monumental leap forward in the precision and safety of radiation therapy for cancer care. With their 99.8% beam transmission rate and 2% detection accuracy, these sensors allow for continuous, real-time monitoring of radiation therapy without disrupting treatment delivery. Their tissue-equivalent properties, which mirror the human body's response to radiation, offer a level of accuracy that traditional detectors simply cannot match. The cost-effective and scalable manufacturing processes of these sensors make them accessible for widespread clinical adoption, addressing the limitations of rigid, expensive traditional systems. Researchers, particularly at institutions like the University of Wollongong, have demonstrated the durability and effectiveness of organic sensors in challenging radiation environments, paving the way for their integration into existing medical workflows. As radiation oncology teams adapt to these new technologies, printable organic sensors are poised to revolutionize cancer treatment, offering improved outcomes for patients through precise, real-time monitoring. This innovation marks a new era in radiation therapy, where safety, accuracy, and patient care are prioritized like never before, promising a brighter future for cancer patients worldwide.

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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.

संपादक

Adapting Under Pressure: Modified CT Positioning in Emergency Stroke Imaging

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A Stroke of Urgency

In stroke care, the golden hour is a race against time. Every minute lost translates to nearly two million neurons destroyed. Diagnostic imaging—particularly Computed Tomography (CT)—has emerged as the frontline tool in distinguishing ischemic strokes from hemorrhagic ones, making it a key player in acute stroke triage.

But while the speed of imaging is critical, the reality of emergency care is rarely ideal. Patients arrive unresponsive, agitated, or severely debilitated. The traditional supine positioning, with precise head alignment, becomes less a standard and more a luxury. As stroke units and emergency departments strive to save time and optimize outcomes, the modification of patient positioning during CT imaging is becoming both a clinical necessity and a field of innovation.

The Science behind the Scan

CT imaging in stroke serves multiple purposes: ruling out hemorrhage, assessing early ischemic changes, identifying large vessel occlusions, and determining the extent of salvageable brain tissue via perfusion imaging. For accurate results, the patient's head must be immobilized and symmetrically positioned within the scanner's field of view.

Misalignment can result in:

- Image artifacts
- Poor resolution of key brain structures
- Increased radiation exposure due to scan repetition
- Diagnostic delays

In emergency situations, however, ideal positioning is often compromised. Radiologic technologists must make quick, creative decisions to get the best possible scan under challenging conditions.

Clinical Modifications: Evidence and Practice

A growing body of clinical experience—particularly in high-volume stroke centers and rural emergency settings—support practical modifications that do not compromise image quality. These include:

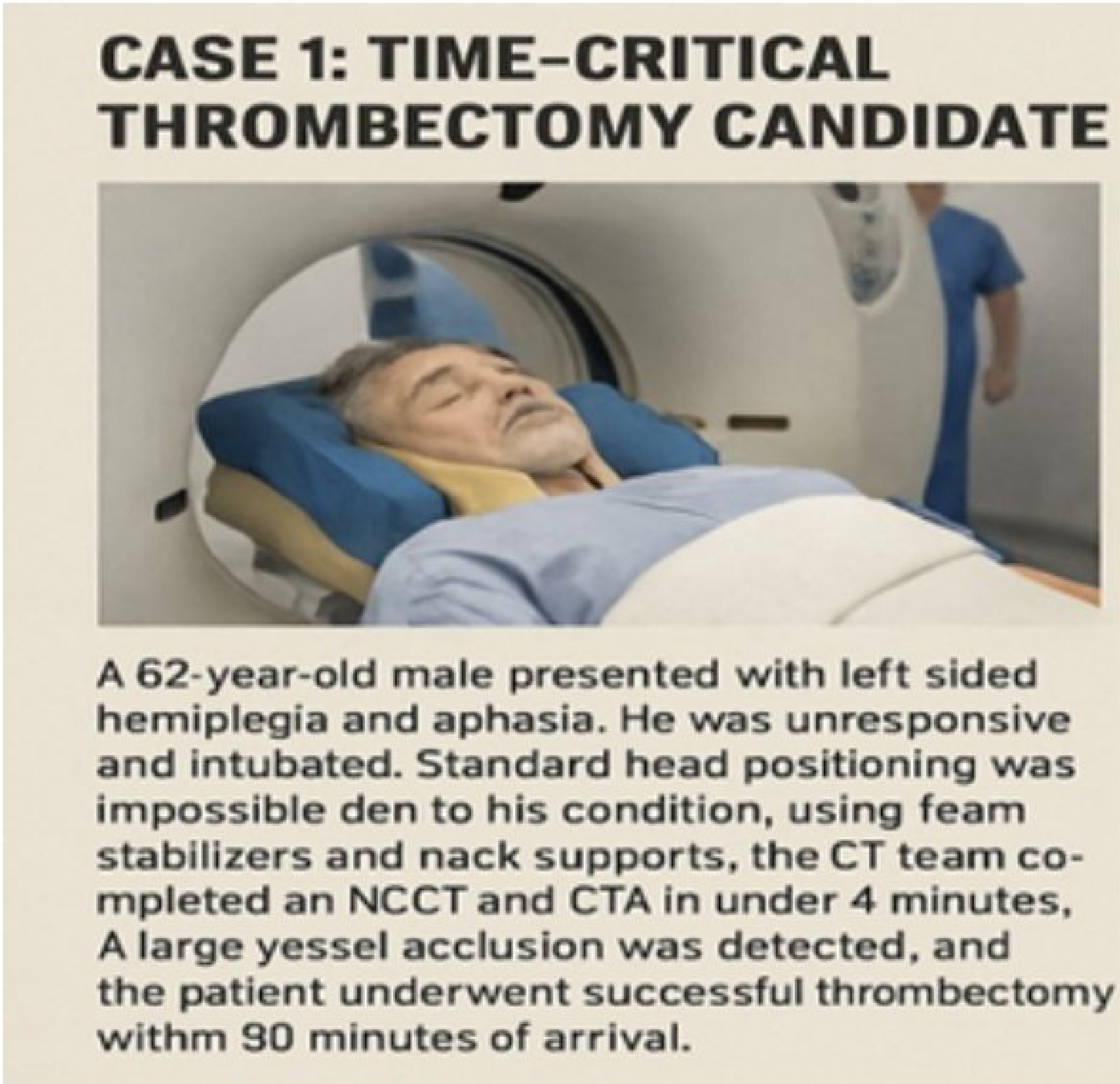
- Foam cushions and sandbags to stabilize the head in semi-conscious patients
- Gentle physical restraints or temporary sedation for agitated or combative individuals
- Orbitomeatal angling of the CT gantry to reduce radiation exposure to the lens in anticipated repeat scans
- Pediatric adaptations, such as towel rolls or custom pads for smaller head sizes
- In-line cervical imaging for patients with suspected spinal trauma, allowing scanning without removing immobilization devices

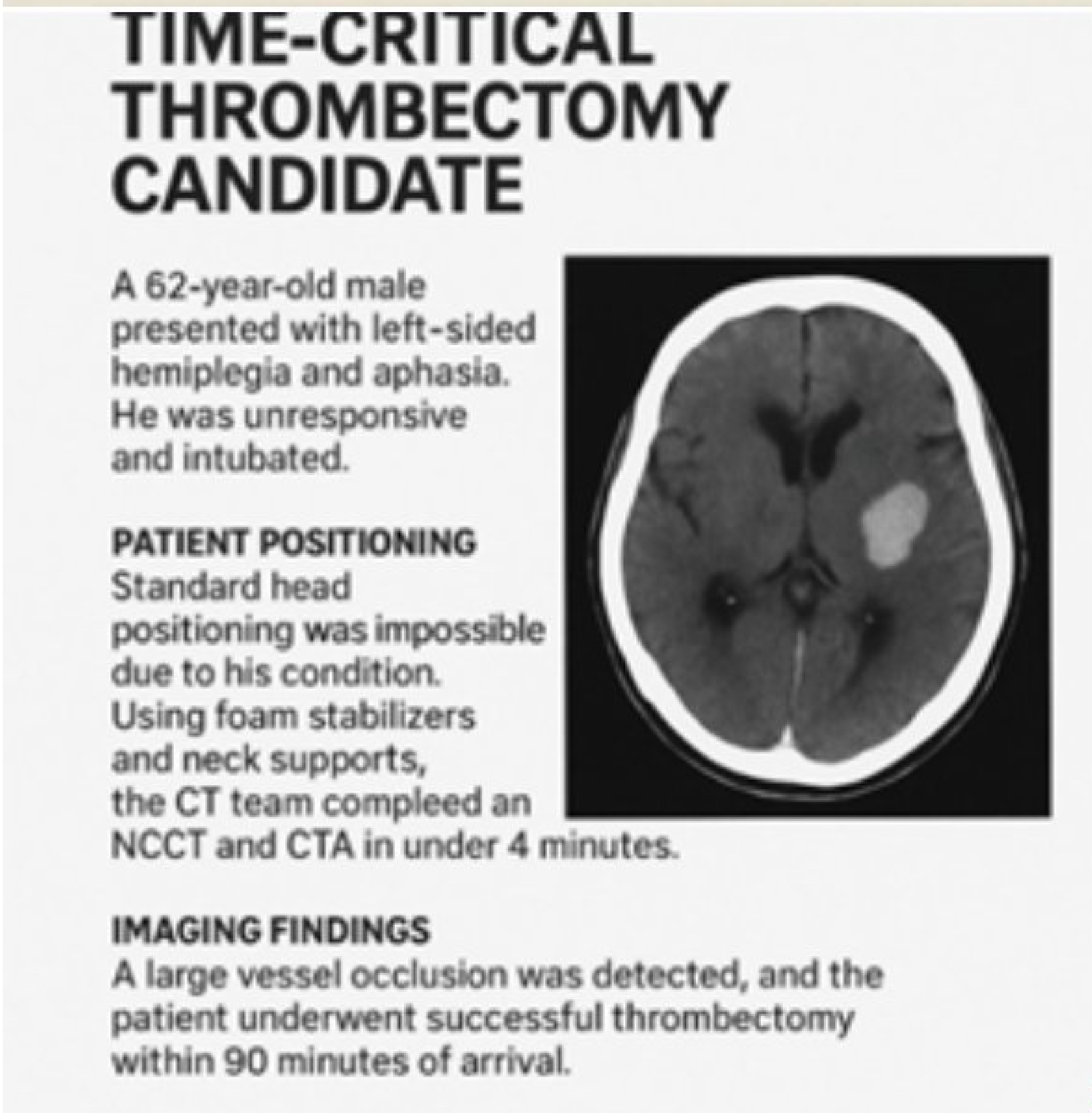
These adaptations must be guided by institutional protocols and safety guidelines, but when used judiciously, they significantly enhance workflow efficiency without affecting diagnostic yield.

Case Perspectives

Case 1: Time-Critical Thrombectomy Candidate

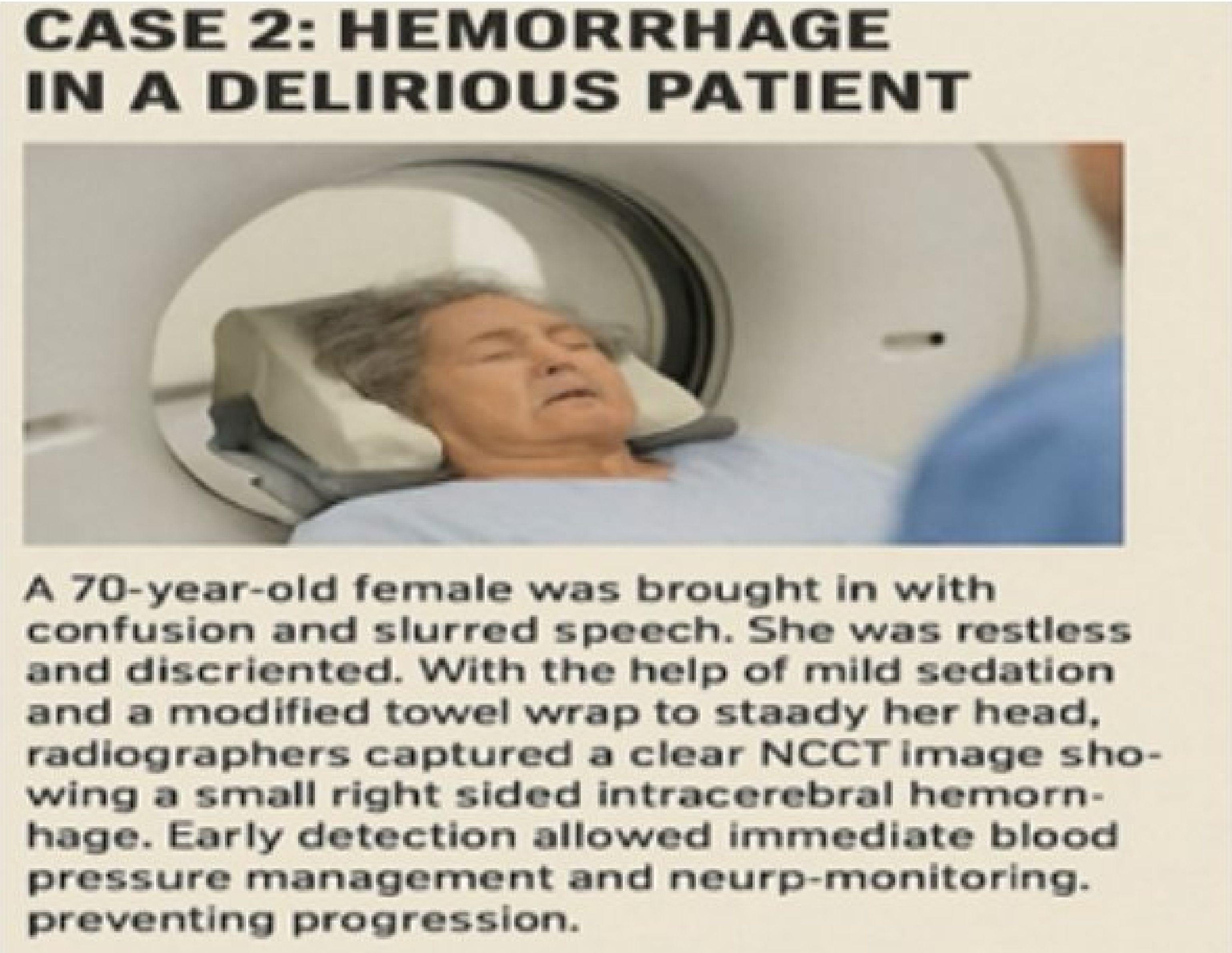
A 62-year-old male presented with left-sided hemiplegia and aphasia. He was unresponsive and intubated. Standard head positioning was impossible due to his condition. Using foam stabilizers and neck supports, the CT team completed an NCCT and CTA in under 4 minutes. A large vessel occlusion was detected, and the patient underwent successful thrombectomy within 90 minutes of arrival.

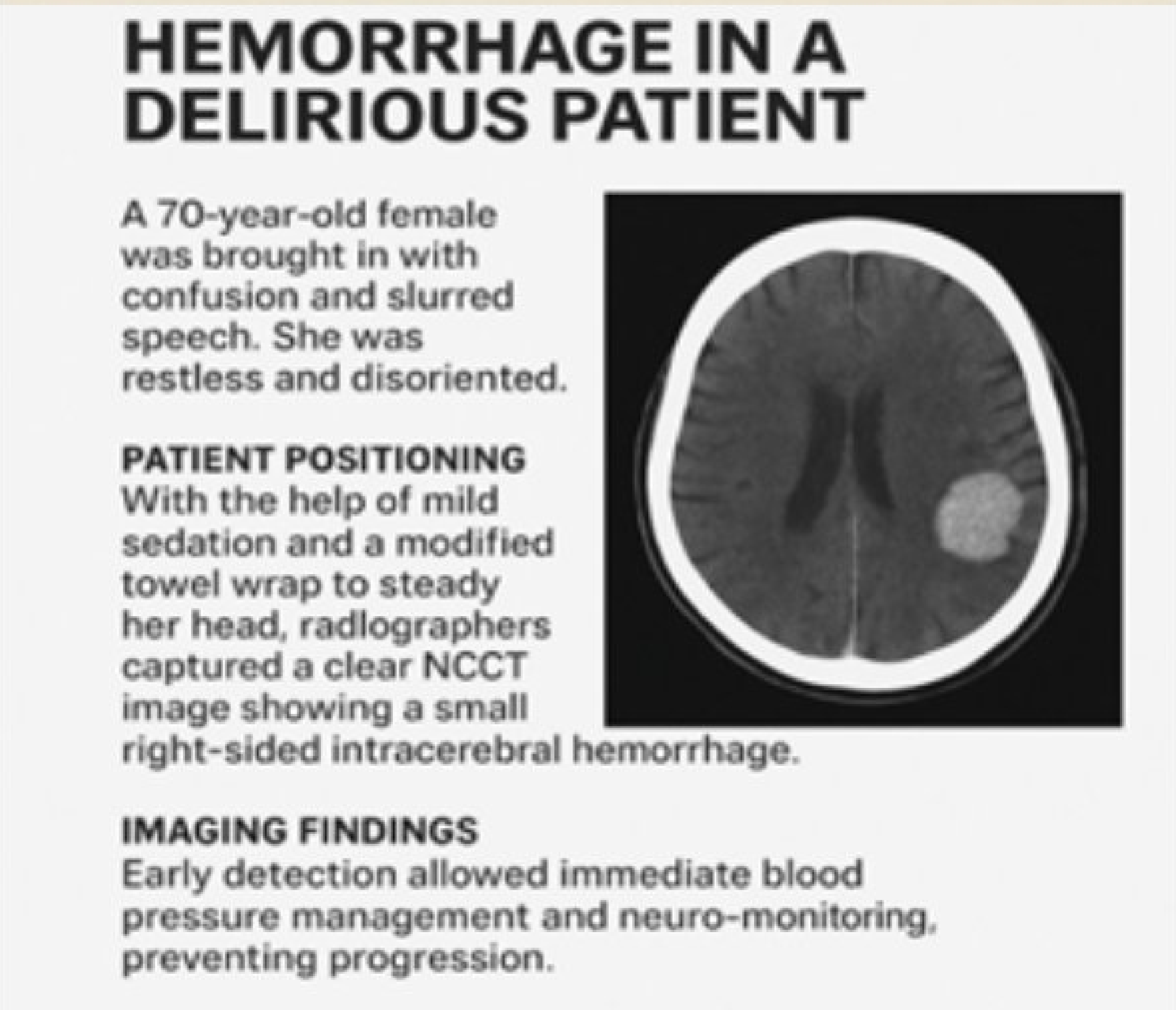




Case 2: Hemorrhage in a Delirious Patient

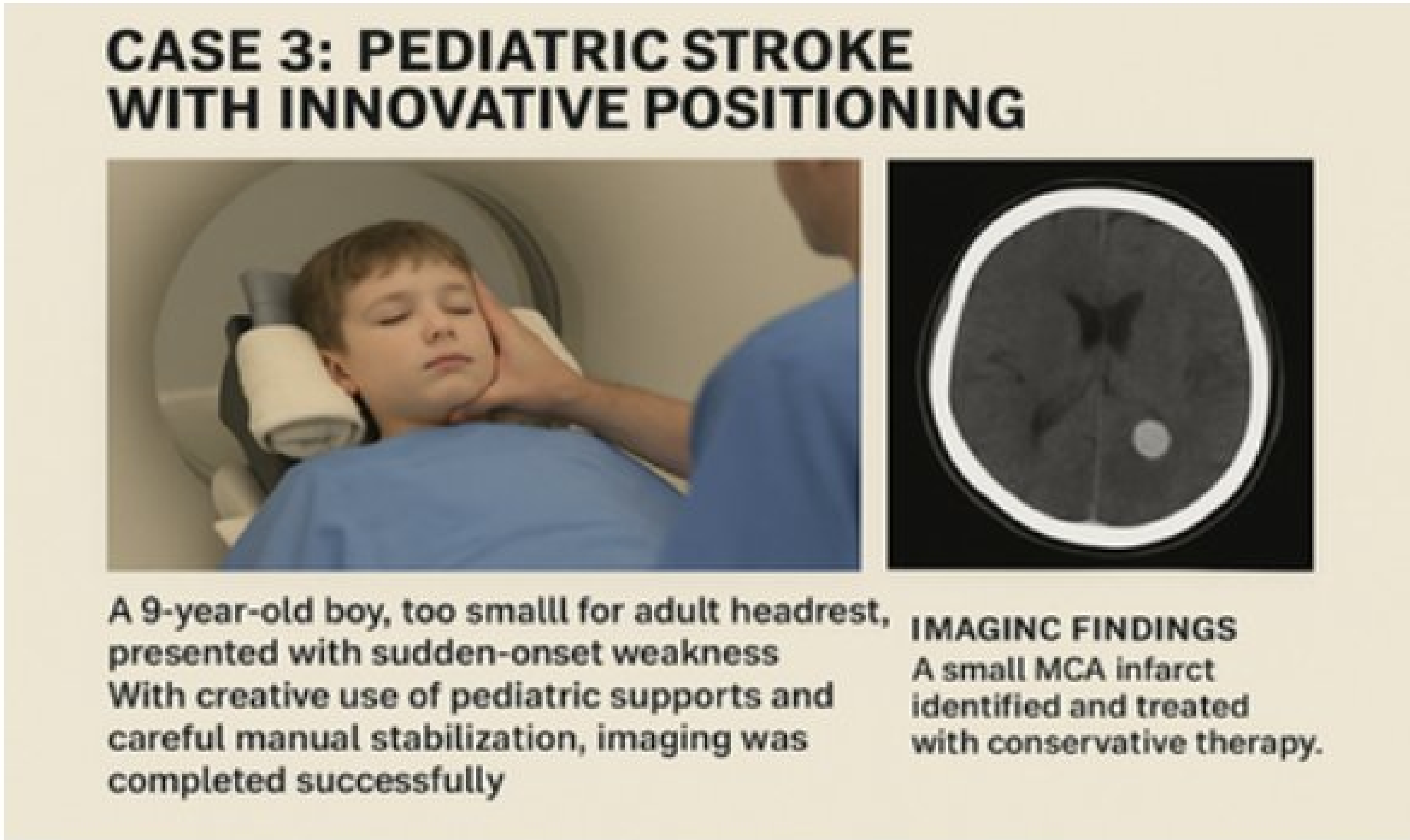
A 70-year-old female was brought in with confusion and slurred speech. She was restless and disoriented. With the help of mild sedation and a modified towel wrap to steady her head, radiographers captured a clear NCCT image showing a small right-sided intracerebral hemorrhage. Early detection allowed immediate blood pressure management and neuro-monitoring, preventing progression.





Case 3: Pediatric Stroke with Innovative Positioning

A 9-year-old boy, too small for the adult headrest, presented with sudden-onset weakness. With creative use of pediatric supports and careful manual stabilization, imaging was completed successfully. A small MCA infarct was identified and treated with conservative therapy.



Implications and Future Directions

These cases underline an emerging concept: technical adaptability in medical imaging can have a direct impact on patient outcomes. As artificial intelligence and automation expand within CT imaging systems, there may soon be real-time feedback on positioning quality and scan adequacy.

Furthermore, low-resource settings, such as in parts of India's Northeast including Mizoram, can benefit from standardized positioning kits and staff training in emergency CT adaptations. With limited access to advanced neurology services, optimized CT imaging becomes the linchpin of stroke care.

Conclusion

Modified patient positioning during emergency CT scans is not merely a workaround—it is an evolving science that intersects clinical urgency, radiologic precision, and human adaptability. As the burden of stroke continues to rise, especially in aging and high-risk populations, the ability to image under pressure could become one of the defining skills of modern emergency radiology.

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