Journal of Advanced Research in Intrumentation and Control Engineering
Volume 12, Issue 1&2 - 2025, Pg. No. 11-17
Peer Reviewed Journal

Review Article

Biomedical Imaging Technologies: A Comparative Study of MRI, CT, and Ultrasound Innovations

Vikram Singh

B Tech Final Year Student, Department of Instrumentation and Control, Indian Institute of Technology (IIT) Indore, India

INFO

E-mail Id:
vikram10singh@gmail.ac.in
Orcid Id:
https://orcid.org/0009-0008-1633-1396
How to cite this article:
Singh V. Biomedical Imaging Technologies: A Comparative Study of MRI, CT, and Ultrasound Innovations. *J Adv Res Instru Control Engi 2025; 12(1&2):* 11-17.

Date of Submission: 2025-02-07
Date of Acceptance: 2025-03-10

ABSTRACT

Biomedical imaging plays a crucial role in modern healthcare, offering non-invasive techniques for diagnosing, monitoring, and guiding treatments for various medical conditions. Advanced imaging technologies have significantly transformed clinical decision-making, enabling early disease detection and precise treatment planning. Among the most widely used imaging modalities, Magnetic Resonance Imaging (MRI), Computed Tomography (CT), and Ultrasound (US) stand out due to their diverse applications across multiple medical fields.

MRI is known for its high soft-tissue contrast and radiation-free imaging, making it ideal for neurological, musculoskeletal, and oncological applications. CT provides rapid, high-resolution cross-sectional imaging, making it invaluable for emergency diagnostics, trauma assessment, and vascular imaging. Ultrasound, being portable, cost-effective, and real-time, is extensively used in obstetrics, cardiology, and point-of-care diagnostics.

Recent innovations in biomedical imaging focus on enhancing resolution, speed, and accuracy while minimizing risks such as radiation exposure and scan-related artifacts. Advances such as AI-powered image reconstruction, photon-counting CT, elastography, and functional MRI (fMRI) are pushing the boundaries of imaging capabilities. Additionally, the integration of machine learning, deep learning algorithms, and hybrid imaging techniques (such as PET-MRI and CT-MRI) is revolutionizing image processing, analysis, and disease prediction.

This review provides a comparative analysis of MRI, CT, and ultrasound, discussing their fundamental principles, clinical applications, benefits, and challenges. Furthermore, we explore the latest developments in contrast agents, AI-driven automation, and wearable imaging technologies, highlighting their potential to improve patient outcomes and advance precision medicine. The continuous evolution of biomedical imaging is shaping the future of healthcare, promising faster, safer, and more accurate diagnostic solutions for a wide range of medical conditions.

Keywords: Biomedical Imaging, Non-Invasive Techniques, Magnetic Resonance Imaging (MRI), Computed Tomography (CT)

Introduction

Biomedical imaging is a cornerstone of modern medicine, revolutionizing diagnostics, treatment planning, and disease monitoring. By providing detailed visualization of internal structures, imaging technologies enable physicians to detect pathological changes, assess organ function, and guide minimally invasive interventions with high precision. Over the decades, imaging modalities have evolved significantly, incorporating technological breakthroughs that enhance resolution, speed, and patient safety.

Among the most widely utilized imaging techniques, Magnetic Resonance Imaging (MRI), Computed Tomography (CT), and Ultrasound (US) each have distinct advantages based on their underlying physics, imaging capabilities, and clinical applications:

- MRI excels in soft-tissue contrast, making it a preferred choice for neurological, musculoskeletal, and oncological imaging without the risks of ionizing radiation.
- CT is renowned for its fast, high-resolution imaging, particularly in trauma, cardiovascular, and pulmonary assessments, providing detailed cross-sectional views of anatomical structures.
- Ultrasound is portable, cost-effective, and real-time, making it invaluable for point-of-care diagnostics, obstetrics, cardiology, and emergency medicine.[1]

As medical demands increase, technological advancements continue to drive the evolution of these imaging modalities. The integration of artificial intelligence (AI) and deep learning algorithms is automating image analysis, enhancing diagnostic accuracy, and reducing scan times. Furthermore, innovations in contrast agents, multi-parametric imaging, and hybrid imaging approaches (such as PET-MRI and SPECT-CT) are expanding the capabilities of conventional imaging techniques. Radiomics and quantitative imaging are also emerging as powerful tools for personalized medicine, enabling non-invasive disease characterization and treatment response monitoring.

This review aims to provide a comprehensive comparison of MRI, CT, and ultrasound, exploring their principles, advantages, limitations, and recent technological breakthroughs. Additionally, we discuss future trends and challenges that are shaping the field of biomedical imaging, with a focus on improving diagnostic precision, reducing radiation exposure, and enhancing clinical workflow efficiency.[2,3]

Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI) is a widely used non-invasive imaging modality that provides high-resolution, multi-planar images of soft tissues, making it indispensable in neurology, orthopedics, oncology, and cardiovascular imaging. MRI works based on the interaction of hydrogen nuclei (protons) in the body with a strong magnetic field and radiofrequency (RF) pulses, producing signals that are processed into detailed anatomical images. Unlike Computed Tomography (CT) or X-ray imaging, MRI does not use ionizing radiation, making it a safer option for repeated imaging in conditions requiring continuous monitoring.

Principle and Mechanism

MRI operates on the principle of nuclear magnetic resonance (NMR), where atomic nuclei, particularly hydrogen protons found in abundance in water and fat molecules, align with an externally applied strong magnetic field. The process follows these key steps:

- **Alignment:** When a patient is placed inside the MRI scanner, the hydrogen protons in the body align parallel or anti-parallel to the magnetic field.
- **Excitation:** A radiofrequency (RF) pulse is applied at a specific resonance frequency (Larmor frequency), causing the protons to absorb energy and move into a higher energy state.[4]
- **Relaxation:** Once the RF pulse is turned off, the protons return to their equilibrium state, releasing energy in the form of signals that are captured by receiver coils. This relaxation occurs through:
- **T1 relaxation (longitudinal recovery):** The return of protons to alignment with the magnetic field.
- **T2 relaxation (transverse decay):** The loss of coherence among spinning protons, leading to signal decay.
- **Image Formation:** The received signals are processed using Fourier transformation to generate high-contrast images based on tissue properties.

Advantages

MRI has several advantages over other imaging techniques due to its high tissue contrast and ability to acquire functional data:

- Superior soft-tissue contrast, making it ideal for brain, spinal cord, joint, and abdominal imaging.
- No ionizing radiation, making it safer for pediatric, prenatal, and follow-up imaging.
- Multiple imaging sequences (T1, T2, FLAIR, DWI, etc.), allowing for comprehensive tissue characterization.
- Functional MRI (fMRI) enables real-time mapping of brain activity, aiding in neurological and psychiatric research.
- Diffusion-Weighted Imaging (DWI) and Diffusion Tensor Imaging (DTI) are essential for stroke detection and nerve fiber mapping.
- Contrast-enhanced MRI (CE-MRI) improves vascular and tumor imaging, aiding in early disease diagnosis[5].

Limitations

Despite its advantages, MRI has certain limitations that can impact its accessibility and usage:

- High cost and long scan times, making it less accessible in emergency and low-resource settings.
- Sensitivity to motion artifacts, requiring patients to remain still for extended periods.
- Loud noise levels during scanning, which can cause discomfort and necessitate the use of ear protection.
- Contraindicated for patients with metallic implants, pacemakers, or aneurysm clips, due to the strong magnetic field.
- Claustrophobia concerns, as traditional MRI scanners are enclosed, requiring sedation or open-MRI alternatives for anxious patients.

Recent Innovations

Continuous advancements in MRI technology aim to improve image quality, reduce scan times, and expand clinical applications:

High-field and ultra-high-field MRI (7T and beyond):

- Enables ultra-high-resolution imaging, particularly useful for brain and musculoskeletal studies.
- Offers improved signal-to-noise ratio (SNR) for detecting subtle lesions and microstructural abnormalities.

AI-powered image reconstruction:

- Uses deep learning algorithms to enhance image clarity, reduce noise, and accelerate scan times.
- Improves motion correction, reducing the impact of patient movement during scans.

Hyperpolarized MRI:

- Enhances metabolic imaging, making it a powerful tool for early cancer detection and treatment monitoring.
- Improves sensitivity to biochemical changes within tumors and other pathologies.

Compressed sensing and parallel imaging:

- Reduces scan times by reconstructing high-quality images from undersampled data.
- Enhances feasibility for dynamic and real-time imaging.

Portable and low-field MRI systems:

- Improves accessibility for point-of-care imaging, particularly in remote and low-resource settings.
- Provides diagnostic capabilities in stroke and traumatic brain injury (TBI) assessment without requiring full-body scanners.[6]
- MRI continues to be a gold standard for soft-tissue imaging, with emerging innovations further enhancing its role in precision medicine, neurology, and oncology. As research progresses, improvements in AI automation, metabolic imaging, and hybrid MRI systems will shape the future of non-invasive medical imaging.

Computed Tomography (CT) is a widely used cross-sectional imaging technique that provides high-resolution images of internal structures using X-ray technology. It plays a crucial role in emergency diagnostics, oncology, cardiology, and trauma assessment, offering fast and detailed visualization of bones, organs, and vascular structures. Over the years, advancements in CT technology have enhanced image quality, reduced radiation exposure, and expanded clinical applications, making it an essential tool in modern medical imaging.

Principle and Mechanism

CT imaging works by using X-ray beams and detectors to capture multiple projections from different angles, which are then reconstructed into cross-sectional images (slices) of the body. The key components and processes involved in CT scanning include:

- **X-ray Tube and Detectors:** A rotating X-ray source emits beams, which pass through the body and are detected by high-sensitivity detectors on the opposite side.
- **Attenuation and Absorption:** Different tissues absorb X-rays at varying rates depending on their density. Bone absorbs the most radiation, appearing white, while air-filled structures (lungs) appear black and soft tissues (muscles, organs) appear in shades of gray.
- **Image Reconstruction:** The captured data undergoes computerized reconstruction using filtered back projection (FBP) or iterative reconstruction algorithms, producing high-resolution cross-sectional images.
- **Helical (Spiral) Scanning:** Modern CT scanners use a continuous rotating motion, capturing a large volume of data in a short time, reducing motion artifacts and scan duration.
- **Multidetector CT (MDCT):** Advanced scanners use multiple rows of detectors, allowing simultaneous acquisition of multiple slices, significantly improving spatial resolution and scan efficiency.[7,8]

Advantages

CT has numerous advantages that make it indispensable for rapid and detailed imaging:

- High-speed scanning, making it the gold standard for emergency cases such as trauma, stroke, and acute chest pain.
- Excellent bone and lung imaging due to its high-density resolution, allowing detailed visualization of fractures, lung pathologies, and calcifications.
- Angiographic capabilities (CT Angiography, CTA): Enables non-invasive vascular imaging, aiding in coronary artery disease detection, aneurysm evaluation, and pulmonary embolism diagnosis.

- Wide availability and cost-effectiveness compared to MRI, making it a more accessible imaging option.
- **Compatibility with contrast agents:** Contrast-enhanced CT improves visualization of blood vessels, tumors, and inflammatory changes.
- **Functional Imaging (Perfusion CT):** Helps assess blood flow dynamics, particularly in stroke and oncology applications.

Limitations

Despite its advantages, CT has certain limitations that must be considered:

- Exposure to ionizing radiation, which limits its frequent use, especially in pediatric and pregnant patients. Efforts to minimize radiation dose through low-dose CT protocols and AI-based reconstruction are ongoing.[9,10]
- Lower soft-tissue contrast compared to MRI, making it less effective for brain, spinal cord, and musculoskeletal imaging.
- Use of contrast agents can pose risks, especially in patients with kidney disease (contrast-induced nephropathy) or iodine allergies.
- Metal artifacts: Presence of metal implants or foreign objects can cause streak artifacts, reducing image clarity.[11]

Recent Innovations

Recent advancements in CT technology focus on enhancing image resolution, reducing radiation dose, and improving diagnostic accuracy:

Photon-Counting CT (PCCT):

- Utilizes photon-counting detectors to improve spatial resolution, contrast, and noise reduction.
- Enables lower radiation dose imaging without compromising diagnostic accuracy.
- Useful for oncology, cardiology, and neuroimaging applications.

Dual-Energy CT (DECT):

- Uses two different X-ray energy levels to differentiate between tissues with similar attenuation properties.
- Enhances material decomposition, aiding in kidney stone composition analysis, virtual non-contrast imaging, and gout diagnosis.

AI-Assisted CT Interpretation:

- Deep learning and AI algorithms automate image analysis, enabling faster and more accurate detection of stroke, lung nodules, and fractures.
- AI-based noise reduction and iterative reconstruction further enhance image quality while reducing radiation exposure.

Low-Dose CT (LDCT) for Lung Cancer Screening:

- Recommended for early lung cancer detection, particularly in high-risk populations such as smokers.
- Provides high sensitivity at a significantly lower radiation dose than conventional CT scans.

Portable and Ultra-Fast CT Scanners:

Innovations in mobile CT units allow imaging in ambulances, intensive care units (ICU), and field hospitals, improving access to real-time diagnostics.

Ultra-fast cardiac CT (256-slice and 320-slice CT) enables detailed coronary artery visualization within a single heartbeat, reducing motion artifacts.[12-15]

CT remains an essential imaging modality, continuously evolving to improve diagnostic precision, minimize risks, and enhance patient care. With innovations in photon-counting technology, AI-powered automation, and dual-energy imaging, CT is set to become even more versatile and efficient in clinical practice.

Ultrasound Imaging (US)

Ultrasound imaging (US) is a non-invasive, real-time imaging modality that uses high-frequency sound waves to visualize internal structures, including organs, soft tissues, blood flow, and fetal development. It is widely used in obstetrics, cardiology, musculoskeletal diagnostics, and emergency medicine due to its radiation-free nature, portability, and cost-effectiveness. Recent advancements in ultrasound technology, such as AI integration, elastography, and high-resolution imaging, have significantly enhanced its clinical applications.

Principle and Mechanism

Ultrasound imaging is based on the transmission and reflection of high-frequency sound waves (typically 2-15 MHz) through the body. The key components and working mechanism include:

- **Transducer Probe:** Emits and receives ultrasound waves. Different types of probes (linear, convex, phased array) are used for various clinical applications.
- **Acoustic Impedance and Reflection:** As sound waves travel through tissues, they reflect at interfaces with different acoustic impedances, generating echoes that form an image.
- **Pulse-Echo System:** The transducer sends pulses of ultrasound waves, and returning echoes are converted into grayscale images based on time delay and intensity.
- **Doppler Ultrasound:** Measures frequency shifts in reflected sound waves caused by moving red blood cells, enabling blood flow visualization in arteries and veins.

- **3D and 4D Imaging:** Advanced techniques reconstruct three-dimensional (3D) images, while 4D ultrasound adds real-time motion, commonly used in fetal imaging and cardiac assessments.[16]

Advantages

Ultrasound has several unique benefits that make it an essential imaging tool in clinical practice:

- **Radiation-Free:** Unlike CT and X-ray, ultrasound does not use ionizing radiation, making it safe for pregnant women, infants, and repeated examinations.

Portable and Cost-Effective:

- Handheld and bedside ultrasound devices provide immediate diagnostics in point-of-care settings (e.g., ICU, emergency rooms, ambulances).
- More affordable than MRI and CT, making it widely accessible in both developed and resource-limited regions.

Real-Time Imaging:

- Live visualization enables dynamic assessment of organ function and movement, making it ideal for guiding interventional procedures such as biopsies, fluid drainage, and catheter placements.
- Dynamic musculoskeletal ultrasound helps assess joint movement and tendon abnormalities in real time.[17]

Doppler Capabilities:

- Color Doppler ultrasound maps blood flow, detecting vascular diseases, deep vein thrombosis (DVT), and heart valve abnormalities.
- Spectral Doppler provides quantitative blood flow velocity measurements, useful for stroke risk assessment and fetal monitoring.

Point-of-Care Applications:

- Widely used in emergency medicine for FAST (Focused Assessment with Sonography for Trauma) to detect internal bleeding and organ injury.
- Portable ultrasound is used in rural healthcare and battlefield medicine for rapid diagnostics.

Limitations

Despite its advantages, ultrasound has some limitations that affect its utility in certain scenarios:

Operator-Dependent:

- The quality and accuracy of ultrasound imaging rely heavily on the skill and experience of the sonographer.
- Interpretation errors can occur due to poor probe positioning or incorrect scanning techniques.

Limited Penetration Depth:

- High-frequency transducers provide high-resolution images but have poor penetration, making them unsuitable for imaging deep structures (e.g., brain, lungs, pancreas in obese patients).
- Low-frequency transducers allow deeper penetration but reduce image resolution.

Lower Spatial Resolution Compared to MRI and CT:

- Soft-tissue contrast is inferior to MRI, making ultrasound less suitable for detailed brain and spinal cord imaging.
- Artifacts (shadowing, reverberation) may obscure structures and reduce diagnostic clarity.
- Limited Field of View: Unlike CT and MRI, which provide comprehensive cross-sectional images, ultrasound imaging only captures a small area at a time, requiring multiple sweeps for a full assessment.

Difficult Imaging in Gas-Filled and Dense Structures:

Ultrasound waves are strongly attenuated by air and bone, making it unsuitable for imaging the lungs (except for pleural effusions) or deep brain structures.[18]

Recent Innovations

Ongoing research and technological advancements are expanding the capabilities of ultrasound imaging, improving its diagnostic accuracy and clinical versatility:

Elastography:

- A technique that measures tissue stiffness, aiding in the early detection of liver fibrosis, thyroid nodules, and tumors.
- Shear-wave elastography (SWE) and strain elastography allow quantitative assessment of fibrosis progression and cancer characterization.

AI-Powered Ultrasound:

- Artificial Intelligence (AI) algorithms enhance image interpretation, lesion detection, and automated measurements, reducing operator dependence.
- AI-based automated fetal biometry improves accuracy in gestational age estimation and fetal growth assessment.
- AI-assisted echocardiography aids in heart function analysis and valve assessment.

3D and 4D Ultrasound:

- 3D imaging reconstructs volumetric images for better anatomical visualization, particularly in obstetric and gynecological applications.
- 4D ultrasound provides real-time motion analysis, improving fetal movement assessment and cardiac imaging.

Contrast-Enhanced Ultrasound (CEUS):

- Involves the use of microbubble contrast agents to enhance vascular imaging.

- Provides real-time perfusion analysis, useful in tumor evaluation, liver lesion characterization, and stroke assessment.

Portable and Wireless Ultrasound Devices:

- Handheld ultrasound scanners with smartphone connectivity enable remote diagnostics and telemedicine applications.
- Wearable ultrasound patches are being developed for continuous monitoring of cardiac and musculoskeletal functions.

HIFU (High-Intensity Focused Ultrasound):

- Used in non-invasive tumor ablation, uterine fibroid treatment, and pain management.
- Provides precise thermal energy delivery to destroy abnormal tissues without surgery.

Ultrasound imaging continues to evolve with AI integration, real-time functional imaging, and portable solutions, making it an indispensable tool in modern medicine. Its non-ionizing, cost-effective, and real-time capabilities ensure its widespread use across diverse clinical fields, from prenatal care to emergency diagnostics and cancer therapy.

Future Directions in Biomedical Imaging

Emerging trends in biomedical imaging are transforming clinical diagnostics and treatment planning. Key advancements include:

- AI and Machine Learning – Automated image segmentation and interpretation for enhanced accuracy.
- Hybrid Imaging – Combining MRI with PET or CT for improved disease characterization.
- Nanoparticle-Based Contrast Agents – Targeted imaging for cancer and neurological disorders.
- Wearable Ultrasound Devices – Real-time health monitoring in personalized medicine.

These innovations will further enhance imaging precision, reduce scan times, and improve accessibility, revolutionizing medical diagnostics.

Conclusion

MRI, CT, and ultrasound are indispensable imaging technologies that play a critical role in modern healthcare. Each modality offers unique advantages based on its underlying principles, making them complementary rather than competing technologies. MRI excels in soft-tissue contrast and functional imaging, CT provides rapid, high-resolution cross-sectional imaging, and ultrasound offers real-time, portable, and radiation-free diagnostics. The continuous evolution of these imaging techniques has led to significant improvements in diagnostic accuracy, speed, and accessibility, directly impacting clinical decision-making and patient outcomes.

Recent innovations are pushing the boundaries of biomedical imaging:

- Artificial Intelligence (AI) and Deep Learning are revolutionizing image reconstruction, noise reduction, lesion detection, and automated diagnosis, enhancing accuracy and reducing human error.
- Advanced Hardware Development, such as high-field MRI (7T and beyond), photon-counting CT, and high-frequency ultrasound transducers, is improving image resolution and reducing acquisition time.
- Hybrid Imaging Technologies, such as PET/MRI and SPECT/CT, are enabling multi-modal imaging for comprehensive disease characterization.
- Contrast-Enhanced Imaging techniques, including hyperpolarized MRI, dual-energy CT, and microbubble ultrasound contrast, are improving tissue differentiation and perfusion analysis.
- Portable and Point-of-Care Imaging innovations, particularly in ultrasound, are expanding accessibility, allowing for rapid bedside diagnostics, emergency medicine applications, and telemedicine integration.

Table 1.Comparative Analysis of MRI, CT, and Ultrasound

Feature	MRI	CT	Ultrasound
Imaging Principle	Magnetic fields & RF waves	X-ray beams & detectors	High-frequency sound waves
Radiation Exposure	None	Ionizing radiation	None
Soft-Tissue	Excellent	Moderate	Moderate
Contrast			
Bone Imaging	Poor	Excellent	Limited
Real-Time Imaging	No	No	Yes
Speed	Moderate to slow	Fast	Fast
Cost	High	Moderate	Low
Portability	Limited	Limited	High

Looking ahead, the future of biomedical imaging will be driven by faster, more precise, and minimally invasive techniques. AI-powered automated imaging workflows will enable real-time diagnostics with reduced dependence on radiologists, improving efficiency in high-demand medical settings. The integration of wearable imaging devices, high-performance computing, and cloud-based image processing will further enhance accessibility and remote diagnostics, particularly in low-resource settings and emergency medicine.

Additionally, the role of biomedical imaging in precision medicine is expanding, allowing for personalized disease detection, monitoring, and treatment response evaluation. With continuous research, interdisciplinary collaboration, and technological advancements, these imaging modalities will continue to shape the landscape of personalized medicine, early disease detection, and targeted therapy planning, making healthcare more accurate, efficient, and patient-centric in the coming years.

References

1. McRobbie DW, Moore EA, Graves MJ, Prince MR. MRI from Picture to Proton. Cambridge university press; 2017 Apr 13.
2. Bushberg JT, Boone JM. The essential physics of medical imaging. Lippincott Williams & Wilkins; 2011 Dec 20.
3. Rinck PA. Magnetic resonance in medicine: a critical introduction. BoD–Books on Demand; 2018 Aug 21.
4. Kalender WA. Computed tomography: fundamentals, system technology, image quality, applications. John Wiley & Sons; 2011 Jul 7.
5. Webb A. Introduction to biomedical imaging. John Wiley & Sons; 2022 Oct 19.
6. Buzug TM. Computed tomography: from photon statistics to modern cone-beam CT. Soc Nuclear Med. 2009 Jul;50(7).
7. Yitbarek D, Dagnaw GG. Application of advanced imaging modalities in veterinary medicine: a review. Veterinary Medicine: Research and Reports. 2022 May 31:117-30.
8. Roemer PB, Edelstein WA, Hayes CE, Souza SP, Mueller OM. The NMR phased array. Magnetic resonance in medicine. 1990 Nov;16(2):192-225.
9. Gebhard C, Fiechter M, Fuchs TA, Ghadri JR, Herzog BA, Kuhn F, Stehli J, Müller E, Kazakauskaite E, Gaemperli O, Kaufmann PA. Coronary artery calcium scoring: influence of adaptive statistical iterative reconstruction using 64-MDCT. International journal of cardiology. 2013 Sep 10;167(6):2932-7.
10. Giger ML, Chan HP, Boone J. Anniversary paper: history and status of CAD and quantitative image analysis: the role of medical physics and AAPM. Medical physics. 2008 Dec;35(12):5799-820.
11. Alyousef K, Assiri A, Almutairi S, Aldalham T, Felimban G. Awareness of radiation protection and common radiation dose levels among healthcare workers. Global journal on quality and safety in healthcare. 2023 Feb 1;6(1):1-5.
12. O'connor JP, Aboagye EO, Adams JE, Aerts HJ, Barrington SF, Beer AJ, Boellaard R, Bohndiek SE, Brady M, Brown G, Buckley DL. Imaging biomarker roadmap for cancer studies. Nature reviews Clinical oncology. 2017 Mar;14(3):169-86.
13. Brau AC, Hardy CJ, Schenck JF. MRI safety. InBasic Principles of Cardiovascular MRI: Physics and Imaging Technique 2015 Oct 29 (pp. 115-127). Cham: Springer International Publishing.
14. Fütterer JJ, Briganti A, De Visschere P, Emberton M, Giannarini G, Kirkham A, Taneja SS, Thoeny H, Villeirs G, Villers A. Can clinically significant prostate cancer be detected with multiparametric magnetic resonance imaging? A systematic review of the literature. European urology. 2015 Dec 1;68(6):1045-53.
15. Liu X, Song L, Liu S, Zhang Y. A review of deep-learning-based medical image segmentation methods. Sustainability. 2021 Jan 25;13(3):1224.
16. Lu G, Fei B. Medical hyperspectral imaging: a review. Journal of biomedical optics. 2014 Jan 1;19(1):010901-.
17. Kahn Jr CE, Langlotz CP, Burnside ES, Carrino JA, Channin DS, Hovsepian DM, Rubin DL. Toward best practices in radiology reporting. Radiology. 2009 Sep;252(3):852-6.
18. Rubin GD. Computed tomography: revolutionizing the practice of medicine for 40 years. Radiology. 2014 Nov;273(2S):S45-74.