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Radiographers' Journal

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

November 2026





Editorial

Shankar K. Bhagat
Editor-in-chief

World Radiography Day 2026: Professionalism in Radiography – Putting Patients First

November is a special month for the radiography profession as we celebrate World Radiography Day on 8 November, commemorating Wilhelm Conrad Röntgen's discovery of X-rays in 1895. The 2026 campaign focus, Professionalism in Radiography, reminds us that our profession is built not only on technological expertise but also on ethical practice, responsibility, compassion, continuous learning and commitment to patient care. As imaging technology advances, the role of radiographers continues to expand, making professionalism and patient-centred care more important than ever.

This month's issue of Radiographers Journal brings together eight valuable contributions from our authors, covering diverse imaging modalities, clinical applications and developments that strengthen the role of medical imaging in modern healthcare.

Patient experience is an essential part of quality imaging. The article "MRI Related Patient Anxiety: Causes, Impact and Strategies for Anxiety Reduction" explores the factors responsible for anxiety during MRI examinations and their effects on patient cooperation and image quality. It highlights practical approaches such as effective communication, patient preparation, reassurance and appropriate anxiety-reduction strategies. It reminds us that compassionate interaction is as important as technical competence.

The article "CT Neuro Perfusion in Ischemic Stroke Management" discusses the importance of perfusion imaging in evaluating cerebral blood flow and identifying potentially salvageable brain tissue. This advanced technique supports timely clinical decision-making and helps guide appropriate treatment strategies in acute ischemic stroke.

Expanding the role of MRI in oncology, "Magnetic Resonance Spectroscopy for Cervical Cancer" examines the potential of metabolic information obtained through spectroscopy to complement conventional imaging. Such advanced techniques may contribute to tumour characterisation, assessment and treatment monitoring.

Revisiting a specialised contrast examination, "Hypotonic Duodenography" highlights its role in demonstrating duodenal anatomy and evaluating selected gastrointestinal conditions. The article also reinforces the importance of appropriate patient preparation, examination technique and image interpretation.

The review "Clinical Applications and Recent Advances in CT Angiography: A Comprehensive Review" presents the expanding applications of CTA in vascular assessment. From evaluating arterial disease and aneurysms to identifying vascular abnormalities, CTA continues to provide rapid, detailed information that supports diagnosis, treatment planning and follow-up.

Similarly, "Angiography of the Intracranial Arteries using Magnetic Resonance" explores MR-based techniques for visualising intracranial vessels. It highlights the value of non-invasive vascular imaging in assessing cerebrovascular conditions and supporting neurological investigations.

The article "Non-Contrast Computed Tomography in Urinary Stone Disease: Association of Stone Size, Location, and Hounsfield Units with Hydronephrosis — A Narrative Review" examines how stone characteristics and their anatomical location relate to urinary obstruction and hydronephrosis. It underlines the importance of accurate CT assessment in clinical decision-making and patient management.

Completing this issue, "Advances in SPECT/CT Imaging" discusses the integration of functional and anatomical imaging. By combining scintigraphic information with CT localisation, SPECT/CT enhances diagnostic confidence and expands applications across several clinical specialties.

Together, these contributions demonstrate how conventional techniques, advanced imaging and evolving technologies continue to improve diagnostic capabilities. They also remind us that every examination involves a patient who deserves safety, dignity, clear communication and professional care.

On the occasion of World Radiography Day 2026, I extend my warm wishes to all radiographers, radiological technologists, educators, students and imaging professionals. Let us continue to uphold professional standards, embrace innovation and strengthen our commitment to excellence in patient care.

My sincere appreciation goes to all contributors for sharing their knowledge and expertise, and to our readers for their continued encouragement and support.

Happy World Radiography Day 2026!

Happy Reading!

SCHOOL OF ALLIED HEALTH SCIENCES
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Jointly Organising

24TH NATIONAL CONFERENCE OF SOCIETY OF INDIAN RADIOGRAPHERS

SCIENTIFIC ADVANCEMENTS, LEARNING AND EXCELLENCE IN MEDICAL IMAGING

SALEM 2027



Date:
5th & 6th FEB. 2027
Friday & Saturday

Venue:
Annapurna Auditorium
VMKV MC&H - Salem

Dear Esteemed Radiographers, Technologists, Educators and Students,

We take immense pride and pleasure in announcing the prestigious **24th National Conference of the Society of Indian Radiographers (24th NCSIR – 2027)**, jointly organized by the **School of Allied Health Sciences (SAHS), Vinayaka Mission's Research Foundation (Deemed to be University), Salem, and the Society of Indian Radiographers - Tamil Nadu Chapter.** We extend our cordial greetings and a heartfelt invitation to each of you.

Historically, national conventions were largely confined to metropolitan cities. Dedicated to democratizing academic excellence and empowering the student and professional community across every region, our society has continually expanded its horizons. Following the successful state-level and national milestones held in Tiruchirappalli (2022), Tirunelveli (2023), Salem (2025), and Tiruchirappalli (2026), we are proud to bring this momentous **24th National Conference** to the historic city of **Salem.**

Salem, popularly hailed as the Steel City and Mango City of India, is blessed with cultural grandeur and natural splendor-surrounded by the Shevaroy, Kalrayan, and Kolli hills, and nurtured by the sacred Kaveri River basin.

We warmly invite you to join this national academic celebration on February 5th and 6th, 2027, at the state-of-the-art Auditorium, Vinayaka Mission's Research Foundation Campus, located conveniently on Sankari Main Road (NH-47), Ariyanoor, Salem.

CONFERENCE THEME: "SCIENTIFIC ADVANCEMENTS, LEARNING AND EXCELLENCE IN MEDICAL IMAGING" SALEM 2027

This two-day national convention will provide a comprehensive platform examining cutting-edge developments in Medical Imaging, Artificial Intelligence, CT/MRI advances, Cath Lab protocols, Nuclear Medicine, Radiation Dosimetry, as well as crucial regulatory frameworks including **AERB e-LORA** and the **NCAHP Act 2021.**

The vision of the **Society of Indian Radiographers (SIR),** conceptualized during the Roentgen Centenary Celebrations in 1995 and formally registered in 1996, has grown into a powerful nationwide movement uniting practicing radiographers, academicians, and young technologists. Over the decades, SIR and its Tamil Nadu Chapter have conducted numerous CMEs, workshops, and state and national conferences, keeping our professional fraternity at the leading edge of medical imaging.

The 24th NCSIR – 2027 marks a historic summit in our ongoing academic journey. Designed to inspire undergraduates, postgraduates, clinical technologists, and researchers alike, this national conference offers keynote addresses by eminent national faculty, scientific paper and e-poster competitions, an inter-collegiate radiography quiz, trade exhibitions, and interactive technical workshops.

On behalf of the Organizing Committee, we cordially welcome you to Salem to share your expertise, network with peers from across India, and contribute to making this 24th National Conference an extraordinary academic triumph.

With regards,

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MRI Related Patient Anxiety: Causes, Impact and Strategies for Anxiety Reduction

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Abstract

An essential non-invasive diagnostic technique that offers comprehensive anatomical and pathological information without the use of ionizing radiation is magnetic resonance imaging, or MRI. However, claustrophobia, strong acoustic noise, extended examination time, limited mobility, new settings, and fear of the technique or diagnosis can all contribute to significant anxiety and suffering in certain patients during an MRI. Patient movement, motion artifacts, repeated sequences, incomplete tests, and, in certain situations, the necessity for sedation are all possible outcomes of increased anxiety. The main causes and consequences of MRI-related patient anxiety are covered in this overview, along with strategies for enhancing patient tolerance. Anxiety may be lessened by non-pharmacological methods include sufficient pre-procedure information, clear communication, assurance, breathing and relaxation techniques, music therapy, distraction, guided imagery, and comfortable placement. Additional chances to enhance patient comfort are offered by technological approaches, such as wide-bore and open MRI systems, quicker scanning protocols, noise-reduction methods, audio-visual systems, and virtual reality. Effective management of MRI-related anxiety can improve patient comfort, co-operation, examination completion, and the overall quality of the MRI experience. Future developments should concentrate on combining patient-centered care with faster, quieter, and more patient-friendly MRI technologies. Radiographers play an important role in identifying anxious patients, providing individualized support, maintaining communication, and creating a reassuring examination environment.

Keywords: Magnetic resonance imaging; patient anxiety; claustrophobia; patient comfort; radiographers; anxiety reduction; patient-centred care.

Introduction

A popular non-invasive imaging technique that uses no ionizing radiation to offer detailed anatomical and pathological information is magnetic resonance imaging (MRI). For some individuals, the MRI test can be a distressing encounter despite its diagnostic benefits. The enclosed scanner environment, strong acoustic noise, extended examination time, strange surroundings, and the need to stay still throughout scanning can all cause anxiety. Particularly troublesome conditions include claustrophobia and dread, which can cause discomfort, movement, incomplete exams or, in certain situations, the necessity for anesthesia. Anxiety in patients can have an impact on their experience as well as the effectiveness and caliber of MRI tests. Unexpected behaviors, including failed scans, the need for sedation, and motion artifacts in MRI patients, have been documented in recent research. Therefore, a key component of patient-centered MRI practice is recognizing anxiety either before to or during the examination. Numerous strategies have been studied to lessen anxiety associated with MRIs. Clear information prior to the examination, excellent communication and reassurance, breathing and relaxation techniques, cognitive-behavioral approaches, music or audio-visual distraction, proper patient positioning, and adjustments to the MRI setting are some of these. Although the quality and efficacy of the available data vary, systematic reviews indicate that a number of these non-pharmacological strategies may enhance patient comfort and lessen anxiety. Because radiographers are actively involved in patient preparation, communication, and examination, they are crucial in helping worried patients. Patients may cooperate better and effectively finish MRI exams if a patient-centered and supportive approach is used. Therefore, improving the overall patient experience and quality of MRI services requires an understanding of the sources of anxiety connected to MRIs and the application of suitable anxiety-reduction techniques.



Siemens Healthineers. MAGNETOM Vida 3T Magnetic Resonance Imaging scanner used for diagnostic imaging. The enclosed scanner environment and limited space within the bore can contribute to discomfort and anxiety in some patients.

MRI-Related Patient Anxiety

The worry, anxiety, discomfort, or distress that patients feel prior to or during an MRI test is referred to as MRI-related patient anxiety. It is frequently linked to the enclosed scanner setting, strange and loud noises, extended test duration, limited mobility, and the requirement to stay still during the process. When entering the MRI bore, patients with a history of claustrophobia may feel more anxious. Anxiety can vary from person to person and can be impacted by a number of factors, including prior medical procedure experiences, unfamiliarity with MRI, anxiety of the test results, physical discomfort or pain, and worries about being unable to speak or exit the scanner while the test is being performed. Psychological anxiety in extremely worried individuals can result in motion artifacts, repeated sequences, trouble staying motionless, early examination termination, or sedation. Therefore, effective patient preparation and communication are crucial elements of MRI care. Uncertainty can be decreased by giving patients precise information about the process, outlining the noises and duration of scanning, letting them ask questions, and reassuring them. Non-pharmacological methods for lowering anxiety during diagnostic imaging have also been studied, including music, relaxation techniques, cognitive strategies, guided imagery, and suitable ambient changes. Radiographers and other medical professionals can offer tailored support by identifying anxiety prior to scanning. Patient comfort, compliance, examination completion, and the overall MRI experience may all be enhanced by early detection and proper management.

Causes of Anxiety During MRI

Anxiety during an MRI examination might be caused by a number of factors:

Claustrophobia: The narrow and enclosed MRI bore can provoke fear of being trapped, especially in people with claustrophobic tendencies.

Loud acoustic noise: It can be unsettling to hear the frequent pounding and buzzing noises made during scanning.

Prolonged examination time: Patients may need to spend a considerable amount of time within the scanner for an MRI exam.

Requirement to remain still: Due to the requirement that they remain in the same position throughout the scanning process, patients may grow apprehensive.

Unfamiliar environment: Patients may be more hesitant if they are inexperienced with the MRI room, equipment, and process.

Fear of the examination or diagnosis: Anxiety can be brought on by worries about the actual surgery or a dread of learning that you have a terrible illness.

Previous negative experiences: Anxiety may be elevated by prior negative experiences with MRIs or other medical procedures.

Physical discomfort: The examination may be more distressing if you are in pain, have trouble breathing, or can't stay in a comfortable position.

Lack of information: Uncertainty and anxiety may rise if the technique is not adequately explained.

Loss of control: Due to their restricted mobility and need to stay inside the scanner while images are being taken, some patients may experience anxiety.

Impact of Anxiety on MRI Examination

The quality of the MRI examination and the patient's experience can both be impacted by anxiety. Among the significant consequences are:

Patient movement: Patients who are anxious may find it difficult to stay still, which could cause them to move when taking pictures.

Motion artifacts: Movement of the patient may result in image artifacts and lower the quality of diagnostic images.

Repeated sequences: Scanning time may increase if specific sequences need to be repeated due to low-quality photos.

Incomplete examination: Patients who are really nervous or claustrophobic could request that the examination be stopped before it is finished.

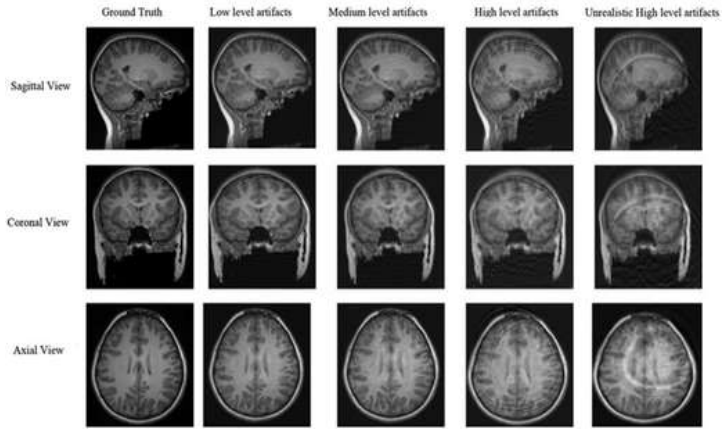
Increased examination time: Movement brought on by anxiety, disruptions, or repeated steps might make the process take longer.

Need for sedation: Pharmacological sedation may occasionally be necessary to finish the evaluation in cases of severe anxiety or claustrophobia.

Reduced patient cooperation: Patients may find it challenging to adhere to advice about retaining their breath or staying still due to fear and discomfort.

Poor patient experience: Anxiety might lower patient satisfaction with the MRI process and cause psychological anguish.

Additional healthcare resources: Workload, scanning time, and total healthcare expenditures may all rise as a result of unsuccessful or repeated exams.



Impact of patient motion on brain MRI image quality. Sagittal, coronal and axial images demonstrate progressively increasing motion artifacts from the ground-truth image through low, medium, high and severe artifact levels. Incresing patient movement produces progressive image blurring, ghosting, distortion and loss of anatomical detail, which may compromise diagnostic image quality. In the context of MRI-related anxiety, difficulty remaining still during the examination can contribute to motion artifacts, potentially necessitating repeated sequences and prolonging the examination.

Anxiety Reduction Strategies

Combining non-pharmacological and patient-centered methods can help minimize anxiety during MRIs. By outlining the process, the length of the scan, the sounds, and the significance of staying still, providing precise information prior to the examination might lessen anxiety about the unknown. The patient's perception of security and control might be enhanced by radiographers' skillful communication and assurances. Deep breathing, guided imagery, and visualization are relaxation strategies that may help patients cope with sensations of claustrophobia and anxiety. Virtual reality, audio-visual distraction, music, and headphones can all offer psychological distraction during scanning. Patient tolerance can be further enhanced with comfortable placement and suitable support. Open or wide-bore MRI scanners could offer a less constrictive setting for people with acute claustrophobia. Patients can be reassured that help is available if two-way communication is maintained and an emergency call button is provided. Medically supervised sedation may be taken into consideration for those people who still cannot bear the examination. In general, patient comfort and compliance can be enhanced and incomplete or repetitive exams may be decreased by combining sufficient preparation, communication, relaxation techniques, diversion, and appropriate MRI equipment.

Role of Radiographers

When it comes to recognizing and controlling patient anxiety during MRI exams, radiographers are crucial. Before and during the scan, they are frequently the medical personnel who deal directly with the patients. During patient preparation, they can evaluate signs of fear or claustrophobia and give straightforward information regarding the operation, scanning time, noise, and the requirement to stay motionless. Building trust and lowering fear can be accomplished by calm conversation, assurance, attentive listening, and addressing patient concerns. Additionally, radiographers can maintain two-way contact, guaranty comfortable placement, offer music or headphones, and demonstrate how to utilize the emergency call system. Patients who are really apprehensive may talk to the clinical team about suitable substitutes or extra assistance, such as open or wide-

bore MRI where available or medically supervised sedation when required. Radiographers can increase patient comfort, compliance, and the chance of a successful MRI exam by offering tailored, patient-centered care.



Role of radiographers in recognizing and managing patient anxiety during MRI examinations.

Recent Advances

A number of strategies to lower anxiety and increase examination tolerance have been introduced by recent developments in MRI technology and patient-centered treatment. Patients with claustrophobia may benefit from wide-bore and open MRI systems because they offer a more roomy scanning environment. Patients may be more comfortable if they spend less time inside the scanner thanks to quicker and shorter MRI procedures. The level of acoustic noise connected to traditional MRI can be decreased by using silent or noise-reduction MRI techniques. Additionally, audio-visual systems and virtual reality (VR) are being investigated as ways to divert patients during scanning and acquaint them with the MRI environment. Furthermore, MRI practice is progressively integrating patient-centered communication, pre-scan education, real-time audio-visual communication, and customized relaxation techniques. These supportive and technological methods are intended to enhance patient comfort, lessen claustrophobia and anxiety, and raise the possibility of successfully finishing MRI exams.

Future Perspectives

Future strategies to lessen anxiety associated with MRIs are probably going to emphasize patient-centered treatment in conjunction with technical progress. Personalized MRI procedures that shorten scanning times and enhance patient comfort could be developed with the use of artificial intelligence. Patients who suffer from claustrophobia or find it difficult to tolerate traditional scanners may benefit from the further development of quicker, quieter, and larger MRI systems. Immersion audio-visual systems, virtual reality, and interactive patient communication may offer more chances for relaxation and distraction prior to and during MRI. Future studies should concentrate on creating standardized techniques for measuring anxiety and identifying people who are more likely to experience anxiety prior to scanning. To find out which strategies work best and how to regularly implement them in MRI departments, well-designed clinical studies are required. In the end, patient comfort, cooperation, examination completion, and the overall MRI experience may all be enhanced by combining technology advancements with efficient communication and tailored support.

Conclusion

During MRI exams, patient anxiety is a major worry. It can be linked to claustrophobia, strong acoustic noise, extended scanning times, new environments, and fear of the treatment or diagnosis. Anxiety can have an impact on a patient's participation, comfort, image quality, and examination completion. Anxiety can be decreased by a combination of proper MRI equipment, music or distraction, relaxation techniques, clear communication, reassurance, and patient education. A more comfortable, effective, and patient-friendly MRI experience may result from ongoing research and the integration of psychological and technological approaches. Radiographers play a crucial role in identifying anxious patients and providing tailored, patient-centered support. Emerging technologies such as faster and quieter MRI systems, wide-bore scanners, virtual reality, and audio-visual techniques offer further opportunities for improving patient tolerance.

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3. 7 minutes for presentation and 3 minutes for Q&A.
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5. Presentation must be original and relevant to the given theme.
6. Participants must report before their allotted time.
7. Judges' decision will be final.

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Rules & Regulations

1. Maximum 5 participants per team.
2. Each team gets 10 minutes for presentation.
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4. Participants must explain the concept and purpose of the model.
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6. Teams must report before their allotted time.
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3. The poster must be original and theme-relevant.
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6. Participants must report before their allotted time.
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CT Neuro Perfusion in Ischemic Stroke Management

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Abstract
Ischemic stroke is a leading cause of death and disability worldwide, caused by reduced blood flow to the brain, resulting in tissue damage. Timely and accurate diagnosis is critical to prevent irreversible injury and guide therapeutic decisions. Computed Tomography Perfusion (CTP) imaging has emerged as an essential tool in the evaluation and management of ischemic stroke, providing dynamic, whole-brain imaging to quantify cerebral perfusion and distinguish between infarct core (irreversibly damaged tissue) and penumbra (salvageable tissue). CTP involves intravenous injection of contrast media with rapid image acquisition during contrast passage, generating time-attenuation curves used to compute perfusion parameters such as Cerebral Blood Flow (CBF), Cerebral Blood Volume (CBV), Mean Transit Time (MTT), and Time to Maximum (Tmax). These parameters help identify hypoperfused brain areas and quantify mismatch volume and ratio between infarct core and penumbra, guiding revascularization treatment decisions. Auto Stroke technology allows fully automated motion correction, vessel segmentation, and parameter calculation, promoting efficient clinical workflows and enabling rapid integration of perfusion maps into the hospital PACS system. This chapter provides a comprehensive overview of the role of Computed Tomography Perfusion (CTP) imaging in the diagnosis and management of ischemic stroke. Ischemic stroke, which results from impaired cerebral blood flow, is a major cause of death and long-term disability globally. Rapid identification of the affected brain tissue is critical to determine the appropriate therapeutic intervention and prevent irreversible brain damage. The chapter explains key concepts including the infarct core, representing non-viable brain tissue, and the penumbra, which is hypoperfused but potentially salvageable with timely treatment. The chapter also discusses advanced acquisition methods such as Adaptive 4D Spiral (A4DS) and Flex 4D Spiral (F4DS), which provide wide brain coverage with improved motion correction and dose efficiency. Siemens Healthineers' syngo.CT Neuro Perfusion software is highlighted for its dual model approach (deconvolution and maximum slope), 4D noise reduction algorithm, and automated processing through Auto Stroke, enabling rapid, high-quality assessment in clinical practice.
Keywords: Ischemic Stroke, Computed Tomography Perfusion (CTP), Infarct Core, Penumbra, Cerebral Blood Flow (CBF)

Introduction

Stroke is a prevalent illness. One in four people may experience a stroke at some point in their lives, and 13.7 million strokes are thought to occur annually worldwide. As the population ages, this is anticipated to rise. In adults worldwide, stroke ranks as the third most common cause of disability and the second most common cause of death1. Hemorrhagic and ischaemic strokes are the two main categories into which strokes fall. The most prevalent type of stroke, an ischaemic stroke, is brought on by inadequate blood flow to the brain. The process by which carbon dioxide and cellular waste are removed from biological tissues and oxygen and nourishment are supplied to them through the circulatory system is known as perfusion. Perfusion is more precisely defined as blood flow, which is typically expressed as the number of millilitres of blood that enter 100 g of tissue in a minute [ml/100 g/min]. When blood flow and, consequently, oxygen supply to the brain are compromised, brain tissue is harmed, leading to an ischaemic stroke. Time is of the essence in stroke therapy, which aims to preserve the tissue before permanent damage develops.

For the treatment of stroke, imaging is crucial. Non-contrast head CT imaging is quite good at identifying cerebral haemorrhage, which usually prevents patients from receiving thrombolytic therapy. Further dynamic imaging, such as CT angiograms (CTA) and CT perfusion (CTP) tests, are carried out if no haemorrhage symptoms are found. CTP aids in describing the functional characteristics of brain tissue, whereas CTA is useful for assessing big vessel intracranial stenoses and occlusions.

Infarct core (non-viable tissue) and penumbra (tissue at risk)

In an acute ischaemic stroke, the non-viable tissue—the area that is irreparably destroyed and cannot be saved by reperfusion—is denoted by the infarct core. The surrounding tissue, known as the penumbra, is at risk because it is hypoperfused but may be saved with prompt reperfusion therapy. In order to make well-informed decisions on revascularisation treatment, CTP can be utilised to determine the existence and extent of the infarct core and penumbra. CTP can be used to forecast the success of such therapeutic interventions, and the presence of a significant penumbra is a good predictor for extending the intravascular therapeutic window. Research has demonstrated that CTP results are in good agreement with the gold standard methods, such as MRP and diffusion-weighted imaging (DWI).

CT Perfusion

To make well-informed decisions on revascularisation treatment, CTP can be used to determine the existence and extent of the penumbra and the infarct core. A quick and brief intravenous bolus of contrast media is used in CTP imaging, and images are continually taken prior to, during, and just after the contrast media's initial passage through the brain. Changes in attenuation over time are thought to be proportional to the contrast media and, consequently, the perfusion. During CTP analysis, many perfusion parameters are obtained and cerebral perfusion maps are created by fitting the acquired data to physical models.Schematics of the temporal attenuation curve for the Maximum Slope (MS) (Figure 1a) and Deconvolution (DC) (Figure 1b) models are displayed in Figure 1 with varying perfusion settings. Representative cerebral perfusion maps generated by CTP analysis utilising the DC model are displayed in Figure 3. The several CTP parameters and their changes in the presence of an ischaemic stroke are detailed in Table 1.

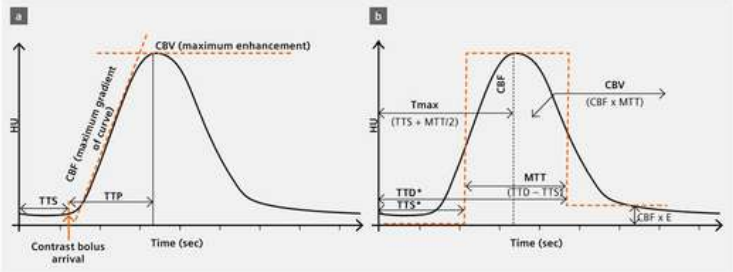


Figure 1 Time attenuation curve schematic showing different CT Perfusion parameters.(a) Maximum Slope model (b) Deconvolution model.

Parameter Name	Definition
Cerebral Blood Flow (CBF)	The amount of blood flowing through a given volume of brain in a specific amount of time (mL/100 mL/min). CBF identifies areas of hypoperfusion, including the infarct core and the penumbra. The infarct core has markedly decreased CBF compared to the penumbra.
Relative CBF (rCBF)	The ratio of the CBF in the affected hemisphere to that in the contralateral hemisphere.
Cerebral Blood Volume (CBV)	The volume of the blood flowing through a given volume of brain (mL/100 mL).
Relative CBV (rCBV)	The ratio of the CBV in the affected hemisphere to that in the contralateral hemisphere.
Mean Transit Time (MTT)	The average amount of time it takes for blood to flow through a given volume of brain (sec). MTT increases as a vasodilatory response to reduced flow.
Time To Peak (TTP)	The time required to reach peak enhancement (sec). Increased TTP indicates delayed flow due to stenosis or occlusion.
Time To Start (TTS)	The time required for the contrast bolus to enter the given volume of brain (sec).
Time To Drain (TTD)	The time required for the contrast bolus to exit the given volume of brain (sec
Tmax	The time required to reach peak after deconvolution (sec). Increased Tmax indicates delay in arrival of the contrast bolus.
Temporal Maximum Intensity Projection (tMIP)	The maximum value image in every projected plane from the time-phase direction on all timepoints from a CTP acquisition. tMIP improves the detection of ischemic area as compared to non-contrast CT and helps assess the vessels, i.e., the collateral status.
Mismatch Volume	The difference in volume between the total hypoperfused region and the infarct core. This equals the ischemic penumbra, the volume of salvageable tissue.
Mismatch Ratio	The ratio of the volumes of the total hypoperfused region and the infarct core.

Table 1 CTP Parameters

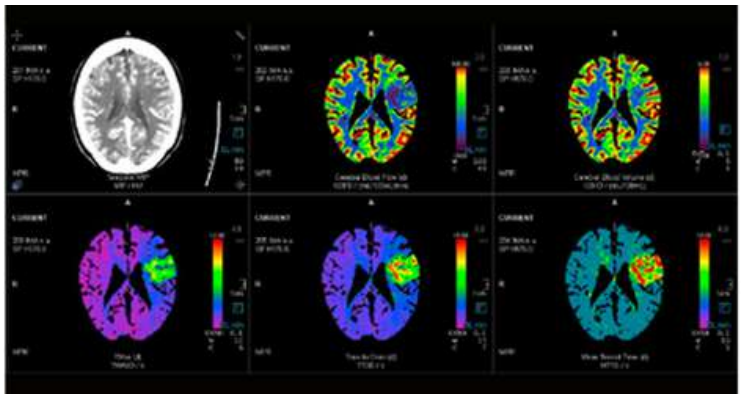


Figure 2 VPCT Neuro multi-parameter analysis with DC model showing axial views of Temporal Maximum Intensity Projection (tMIP), Cerebral Blood Flow (CBF), Cerebral Blood Volume (CBV), Tmax, Time To Drain (TTD) and Mean Transit Time (MTT). Figure shows a case with left MCA occlusion, the left hemisphere has decreased cerebral blood flow as seen in the CBF map (top center). The increased cerebral blood flow is also reflected in the increased Tmax (bottom left) as well as the TTD (bottom center) and MTT (bottom right). The CBV values (top right) on the other hand are not lowered to the same extent as the CBF values indicating a potential tissue at risk area.

Numerous post-processing techniques for CTP analysis have been investigated, and several definitions for the best predictors of infarct core and penumbra have been put forth based on a combination of various CTP characteristics and thresholds.. Certain of these studies, such as absolute CBF, are predicated on thresholds for a single parameter. Others, however, are predicated on the idea of cerebral vascular autoregulation, which is lost in the core but maintained in the penumbra. These studies employ a variety of metrics, such as CBF and CBV or CBV and MTT, to mention a couple.

Acquisition

The whole brain volume can be evaluated by extending the CTP scan coverage range to 8 cm and beyond. The table constantly executes a smooth (but rather quick) dynamic scan with periodic motion between two end positions in the Adaptive 4D Spiral (A4DS) and Flex 4D Spiral (F4DS) modes (Figure 4). This method provides enough temporal sampling to examine minute variations in regional cerebral mean transit time (MTT). The "toggling table" technique, which doubles the coverage by moving the table back and forth between two neighbouring spots (for example, from 4 to 8 cm or from 8 to 16 cm), is an alternative method for extending the CTP scan range. A standard axial CTP acquisition is carried out at each point, permitting temporal sampling rates of three to four seconds. The patient's comfort is impacted by the table motion's shocks. The quality of the images is also negatively impacted if these very sick patients are unable to stay motionless. This technique's inability to perform 3D motion correction is an additional disadvantage. Using extra wide detectors is another method to extend the CTP scan range. Systems with very wide detectors (16 cm) suffer from significantly higher levels of scatter radiation, which lowers their low contrast detectability and reduces their dosage efficiency (noise increase of roughly 20%).

Their proponents have proposed a number of heterogeneous sampling techniques that lower the sample rate to 5 s in later stages of the acquisition in order to make up for the higher dosage needed by the extra broad detectors. Regretfully, not all patients in clinical settings may benefit from these regimens. Relevant stages of the regional time attenuation curves may not

be appropriately sampled in the event of a significant contrast delay (such as in a patient with limited cardiac output or an extracranial bypass), endangering the calculation's accuracy. The best coverage should be chosen based on the clinical needs of each patient; the maximum coverage should only be used when it is warranted, as larger coverage is linked to a higher radiation dose and may cause direct irradiation of the eye lenses. This strategy better adheres to the ALARA (As Low As Reasonably Achievable) guideline by preventing needless radiation. For stroke imaging, a VPCT scan range of around 10 cm is typically regarded as sufficient since it covers the entire supratentorial brain without directly irradiating the eye lenses and permits an appropriate prediction of tissue outcomes.

Because 70 and 80 kVp offer the lowest radiation doses for a certain iodine contrast to noise ratio (CNR), these settings are used for neuro VPCT regimens. The kVp shouldn't be increased to higher amounts because the most important parameter for a perfusion scan is the iodine CNR. This could result in dosage values that are too high. A typical VPCT scan of the entire supratentorial brain with a 12.5 cm coverage (70 kVp, 167 mAs, 46.5 s) yields a CTDIvol of 184 mGy when using the usual protocol settings. The stochastic radiation risk is equivalent to roughly two years of natural background radiation, and this is far below any possible skin reaction.

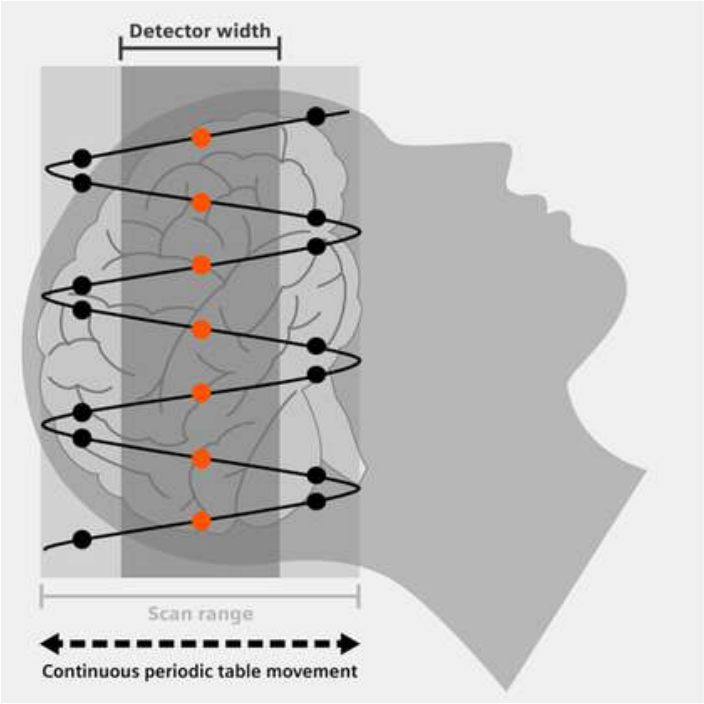


Figure 3 The A4DS mode allows dynamic time-resolved scanning of areas larger than the detector width by continuous periodic table movement between two end positions. The temporal sampling of the scan range is equidistant in the central region (empty circles) and non-equidistant in the peripheral regions (filled circles).

Recommendation for injection protocol:

- Injection flow rate of 5–6 ml/s or higher.
- Pre-heat the contrast medium to decrease viscosity and enable high flow rates.
- 18 g needle (green), or larger, into right antecubital vein.
- Injection duration lower than 8 seconds.
- A contrast medium volume not too small, to ensure detectable enhancement changes.
- Saline flush at the same flow rate. Short delay between injection and scan (~ 4 seconds), unless using test bolus to determine delay.

Postprocessing

These spiral acquisition modes' volume coverage aids in improving motion correction in 3D, which is sometimes not possible with the traditional 2D method. Accurate perfusion analysis depends on appropriate motion correction because it is typical for stroke patients to move during the acquisition. This is particularly true for DC models, which depend heavily on the artery input function's (AIF) precise shape. It is advised to make reconstructions at 1.5 mm thickness and 1 mm increment or 5 mm thickness and 3 mm increment. The efficacy of 3D motion correction may be limited by thicker slices and greater increments; that is, it may not be feasible to accurately correct patient motion with excessively thick slices. The reconstructed images intentionally overlap by 50% to enhance the detection of minute objects, such as collaterals. For perfusion analysis, the CTP algorithms' sensitivity to delayed contrast arrival is especially crucial.

The unique 4D noise reduction algorithm CT Neuro Perfusion employs a spatiotemporal multi-band filtering technique. Images from each time period in the dynamic series are broken down into several (spatial) frequency bands using this method. Information regarding smooth image content, or image contrast, is primarily found in the lowest frequency band, whereas information about edge features and noise is primarily found in the upper frequency bands. The final image is created by recombining all of the bands after they have been averaged using various weighting functions in the temporal domain (i.e., a very narrow function for the lowest frequency and broader functions for the higher frequencies). Since the temporal averaging of the higher (spatial) frequency bands is equal to gathering more x-ray photons, this final image has less noise but still retains the same information on iodine enhancement (i.e., the time attenuation curves are not altered).

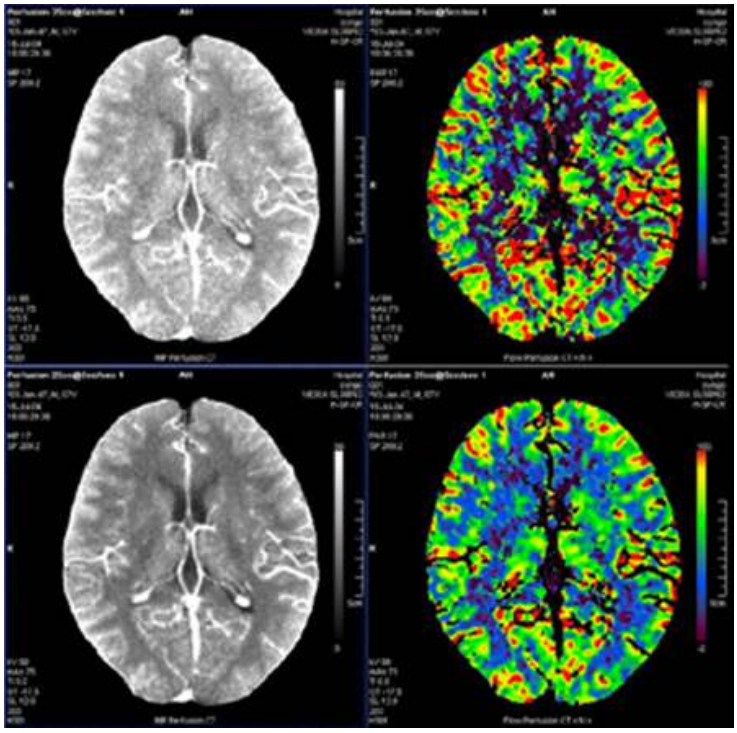


Figure 4 An example of how the 4D noise reduction algorithm improves the quality of the MIP (left column) and CBF (right column) images. The CBF image with the 4D noise reduction (bottom row) has fewer areas where the model fails due to insufficient signal-to-noise ratio, compared to the image without 4D noise reduction (top row).

Either the radiation dose can be decreased while preserving the same picture quality, or the 4D noise reduction can be employed to enhance the quality of the perfusion maps (i.e., fewer regions where the model fails because of an inadequate signal-to-noise ratio, as illustrated in Figure 4). Since a dynamic acquisition at several time periods might produce radiation dose levels higher than those of standard diagnostic CT exams, maintaining a low dosage is crucial for brain perfusion.

The VPCT scan range's core slice experiences an equidistant temporal sampling due to periodic table movement during dynamic scan collection, while the outer slices experience non-equidistant temporal sampling (Figure 3). It has been questioned if the dynamic spiral acquisition approach may enable a reliable estimate of the quantitative perfusion parameters, given that traditional cerebral perfusion requires equidistant sampling (between 1 and 4 s). However, the syngo. CT Neuro Perfusion program uses specific algorithms that specifically account for the non-uniformity of the A4DS and F4DS modes with the dynamic spiral acquisition sampling method. Even with a significant contrast delay, the middle slice, which has an equidistant sample of 1.5 s, can provide the precise form of the artery input function (AIF). Even with non-equidistant temporal sampling in the peripheral slices, the shape-based DC model and the AIF can accurately predict the perfusion parameters for the time-attenuation curves of brain tissue.

Whole-brain coverage allows for the evaluation of the disease's entire extent and the 3D visualisation of perfusion parameters using axial, coronal, and sagittal views. Furthermore, the infarct core and penumbra regions can be distinguished and colour coded to make the examination of the core/penumbra mismatch easier by utilising the proper adjustable threshold settings for various perfusion metrics (such as CBV and CBF) (Figure 5). This method is more objective for determining core/penumbra mismatch than the often utilised qualitative assessment. However, it should be mentioned that the user must determine the precise thresholds for the core and penumbra in accordance with the policies of their individual institutions. Perfusion values in the infarcted and surviving zones significantly overlap, according to studies. The optimal threshold maximally predicts the final infarct with the least amount of over or under estimation.

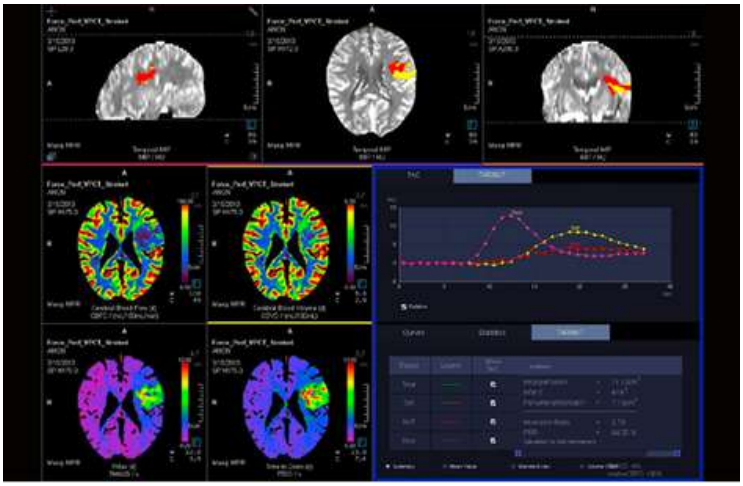


Figure 5 With the user defined perfusion parameters and threshold values, a 3D evaluation of brain tissue for the mismatch between the infarct core (red) and the penumbra (yellow) can be performed demonstrating the full extent of ischemic damage. Figure shows the results for the case presented in Figure 2.

Without requiring human input, auto stroke carries out the Motion Correction, Segmentation, and Vessel Definition processes automatically. Before verifying the analysis, the results can then be examined by navigating through the data.

Recommendation for injection protocol:

- **Patient Motion:** Check the shape of the AIF. Patient motion can be inferred from jumps in the AIF or the reference vessel venous output function (VOF). Patient motion is also indicated by unusually thick bones in the tMIP as well as blurry vessels. Violet areas close to the skull in the vessel masks are also indicative of patient motion.
- **Insufficient cardiac output:** Check the position of the AIF. Insufficient cardiac output is reflected in a delayed AIF peak.
- **Delayed contrast bolus:** Check the AIF and specifically the extent of the downslope of the curve that has been obtained. If the downslope is not captured, the MS model would be a better alternative to the default DC model.
- Injection duration lower than 8 seconds.
- A contrast medium volume not too small, to ensure detectable enhancement changes.
- Saline flush at the same flow rate.
- Short delay between injection and scan (~ 4 seconds), unless using test bolus to determine delay.

Measures to salvage a CTP scan in case of failed automatic evaluation:

- Choose a different registration base image or delete a time point if it does not align with the other volumes. Note that volumes close to the bolus peak are critical, and if these are deleted, results might be unreliable (due to an incorrect approximation of the AIF shape).
- Place the VOF manually if the auto detection fails.
- Place the AIF manually if the auto detection fails.

Conclusion

The way ischaemic stroke is managed and treated has changed significantly in recent years (Figure 6). In order to assess the severity of the stroke and make well-informed treatment decisions, advanced neuroimaging techniques such as CTP are required. Whole brain perfusion imaging with nearly isotropic resolution is made possible by dynamic spiral acquisition techniques (A4DS and F4DS) with a 4D noise reduction algorithm. Even under less than ideal circumstances, two distinct delay-insensitive models for perfusion analysis and robust motion correction provide diagnostic results. A simplified workflow for processing and automatically archiving the perfusion findings to PACS is made possible by CT Neuro perfusion Auto Stroke and Recon&GO, also known as Rapid findings technology. Time is brain: Rapid imaging, diagnosis, and treatment, together with interactions throughout the healthcare continuum, are essential for the best stroke care. The CT imaging systems have the potential to help decrease door-to-needle time, preserve brain tissue, and enhance stroke outcomes in addition to enabling a prompt and precise treatment to ischaemic stroke.

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QUIZ to Recapitulate - November 2026

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

1. What is Difference in sodium thiosulfate and ammonium thiosulphate in their use?

2. Why KBr is absent in developer replenisher solution?

3. What is moving jaw technique and its use in Radiography?

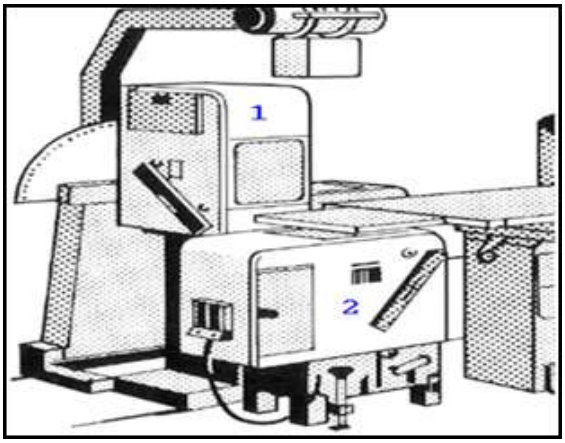
4. What is the recommended concentration of Barium Sulphate suspension for Single Contrast Barium Enema?

5. Technically What is the difference in CT and Tomosynthesis ?

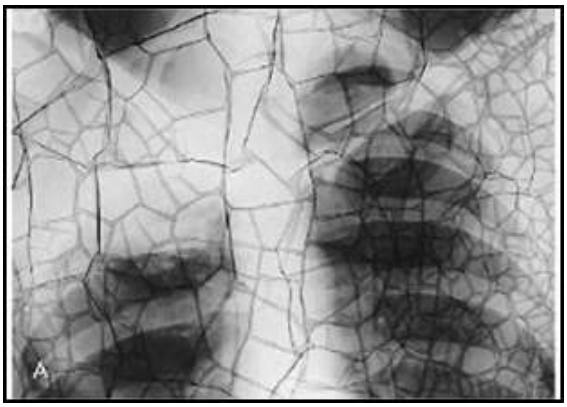
6. What is ratio of Sodium and Meglumine diatrizoate in 76% contrast media?

7. After how long we should scan the patient for CT enterography after giving oral mannitol?

8. Identify structures Marked 1 and 2



9. Name the Artifact



10. Identify the object



- Please send your answers through email on **pkpopli@gmail.com** on or before **30th November 2026.**
- Send your **Name with Hospital/Institution Information** and Passport size **photograph** along with the answers.
- 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 - October 2026 issue

1. Heal pad thickness is soft tissue radiography whereas Calcaneal spur is bone radiography.

2. To protect the patient from leakage current.

3. To visualize the Entire Vascular Tree in One Image.

4. 200% to 250% w/v .

5. X-ray source and the receptor remain fixed in one place, whereas overlying anatomical structures are made to move during exposure keeping the required part stable.

6. Less than 5 %.

7. Minimum possible time, otherwise distended bowl loops may lose distension.

8. Hair braid artifact is seen .

9. Loopogram. Contrast medium is instilled into ileal conduit demonstrating the parts of renal system .

10. RF ablation probe.

Diagnostic Radiology QA Accessories

PRODUCTS & SERVICES



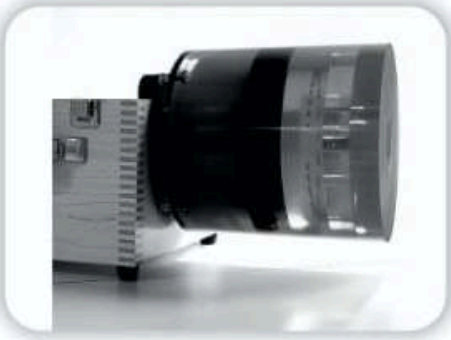
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QUART Dido CT Probe



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Magnetic Resonance Spectroscopy for Cervical Cancer

Mansi Sharma, Msc Research Fellow, **Nayeem Ahmad Sheikh, Dr. Bhanu Pratap** Assistant Professors,
Department of Radiology, NIMS University, Jaipur

Introduction

Cervical cancer is one of themajor cancers that affect women globally. Imaging is crucial for diagnosis, staging, treatment planning, and follow-up. The cervix, uterus, parametrial tissues, and surrounding pelvic structures can all be seen with magnetic resonance imaging (MRI), which is especially helpful due to its superior soft-tissue contrast. However, the primary information provided by conventional MRI is anatomical, such as the location, size, and relationship of a tumor with surrounding tissues. It does not directly depict the biochemical alterations taking place within the tumor. MagneticResonance Spectroscopy (MRS) is helpful in this situation. By identifying various metabolites, MRS is a sophisticated MRI method that reveals detailsabout the chemicalmakeup and metabolism of tissue. MRS has been studied in cervical cancer to detectmetabolic changes linkedto cancer, especially those involving lipids, choline, and other metabolites. As a result, MRS can offer data that enhances traditional anatomical MRI.

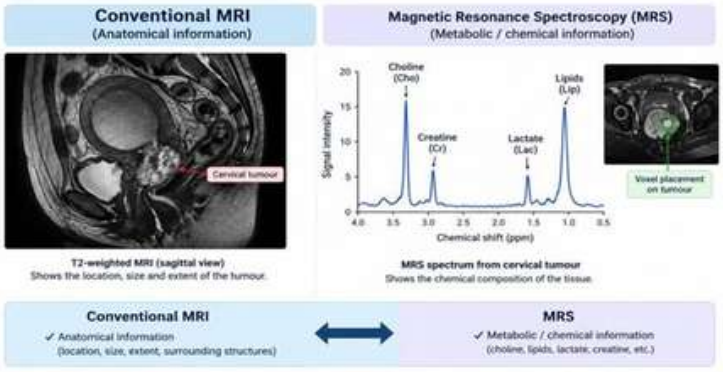


Fig 1: showing Conventional MRI provides anatomical information, whereas magnetic resonance spectroscopy provides additional metabolic information from the tissue.

What is MagneticResonance Spectroscopy?

The biochemical makeup of tissues can be examined using an MRI-based method called magnetic resonance spectroscopy. MRS creates a spectrum with peaks that correspond to various metabolites ratherthan just a traditional anatomical image. These peaks'locations and relative sizes reveal detailsabout the chemicalenvironment of the chosen tissue.Proton (^1H) spectroscopy is used in the majorityof clinical MRS applications due to the high concentration of hydrogen in the human body. A tissue region of interest known as a voxel is chosen during MRS. Within that voxel, the MR system picks up signals from various chemical compounds. A spectrum is created after these signals are processed. Chemical shift is represented by the horizontal axis of the spectrum and is typically expressed in parts per million (ppm), while signal intensity is represented by the vertical axis.

How MRS Works

MRS is based on the same basic principle of nuclear magnetic resonance as MRI. When the patient is inside the MRI scanner, hydrogen nuclei align with the strong magnetic field. Then, radiofrequency pulses are appliedto disrupt this alignment. As hydrogen nucleireturn to their equilibrium state after excitation, they produce observable magnetic resonance signals. Different chemical compounds come into contact with slightly different

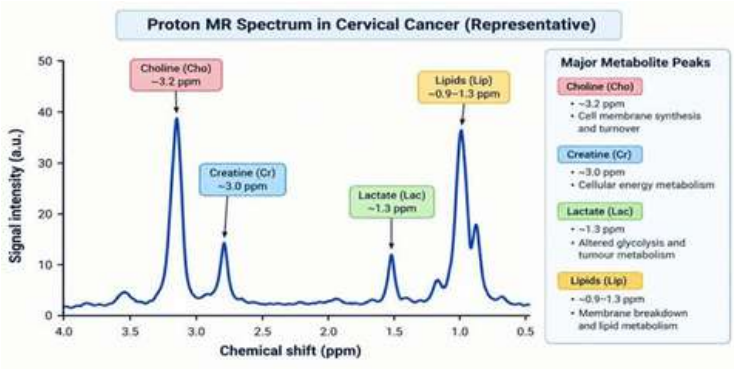


Fig 2: Representative protonMR spectrum demonstrating metabolite peaks used for metabolic assessment of tissue.

magnetic environments. As a result, their signals occur at somewhat different frequencies. The phrase "chemical shift" refers to this phenomenon. The MRI system analyzes these frequency variations and converts them into a spectrum.

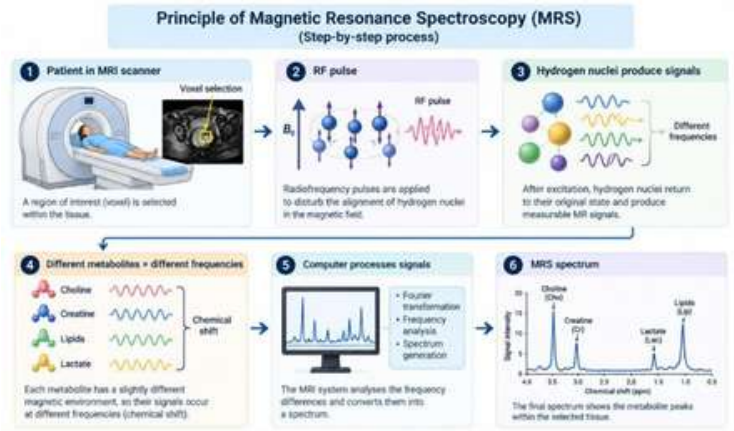


Fig 3: Simplified principle of magnetic resonancespectroscopy, showing how tissue signals converted into a metabolite spectrum.

MRS in Cervical Cancer

Cancer cells have drastically changed cellular metabolism. Rapid proliferation, increased membrane synthesis, and modified energy metabolism can all cause changes in some metabolite concentrations. MRS allows for the non-invasive investigation of some of these metabolic changes. Cervical cancer has received particular attention in studies on choline-containing compounds and lipid signals. Changes in these metabolites may help differentiate malignant tissue from surrounding normal tissue and provide additional information about the biology of tumors. As a result, MRS is considered an additional technique rather than a replacement for conventional MRI. As a result, MRS is considered an additional technique rather than a replacement for conventional MRI.

Conventional MRI provides information about:

Tumor's size, Tumor's location, Local extension, Taking part in the parametrium, Pelvic anatomy.

MRS may provide additional information about:

The cell's metabolism, Membrane tumor, Lipid metabolism, changes in the metabolism of the tumor.

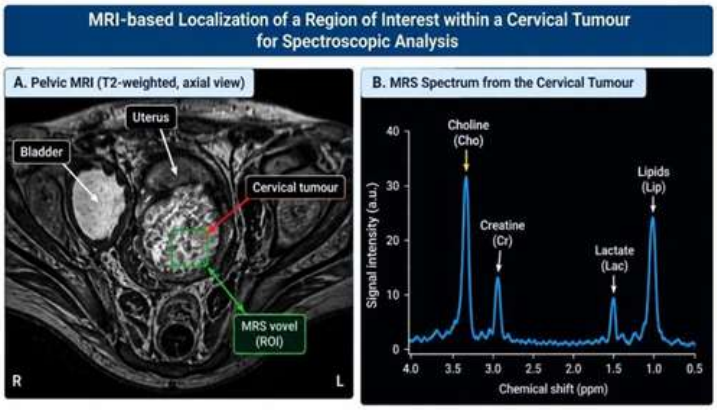


Fig 4: MRI-based localization of region of interest withina cervical tumor for spectroscopic analysis

Important Metabolites in Cervical Cancer

1. Choline

Choline-containing metabolites may change within malignant tissue because cancer cells typically have increased cellular proliferation and membrane production. As a possible metabolic indicator of cervical cancer, a changed or elevated choline signal has been studied. Choline shouldnot be interpreted in a vacuum, though.MRS results must be taken into account in conjunction with traditional MRI results and the clinical setting.

2.Lipids

Lipids are another importantclass of metabolites present in MRS. Changes in lipid signalscan be connected to changes in cellular membranes, tumor metabolism, and cellular disintegration. Numerous studieson cervical cancerhave looked at lipid peaksand their relationship to tumor characteristics. However, because lipid signals can be affected by tissue composition and technical factors,appropriate MRS acquisitionand analysis are required for their interpretation.

3.Lactate

Lactate is associated with cellular energy metabolism. Cancer cells may exhibit increased lactate production and altered glucose metabolism. As a result, lactate has been studied as an additional possible metabolic marker in spectroscopy for cancer. Lactatedetection is dependent on a number of variables, including the metabolite's concentration, spectral quality, and scanning method.

4.Creatine

Creatine, which is involved in the metabolism of cellular energy, can be found using proton MRS. A tissue's overall metabolic profile may be influenced by variations in creatine signals. Researchersmay evaluate the general patternof multiple metabolite peaks rather than focusing only on one metabolite.

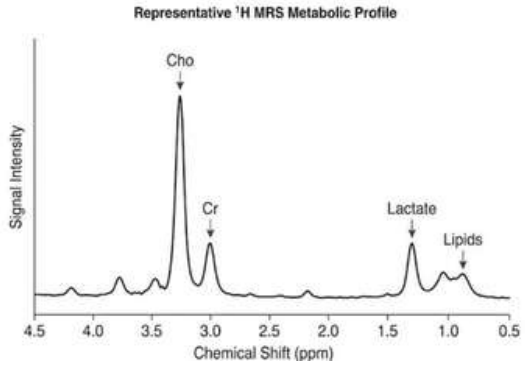


Fig 5:- Representative metabolic profile demonstrating multiple metabolite signal that can be evaluated using proton MRS

Conclusion

Magnetic resonance spectroscopy provides a unique metabolic perspective to conventional MRI, allowing researchers and medical practitioners to assess not only the anatomical appearance of a cervical tumor but also its biochemical behavior. Choline and lipids have received particular attention among the metabolites studied because their changes may reflect changes in cellular membrane turnover and tumor metabolism, even though metabolites like lactate and creatine can provide more metabolic information. Tumor characterization, tumor grade assessment, and treatment-related metabolic change monitoring can all be done with MRS. However, its routine clinical use is limited by technical difficulties, variations in acquisition and analysis techniques, and small samplesizes in currentstudies. A more thorough understanding of the biology of cervical cancer may result from the future integration of MRI, DWI, MRS, artificial intelligence, and radiomics. Therefore, MRS should be considered a useful metabolic supplement that may aid in the development of more precise, non-invasive, and personalized cervical cancer imaging rather than a substitute for traditional MRI.

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From the Darkroom to the Boardroom

A Radiographer's Journey of Grit, Gratitude, Growth and Leadership

Anto Ramesh Delvi Dass
Founder & CEO – RADBLOX Healthcare Services Pvt. Ltd.
Director – Victory Healthcare Services Pvt. Ltd.

"My career began in an X-ray darkroom. My dreams took me to the boardroom. But my purpose has always remained the same — to serve patients, empower professionals, and contribute to better healthcare."

Where the Journey Began

Every professional journey has a beginning, but not every beginning reveals the destination.

Mine began in a hospital X-ray darkroom, surrounded by radiographic films, processing chemicals, developing tanks, and the familiar routines of conventional radiography. It was a modest workplace, but it became the foundation of a much larger dream.

As a young X-ray technologist, I never imagined that one day I would be participating in international healthcare discussions, building radiology services, exploring artificial intelligence, developing healthcare partnerships, and leading my own organizations.

I did not begin my career with a boardroom, a business plan, or a leadership title. I began with a willingness to work, learn, accept responsibility, and improve myself every day.

Looking back, I realize that the greatest limitation in life is often not where we begin, but how far we allow ourselves to dream.

My journey has taught me one powerful truth: your starting position does not determine your final destination.

The Darkroom Was My First Leadership Classroom

In the 1990s, radiography was very different from the technology-driven profession we know today. There were no instant digital images, advanced PACS platforms, automated reporting workflows, or artificial intelligence systems to assist us. Every radiographic examination required technical precision, appropriate patient positioning, exposure selection, film processing, and careful image evaluation.

A small mistake could mean repeating an examination, delaying a diagnosis, or exposing a patient to unnecessary radiation. The darkroom taught me discipline, patience, accuracy, accountability, and respect for the profession. More importantly, it taught me something that no management textbook could fully explain: Behind every radiological image is a patient, a family, a clinical question, and a decision that may change someone's life. That belief remains the foundation of my professional and entrepreneurial journey. Technology has transformed radiology, but the responsibility of the healthcare professional has not changed.

Beyond Radiography: Learning to Lead

My professional journey gradually expanded from clinical radiography into radiology administration, hospital operations, healthcare management, technology integration, business development, and entrepreneurship. Each transition required me to step outside my comfort zone. I had to understand not only how to perform an examination, but also how a department functions, how teams collaborate, how healthcare organizations make decisions, and how quality, patient safety, financial sustainability, and operational efficiency must work together. I learned that professional growth requires more than technical expertise. It demands continuous education, effective communication, financial understanding, adaptability, emotional maturity, and the courage to accept responsibility. There were challenges, setbacks, difficult decisions, and moments of uncertainty. Not every opportunity became a success, and not every effort produced the expected outcome. However, every experience contributed to my development.

I never considered radiography a profession I needed to leave behind to become a leader. Instead, radiography became the foundation upon which I built my leadership career.

A radiographer's understanding of imaging technology, clinical workflows, patient care, departmental coordination, and diagnostic quality can become a powerful advantage in healthcare leadership.



Gratitude: Remembering the Institutions That Built Me

No professional journey is accomplished alone. As I reflect on my career, I remain deeply grateful to the institutions that gave me opportunities to learn, grow, make decisions, and develop as a healthcare professional. I sincerely acknowledge CSI (CMAI) Hospital, Bengaluru; Jindal Manav Charitable Hospital; Columbia Asia Group of Hospitals, India; and Columbia Asia Radiology Group.

Each institution played a meaningful role in shaping my professional identity. My years at Jindal Manav Charitable Hospital strengthened both my clinical and administrative knowledge. My experiences within the Columbia Asia healthcare environment further broadened my understanding of organized healthcare systems, radiology operations, professional standards, teamwork, and leadership. These organizations were not merely places where I worked. They were institutions where I learned lessons that continue to influence my decisions today. I remain equally grateful to the mentors, senior professionals, radiologists, radiographers, administrators, colleagues, and leaders who trusted me with responsibilities and encouraged my growth.

My family and friends have also been an essential part of this journey, offering encouragement, patience, and strength through both achievements and difficult periods. **I may have moved from one institution to another, but I have never moved away from the values, lessons, and people who helped shape my career.**

RADBLOX: Transforming Experience into Entrepreneurship

In 2021, I took another significant step in my professional journey with the establishment of **RADBLOX Healthcare Services Pvt. Ltd.**

For me, entrepreneurship was not simply about starting a company or becoming a CEO. It was an opportunity to apply decades of clinical and administrative learning toward addressing real challenges in healthcare delivery. Radiology plays a crucial role in emergency medicine, stroke management, trauma, oncology, and many other areas where timely, accurate interpretation can influence patient outcomes. Our vision at RADBLOX is to strengthen access to dependable diagnostic expertise through international teleradiology services, structured reporting workflows, experienced radiologists, skilled radiographers, quality assurance professionals, and dedicated operational teams. One principle remains central to our approach:

A radiology report must not merely describe an image. It must address the patient's clinical history, answer the referring physician's question, and support an appropriate clinical decision. Accuracy, clinical relevance, accountability, and turnaround time must never be treated as competing priorities.

A report delivered quickly but lacking diagnostic accuracy or clinical relevance does not fulfill the true purpose of radiology. As healthcare becomes increasingly interconnected, we are also exploring the responsible integration of artificial intelligence, workflow automation, imaging informatics, and quality assurance systems. I believe the future of radiology will be shaped not by technology replacing professional responsibility, but by technology strengthening the capabilities of skilled healthcare professionals.

Victory Healthcare: Investing in the Next Generation

Alongside RADBLOX, my involvement with Victory Healthcare Services Pvt. Ltd. reflects another important purpose: contributing to healthcare development, professional education, practical training, and new opportunities for the next generation.

One of my greatest passions is encouraging radiography students and young professionals to look beyond conventional career boundaries. The radiographer of tomorrow can become much more than an imaging technologist. Opportunities are expanding in teleradiology operations, PACS administration, imaging informatics, clinical applications, artificial intelligence, healthcare quality management, hospital administration, education, research, and entrepreneurship. However, these opportunities require continuous learning and a willingness to develop new competencies. My message to young radiographers is clear: **Do not limit your future to the designation on your first appointment letter.**

Your technical education is your foundation, not your ceiling. Develop your clinical knowledge. Learn healthcare technology. Understand administration. Improve your communication. Build professional relationships. Seek mentorship. Accept challenges. Most importantly, never compromise patient safety or professional ethics in the pursuit of career advancement. Through RADBLOX and Victory Healthcare, our aspiration is to help bridge the gap between academic education and industry expectations by supporting practical learning, professional development, and exposure to emerging healthcare technologies.

Leadership Is Responsibility, Not Position

My transition from radiographer to entrepreneur has fundamentally shaped my understanding of leadership. I have learned that leadership is not defined by designation, authority, office size, or the chair one occupies in a boardroom. Leadership is demonstrated through decisions, accountability, integrity, and the ability to bring people together toward a meaningful purpose. In healthcare, every decision carries responsibility because our work ultimately affects patients and their families. A leader must have the courage to acknowledge mistakes, address weaknesses, invest in people, and improve systems rather than search for excuses

I firmly believe that sustainable healthcare organizations are built through competent teams, ethical practices, clinical accountability, and a culture of continuous improvement. **A CEO may lead an organization, but no CEO can build a successful healthcare institution alone.** Behind every achievement are professionals who contribute their knowledge, dedication, and commitment, often without public recognition. I consider it my responsibility to recognize those contributions and create opportunities for others to grow.

The Journey Continues: Learning Has No Finish Line

Even after moving into executive leadership, I continue to see myself as a student of healthcare. Completing the Chief Executive Officers Certificate Programme at the **Indian Institute of Management Indore (IIM Indore)** in 2026 marked another important milestone in my commitment to continuous learning. The experience strengthened my understanding of strategy, leadership, organizational development, and the importance of adapting to an increasingly complex business environment. For someone whose professional journey began in an X-ray darkroom, learning alongside business leaders and entrepreneurs was a meaningful reminder of how far determination and education can take an individual. But I do not consider any qualification, achievement, or leadership position the final destination. Every new responsibility brings another opportunity to learn. **The day we believe we have learned everything is the day our professional growth begins to stop.**

My Message to Every Radiographer

To every radiography student, young technologist, and experienced professional reading this article, I would like to share a message from my own journey. Never underestimate the value of your profession. Be proud of your technical knowledge, the patients you care for, the diagnostic equipment you operate, and the contribution you make to healthcare every day. Do not compare your beginning with someone else's achievements. Your journey may be difficult. Your progress may be slow. Opportunities may not always arrive when expected. There may be failures, disappointments, and people who question your ambitions. Keep learning. Keep improving. Remain disciplined. Build your professional credibility. Surround yourself with people who encourage your growth. Above all, never allow your present circumstances to decide the limits of your future. **You may begin your career in an X-ray room, but your knowledge, character, determination, and vision can take you into classrooms, research laboratories, technology companies, hospital leadership, entrepreneurship, and boardrooms across the world.**

From the Darkroom to the Boardroom — With Gratitude

Today, when I look back at my journey, I do not see only the transition from an X-ray technologist to a Founder and CEO. I see the people who trained me, the institutions that trusted me, the colleagues who worked alongside me, the family and friends who supported me, the challenges that strengthened me, and the lessons that shaped my decisions.

I remain grateful to God for the opportunities, strength, and guidance throughout this journey. The darkroom taught me to develop X-ray films. Life taught me to develop people, build teams, and create opportunities. The environment has changed. The responsibilities have grown. The vision has expanded internationally. But my professional identity remains deeply rooted in radiography.

I began my career developing images in a darkroom. Today, my mission is to develop people, strengthen healthcare systems, and create opportunities through leadership.

And if my journey can inspire even one radiography student to believe in a bigger future, it will be among my most meaningful achievements.

"The darkroom was where my career began. The boardroom is where my responsibilities expanded. But serving healthcare will always remain my purpose."





SCIENTIFIC PROGRAM

8:00 AM - 9:00 AM | BREAKFAST/REGISTRATION

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2	9:30 AM - 10:00 AM	ADVANCEMENTS IN MRI TECHNOLOGY	**Mr. MOHIT KUMAR PANDEY** ASSO.PROF DEPT MEDICAL RADIOLOGY & IMAGING TECH GMC GOA
3	10:00 AM - 10:30 AM	STRUCTURAL AND FUNCTIONAL MRI NEUROIMAGING	**Dr.SAIKIRAN P** ASSO. PROF DEPT MEDICAL RADIOLOGY & IMAGING TECH MCHP, MAHE MANIPAL
10:30 AM - 11:30 AM INAUGURATION CEREMONY & TEA BREAK			
4	11:30 AM - 11:45 AM	CT UROGRAPHY TECHNICAL CONSIDERATION PROTOCOL OPTIMIZATION AND DOSE REDUCTION	**Ms. NEHA KOLWALKAR** ASST.PROF DEPT MEDICAL RADIOLOGY & IMAGING TECH, SCHOOL OF ALLIED HEALTH SCIENCES D.Y. PATIL NAVI MUMBAI MAHARASHTRA
5	11:45 AM - 12:00 PM	BEYOND IMAGING :- ENHANCING PATIENT CENTERED CARE IN RADIOLOGY	**Mr. GIRISH BISANAL** ASST.PROF DEPT MEDICAL RADIOLOGY & IMAGING TECH BLDE DEEMED TO BE UNIVERSITY SCHOOL OF ALLIED HEALTH SCIENCES BIJAPUR
6	12:00 PM - 12:15 PM	CARDIAC CT WORKFLOW : FROM CALCIUM SCORING TO CORONARY ANGIOGRAPHY	**Mrs. R. JYOTHILAXMI** LECTURER DEPT MEDICAL RADIOLOGY & IMAGING TECH CAHS, SHS DAYANANDA SAGAR UNIVERSITY BANGALORE SOUTH
1:00 PM - 2:00 PM LUNCH BREAK			
2:00 PM - 3:30 PM E-POSTER COMPETITION			
3:30 PM - 4:00 PM HIGH TEA BREAK			
4:00 PM - 5:00 PM VALEDICTORY CEREMONY			

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Hypotonic Duodenography

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Abstract

Hypotonic duodenography is a specialized fluoroscopic contrast examination designed to demonstrate the duodenal lumen and mucosal contour after temporary reduction of duodenal tone and peristaltic activity. The classical technique combines selective or oral administration of barium with pharmacologically induced hypotonia and, in double-contrast examinations, air or gas to outline the mucosal surface. By reducing superimposition from active peristalsis and improving luminal distension, the examination can demonstrate the duodenal bulb, descending segment, periampullary region, horizontal segment and proximal jejunum in greater detail. Historically, hypotonic duodenography was used in the evaluation of suspected duodenal lesions and pancreaticoduodenal disease, including ulcers, stenosis, tumors, inflammatory change and abnormalities affecting the ampulla or adjacent pancreatic head. Published studies established the technical value of glucagon and anticholinergic agents, while also showing that the method does not always add information beyond a well-performed conventional barium examination. In contemporary practice, endoscopy, multidetector CT, MRI and MRCP have reduced the role of hypotonic duodenography, but the technique remains important for understanding gastrointestinal fluoroscopy and may be useful in selected cases where detailed luminal morphology is required. This chapter reviews the principles, indications, preparation, contrast administration, hypotonic agents, fluoroscopic technique, projections, normal appearances, abnormal findings, limitations, radiation protection, complications and the radiographer's responsibilities.

Keywords: Hypotonic duodenography; Duodenogram; Double-contrast study; Barium; Glucagon; Fluoroscopy; Duodenum; Gastrointestinal radiography; Ampulla of Vater; Radiographic technique

1. Introduction and Principle

The duodenum is a relatively short but anatomically complex segment of the gastrointestinal tract. It forms a C-shaped loop around the head of the pancreas and is conventionally divided into four parts: the superior or first part (D1), descending or second part (D2), horizontal or third part (D3), and ascending or fourth part (D4). The major papilla, where the common bile duct and main pancreatic duct usually enter the bowel, is located in D2. Because the duodenum lies deep in the upper abdomen and changes direction in several planes, its mucosal surface may be difficult to evaluate completely on a routine single-contrast examination. Continuous peristalsis may further alter the shape of the loop and produce transient folds or incomplete distension.

Hypotonic duodenography was developed to overcome this problem by temporarily reducing smooth-muscle tone and peristaltic activity before the duodenum is distended with contrast material. The classical description involved duodenal intubation, drug-induced atony and visualization with barium and air. The resulting flaccid, distended bowel provides a more stable outline and permits careful assessment of the wall, mucosal folds and contour. The historical literature describes both probe-based and later tubeless approaches. Modern practice should not assume that one technique or one drug dose is universally appropriate; the method must follow the radiologist's protocol, the selected agent's prescribing information and local safety procedures [1,2].

The central imaging concept is double contrast. A relatively dense barium suspension coats the mucosa, while gas distends the lumen and provides a radiolucent background. When the duodenum is adequately relaxed and distended, barium coating outlines subtle mucosal irregularity, small filling defects and contour changes. Hypotonicity is therefore not itself the diagnostic endpoint. It is a technical means of reducing motion and improving the conditions under which the duodenum is examined. The final diagnostic value depends on adequate preparation, appropriate contrast coating, sufficient distension, correct positioning, fluoroscopic observation and targeted spot imaging.

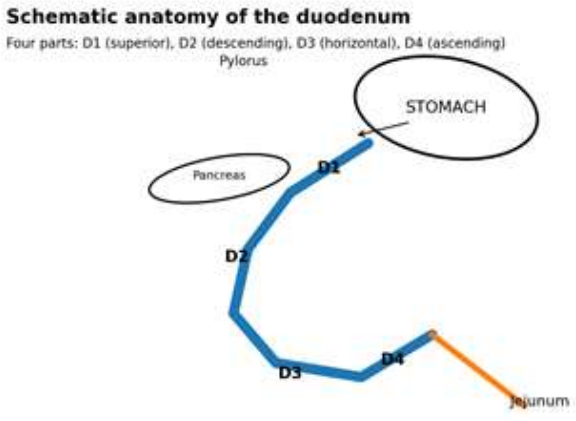


Figure 1. Educational schematic of the four parts of the duodenum (D1–D4) used to orient fluoroscopic interpretation.

2. Clinical Indications and Limitations

Historically, hypotonic duodenography was particularly useful when there was clinical or radiographic suspicion of pancreaticoduodenal disease. The examination could demonstrate deformation of the medial duodenal wall caused by a pancreatic head lesion, irregular narrowing, mucosal destruction, ulcers, diverticula, intraluminal masses and changes around the major papilla. Early clinical series reported substantial diagnostic accuracy for pancreaticoduodenal cancer, although these results reflect an era before modern cross-sectional imaging and should not be extrapolated directly to current practice [8].

Potential indications include evaluation of unexplained abnormalities seen on an upper gastrointestinal examination; characterization of a suspected duodenal mass or stenosis; assessment of selected periampullary abnormalities; clarification of subtle mucosal or contour changes; and selected evaluation of duodenal involvement in inflammatory disease. The technique has also been described after enteroclysis for patients with unexplained gastrointestinal bleeding and suspected duodenal Crohn disease [9]. In present-day practice, however, the clinical question should determine whether fluoroscopic duodenography is justified or whether endoscopy, CT, CT enterography, MRI/MRCP or another modality is more appropriate.

An important limitation is that the examination is primarily a luminal and contour study. It may suggest extrinsic disease by

demonstrating displacement, narrowing or impression, but it does not provide the comprehensive tissue characterization and cross-sectional staging available from CT or MRI. Endoscopy offers direct mucosal inspection and biopsy. Consequently, hypotonic duodenography should not be presented as a replacement for modern cross-sectional or endoscopic evaluation. A historical comparison found that properly performed conventional spot films were diagnostically equal to hypotonic duodenography in most cases, while hypotonic imaging was superior in only a minority [7]. This finding supports a selective rather than automatic approach.

3. Patient Preparation and Contrast Media

Patient preparation should be standardized according to the local gastrointestinal fluoroscopy protocol. The indication, previous imaging, relevant symptoms, previous gastrointestinal surgery and medication history should be reviewed. The patient should receive a clear explanation of the procedure, including the need to swallow contrast, change position and remain still during fluoroscopic imaging. Invasive tube-based techniques require additional explanation and informed consent according to institutional policy. Pregnancy status should be considered whenever ionizing radiation is used and the examination should be justified in accordance with applicable regulations.

Fasting is traditionally used before upper gastrointestinal contrast examinations because gastric contents can interfere with mucosal coating and visualization. The exact fasting period is institution-specific and may depend on the patient's age, diabetes, aspiration risk, sedation status and the planned technique. Dehydration should be avoided when prolonged preparation is unnecessary. Patients at increased aspiration risk require particular attention to positioning and clinical suitability.

Barium sulfate is the conventional positive contrast medium when gastrointestinal perforation is not suspected. A high-density preparation may be selected for mucosal coating in double-contrast work, whereas a lower-density suspension may be used when broader luminal filling is required. The concentration, viscosity and volume should be selected according to the radiologist's protocol and the manufacturer's preparation instructions. If perforation or a high-risk leak is suspected, the choice of contrast agent must be made by the supervising clinician because water-soluble iodinated contrast or subsequent barium may be appropriate depending on the clinical circumstances. Barium should not be administered indiscriminately when aspiration or perforation presents a significant concern.

The term hypotonic agent refers to a drug used to reduce gastrointestinal smooth-muscle activity. Glucagon has been studied extensively for this purpose. A controlled double-blind study reported satisfactory gastric, duodenal and small-bowel hypotonicity with relatively small intravenous doses and found that larger doses mainly prolonged the duration of action [3]. Other studies compared glucagon with anticholinergic agents and demonstrated that the choice of agent can influence the quality and timing of visualization of the stomach and duodenum [2,4]. Drug selection and dose must not be copied from historical articles without checking the current product information and local protocol.

Anticholinergic agents such as hyoscine butylbromide have also been used in gastrointestinal fluoroscopy. Their pharmacological effect is different from glucagon, and their contraindications and adverse effects must be considered before administration. The radiographer should confirm that the responsible clinician has screened the patient appropriately and should be familiar with the expected effects of the chosen drug. Tachycardia, dry mouth, visual disturbance and other anticholinergic effects may occur with some agents. Emergency equipment and appropriate monitoring should be available whenever pharmacological hypotonia is induced.

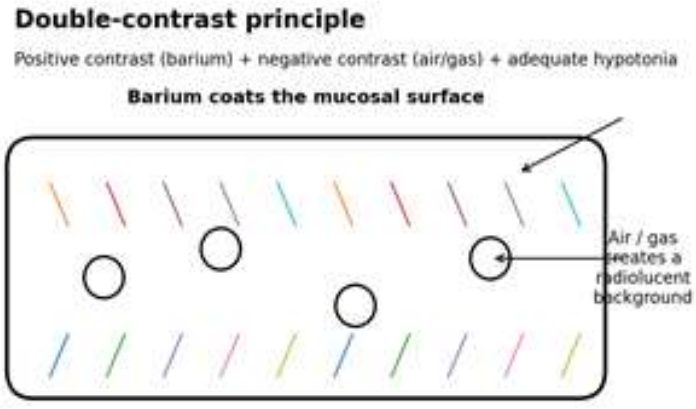


Figure 2. Educational schematic illustrating the double-contrast principle: barium coating plus air/gas distension.

4. Technique of Hypotonic Duodenography

The classical probe technique begins with placement of a suitable tube into the duodenum under fluoroscopic guidance. Historical descriptions used specialized tubes and selective catheter systems, whereas modern equipment may use a gastrointestinal or enteroclysis catheter according to the clinical purpose [1,13]. Tube placement must be performed gently because the duodenal wall is vulnerable to trauma, particularly in patients with obstruction, inflammation, recent surgery or suspected perforation. The position of the catheter tip should be confirmed fluoroscopically before contrast injection.

After satisfactory tube placement, a controlled quantity of contrast is introduced to outline the duodenal loop. The patient may be rotated to distribute the barium evenly over the mucosa. Once appropriate coating is achieved, the hypotonic agent is administered according to protocol. The timing of imaging is important because the effect is temporary. Fluoroscopy should be used to determine when the duodenum is adequately relaxed and distended rather than relying on a fixed time alone. A study of glucagon reported onset of effect at approximately 45 seconds, with duration increasing as dose increased [3].

Air is then introduced when a double-contrast examination is required. The aim is not excessive distension but sufficient expansion to separate mucosal folds and expose the contour of the bowel wall. Overdistension may obscure a localized lesion or make the examination uncomfortable. The radiologist observes the loop dynamically and directs the radiographer to obtain spot images when the desired segment and mucosal pattern are optimally demonstrated. Historically described examinations used supine and prone-oblique positions; current positioning may be individualized according to the anatomy, lesion location and equipment [1].

The radiographer must maintain close communication with the radiologist throughout the examination. Fluoroscopy is used to follow contrast movement, assess distension and select the most informative moments for spot imaging. The number of images should be minimized while maintaining diagnostic coverage.

Modern digital fluoroscopy permits image storage and post-processing, but digital systems do not eliminate the need for appropriate collimation, pulsed fluoroscopy where available, dose monitoring and avoidance of unnecessary acquisitions.

5. Positioning and Radiographic Projections

No single projection demonstrates every part of the duodenum optimally. The patient may be examined in supine, prone, right anterior oblique, left anterior oblique and lateral or modified oblique positions. The exact sequence is determined by the radiologist and the clinical question. RAO positioning can help separate the duodenal loop from the spine and may be useful for demonstrating the bulb and descending segment. Prone or prone-oblique positioning can alter the relationship between the stomach and duodenum and may assist in coating the loop. LAO and lateral projections can provide complementary views of the duodenal sweep and periampullary region.

Compression may be used selectively to separate overlapping structures or to evaluate a focal contour abnormality, but it should be applied carefully. Excessive compression may collapse a distended segment and can make a subtle lesion more difficult to characterize. The radiographer should therefore respond to the radiologist's specific instruction and use compression as a diagnostic tool rather than as a routine forceful maneuver. Spot images should document the clinically relevant region with the patient and bowel position recorded as required by departmental practice.

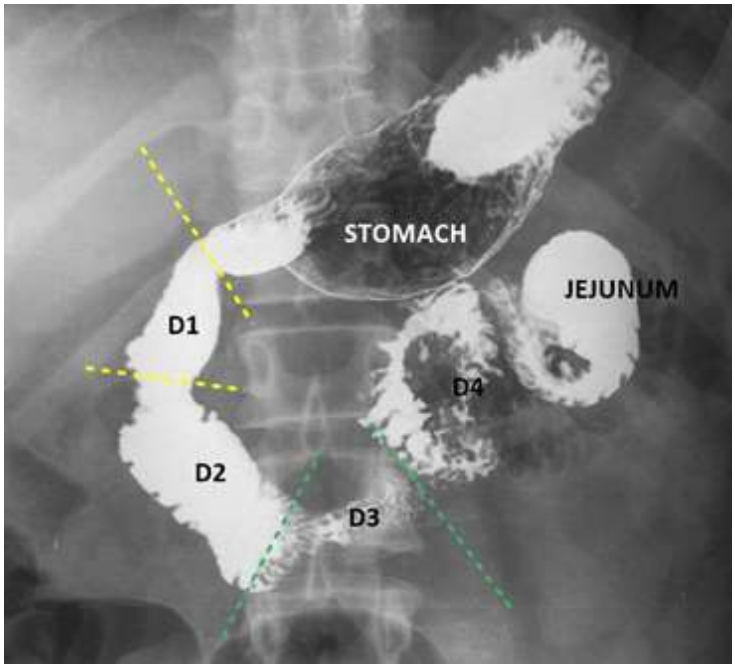


Figure 2. Normal duodenal anatomy on an upper gastrointestinal series, with D1–D4 identified.

6. Normal Radiographic Appearance

A technically adequate hypotonic duodenogram should show a smoothly distended duodenal loop with a recognizable mucosal pattern and without significant motion during the critical exposure. The bulb should have a smooth contour, while the descending segment should demonstrate orderly folds and a stable relationship to the pancreatic head. The horizontal and ascending portions should be followed as far as technically possible. The exact appearance varies with patient position, degree of distension and amount of contrast coating.

The mucosal folds of the duodenum are normally relatively fine and regular. Double contrast emphasizes these folds because the barium coats their surfaces while air provides a contrasting background. The major papilla may appear as a subtle contour prominence in the descending duodenum, although routine radiographic demonstration is not guaranteed. A classic study of routine double-contrast barium meals reported visualization of the ampulla of Vater in 72% and the accessory papilla in 26% of patients, illustrating both the potential and limitations of fluoroscopic visualization [6].

The examination should also be assessed dynamically. Normal peristalsis may be observed before the hypotonic effect becomes complete and should diminish after adequate pharmacological relaxation. The radiologist should correlate static spot images with the fluoroscopic appearance because a contour that seems abnormal on one image may represent transient contraction. Conversely, persistent narrowing, irregularity or distortion after adequate relaxation deserves careful evaluation.

7. Radiographic Findings and Clinical Applications

Duodenal ulcer disease may produce a niche, mucosal irregularity, deformity of the bulb or localized spasm. In a hypotonic study, reduction of muscular contraction can make persistent contour abnormalities easier to distinguish from transient spasm. However, a negative radiographic examination does not exclude mucosal disease, particularly when endoscopy is more sensitive for small ulcers or permits direct inspection and biopsy.

Duodenal tumors may appear as filling defects, irregular narrowing, ulceration or distortion of the normal mucosal pattern. Villous or polypoid lesions may be difficult to see when folds overlap; good distension and double contrast can improve their conspicuity. Hypotonic duodenography has historically been described as useful for postbulbar lesions and for assessing stenosis or nonspecific luminal abnormalities [10]. Periampullary tumors may alter the medial wall of D2, but cross-sectional imaging and endoscopy are usually required for complete characterization and staging.

Pancreatic head disease can produce an extrinsic impression, narrowing or displacement of the medial duodenal contour. Historically, these signs were important because cross-sectional imaging was limited. Early series reported high overall accuracy for pancreaticoduodenal cancer, but the lower sensitivity for confirmed cancer emphasizes that radiographic appearance alone cannot establish a diagnosis [8]. Today, CT and MRI provide much more comprehensive assessment of the pancreatic parenchyma, vessels, biliary tree and surrounding tissues.

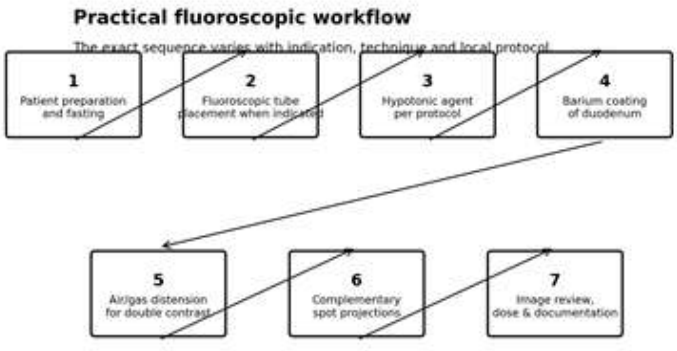


Figure 3. Educational schematic of a typical hypotonic duodenography workflow from preparation to image review.

Duodenal diverticula may appear as contrast-filled outpouchings, most commonly in the descending segment. Their location near the ampulla may be clinically relevant because they can affect adjacent biliary or pancreatic structures. A modern case report illustrates that hypotonic duodenography can document a diverticulum and contrast leakage in selected circumstances, although CT and endoscopic techniques are generally more useful for complications such as perforation.

8. Radiation Protection and Patient Safety

Hypotonic duodenography uses ionizing radiation and should therefore be justified and optimized. The radiographer should apply the principles of time, distance and shielding for occupational protection while using equipment-specific dose-reduction features. Fluoroscopy time should be kept as short as reasonably achievable, beam-on time should be limited to periods of active diagnostic need, and the field should be tightly collimated. Last-image hold, pulsed fluoroscopy, appropriate frame rates and stored fluoroscopic images can reduce unnecessary repeat exposure when available.

Patient dose is influenced by fluoroscopy time, pulse rate, acquisition mode, field size, patient thickness, source-to-image distance and the number of spot images. Because the examination may involve repeated oblique and lateral views, careful planning is important. The radiographer should avoid routine duplication of images when an adequate stored fluoroscopic image already answers the question. Radiation dose indicators available on modern fluoroscopy systems should be recorded and reviewed as part of quality assurance.

Occupational protection requires the radiographer and other staff to remain as far from the patient and radiation field as practicable while maintaining clinical control. Structural shielding should be used as designed, and personal protective devices should be worn according to local radiation-safety policy. The principle is not simply to add shielding but to reduce exposure at its source through appropriate technique, positioning, collimation and efficient fluoroscopy.

9. Advantages, Limitations and Contemporary Role

The main advantage of hypotonic duodenography is its ability to provide a detailed, relatively stable view of the duodenal lumen when normal peristalsis would otherwise interfere with interpretation. Double contrast can improve mucosal visualization, and selected projections can demonstrate subtle contour abnormalities. The technique also provides real-time assessment of contrast passage and can document a specific luminal abnormality during fluoroscopy [1,5].

Its disadvantages include dependence on operator experience, exposure to ionizing radiation, discomfort associated with tube placement when a selective technique is used, possible pharmacological adverse effects, incomplete visualization and limited assessment of extraluminal disease. The method can also be time-consuming. Importantly, evidence from comparative studies shows that hypotonic duodenography does not consistently outperform a carefully performed conventional examination [7]. This is one reason why its routine use has declined.

Modern CT, CT enterography, MRI, MRCP and endoscopy have changed the diagnostic pathway. Endoscopy can directly inspect the mucosa and obtain tissue. CT can evaluate the bowel wall, adjacent pancreas, vessels and complications. MRI and MRCP can provide high-quality cross-sectional and ductal information without ionizing radiation. Nevertheless, understanding hypotonic duodenography remains valuable for radiography students because it integrates anatomy, contrast physics, pharmacology, fluoroscopic positioning, radiation protection and image-quality assessment in one examination.

10. Role of the Radiographer

The radiographer has a central technical and patient-care role. Before the examination, the radiographer confirms patient identity, clinical indication, preparation status and relevant safety information; checks the fluoroscopy equipment; prepares contrast and accessories according to protocol; and explains the procedure. During the examination, the radiographer assists with positioning, maintains aseptic technique when a tube or catheter is used, observes the patient for discomfort or adverse effects, performs technically appropriate fluoroscopic acquisitions and responds rapidly to the radiologist's instructions.

The radiographer should recognize when the study is technically inadequate. Common problems include insufficient duodenal distension, poor mucosal coating, excessive gastric overlap, motion, inadequate visualization of the periampullary region, incorrect patient rotation and unnecessary exposure. Immediate technical correction is preferable to repeated imaging after the patient has left the room. Accurate laterality, projection, patient identification and image labeling are essential for safe interpretation and archiving.

The radiographer must also understand that a successful hypotonic Duodenogram is not defined by the number of images obtained. The objective is a diagnostic answer with the fewest necessary exposures. Efficient communication between the radiologist, radiographer and patient is therefore an essential component of quality. In modern departments, the examination should be performed only when the expected diagnostic information is likely to influence management and when another modality is not more appropriate.

11. Complications, Quality Assurance and Practical Checklist

Complications are uncommon when the examination is appropriately selected and carefully performed, but the team should remain alert to contrast aspiration, vomiting, abdominal pain, vasovagal symptoms, medication-related adverse effects and, rarely, gastrointestinal perforation or traumatic injury related to tube or catheter manipulation. The risk profile depends on the patient, the route of contrast administration and the hypotonic agent. Patients with suspected obstruction, severe inflammation, recent surgery or possible perforation require particular clinical judgment before a probe-based examination is attempted. Any sudden severe pain, unexpected resistance during catheter advancement, marked abdominal distension or clinical deterioration should be communicated immediately to the radiologist and managed according to the department emergency protocol.

Quality assurance begins before fluoroscopy. The radiographer should check that the fluoroscopy unit, image receptor, contrast delivery system, catheter or tube, suction and emergency equipment are functioning. Image quality should be reviewed for adequate coating, distension, anatomical coverage, absence of motion and correct labeling. Dose indicators and fluoroscopy time should be documented where available. Repeat-image analysis should identify whether inadequate preparation,

positioning, timing or technical factors are responsible for avoidable exposures. Periodic review by radiographers, radiologists and medical physicists can identify opportunities to reduce dose without compromising diagnostic information.

A practical workflow is: verify identity and indication; confirm preparation and relevant contraindications; explain the examination; prepare the fluoroscopy system and contrast; assist with tube placement when required; observe contrast passage; administer or assist with the prescribed hypotonic agent; obtain adequate barium coating and controlled air distension; acquire targeted spot images in complementary projections; review images before ending the examination; document the procedure and relevant dose information; and provide post-procedure instructions. This sequence supports reproducibility and helps students understand that gastrointestinal fluoroscopy is a coordinated clinical procedure rather than a collection of isolated radiographic views.

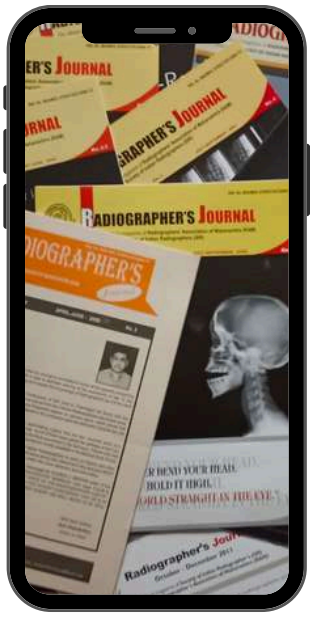
Conclusion

Hypotonic duodenography is a historically important specialized fluoroscopic examination that temporarily reduces duodenal motility to improve luminal distension and mucosal visualization. Classical double-contrast technique combines barium coating with air distension and carefully selected projections to demonstrate the duodenal loop, including the periampullary region. Glucagon and anticholinergic agents have both been used to achieve hypotonia, but drug selection and dosing must follow current clinical protocols rather than historical doses. The examination can demonstrate ulcers, stenoses, diverticula, tumors and extrinsic contour abnormalities, yet its diagnostic scope is limited when compared with endoscopy, CT and MRI. Comparative evidence also indicates that it does not consistently add information beyond a high-quality conventional barium examination. Its modern role is therefore selective rather than routine. For radiographers, mastery of the technique remains valuable because it develops a practical understanding of gastrointestinal anatomy, contrast administration, fluoroscopic positioning, image evaluation, pharmacological safety and radiation protection. When properly justified and carefully performed, hypotonic duodenography can provide high-quality luminal information while maintaining patient comfort and minimizing avoidable radiation exposure.

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Clinical Applications and Recent Advances in CT Angiography: A Comprehensive Review

Ugyen Phuntsho, Paridhi Tripathi, B. Sc. Scholars, **Nischal Yadav,** Assistant Professor,
Maharishi Markandeshwar (Deemed to be University)

Abstract
Computed tomography angiography (CTA) has become an important non-invasive imaging technique for evaluating the arterial and venous vascular systems. The development of multidetector computed tomography (MDCT), rapid gantry rotation, high-quality multiplanar reconstruction, and three-dimensional visualization has substantially expanded the diagnostic applications of vascular CT. CTA can provide detailed information regarding vessel anatomy, luminal stenosis, occlusion, aneurysm, dissection, thromboembolism, vascular malformation, plaque, and treatment-related complications. It is widely used for cerebral, coronary, pulmonary, aortic, renal, mesenteric, and peripheral vascular imaging. Modern CTA is increasingly progressing beyond anatomical visualization toward quantitative and functional assessment. Spectral and dual-energy CT can generate iodine maps, virtual monoenergetic images, and virtual non-contrast images, providing additional information about iodine distribution and material composition. More recently, photon-counting CT has introduced improved spatial resolution, spectral capabilities, noise characteristics, and material discrimination, with potential applications in coronary and peripheral vascular imaging. Artificial intelligence is also being incorporated into CTA workflows for image reconstruction, vessel segmentation, plaque quantification, stenosis detection, and automated reporting. Despite these developments, radiation exposure, iodinated contrast-related considerations, motion artifacts, heavy vascular calcification, and variability in acquisition protocols remain important limitations. This review discusses the basic principles, major clinical applications, recent technological developments, advantages, limitations, and future perspectives of CT angiography.
Keywords: CT angiography, multidetector CT, vascular imaging, coronary CT angiography, dual-energy CT, spectral CT, photon-counting CT, artificial intelligence, vascular disease.

Introduction

Computed tomography angiography is a contrast-enhanced CT technique designed to demonstrate blood vessels with high spatial and temporal resolution. Unlike conventional catheter angiography, CTA is non-invasive and can provide extensive anatomical information within a short acquisition period. The introduction of spiral CT followed by multidetector technology substantially improved vascular imaging by enabling rapid volumetric acquisition and thin-section reconstruction. Modern CT scanners can acquire large anatomical volumes rapidly and generate datasets suitable for multiplanar reconstruction (MPR), maximum intensity projection (MIP), curved planar reconstruction, and three-dimensional volume rendering (VR). These techniques permit evaluation of vascular structures from different orientations and can assist in diagnosis, treatment planning, and postoperative assessment. CTA has applications across a broad range of vascular territories. Cerebral and carotid CTA are used for evaluation of cerebrovascular disease, while coronary CTA provides non-invasive assessment of coronary artery anatomy and atherosclerotic disease. CT pulmonary angiography (CTPA) is an established technique for detecting pulmonary embolism. Aortic CTA is important in the evaluation of aneurysm, dissection, penetrating atherosclerotic ulcer, and traumatic vascular injury. Peripheral CTA provides information regarding arterial stenosis and occlusion and can assist in treatment planning for peripheral arterial disease.

Technological advances have further expanded CTA capabilities. Dual-energy CT (DECT) and spectral CT provide material-specific information in addition to conventional anatomical images. Low-energy virtual monoenergetic images can increase iodine conspicuity, while iodine maps can demonstrate contrast distribution [8,9]. Photon-counting CT (PCCT) represents a newer development that provides high spatial resolution and multi-energy capabilities and may improve visualization of small vessels, calcified plaques, and vascular stents [1-3].

Basic Principles of CT Angiography

CTA is based on intravenous administration of iodinated contrast material followed by rapid CT acquisition during an appropriate vascular enhancement phase. The contrast injection protocol is selected according to the vascular territory being examined, scanner characteristics, patient circulation, and clinical indication. Important technical parameters include tube voltage, tube current, pitch, gantry rotation time, detector configuration, scan range, contrast concentration, injection rate, contrast volume, and acquisition timing. Bolus tracking is frequently used to initiate scanning when contrast reaches a predefined attenuation threshold in a selected vessel. Test-bolus techniques may also be used in selected examinations.

Following image acquisition, thin-section axial datasets can be processed using MPR, MIP, curved planar reformations, and VR. Axial images remain essential for primary interpretation, whereas reconstructed images can facilitate evaluation of vessel continuity, stenosis, aneurysm morphology, vascular branching, and anatomical relationships. The quality of CTA depends on adequate vascular enhancement, appropriate scan timing, sufficient spatial resolution, control of patient motion, and radiation-dose optimization. Consequently, CTA should be considered a complete imaging workflow involving patient preparation, contrast administration, acquisition, reconstruction, post-processing, and interpretation.

Cerebral and Carotid CT Angiography

Cerebral CTA provides rapid visualization of intracranial arteries and is particularly important in emergency neurological imaging. It can demonstrate large-vessel occlusion, intracranial aneurysms, arterial stenosis, dissection, and vascular malformations. In acute ischemic stroke, CTA can identify major arterial occlusion and provide vascular information that complements non-contrast CT. CTA can also be combined with CT perfusion imaging to provide additional information about cerebral hemodynamic and potentially viable tissue. Carotid CTA is useful for evaluating extracranial carotid stenosis, plaque morphology, occlusion, and dissection. Compared with ultrasound, CTA provides a broader anatomical field and is less dependent on an acoustic window. It can simultaneously demonstrate the vascular lumen, vessel wall, surrounding soft tissues, and osseous structures. One important limitation is the presence of dense calcification, particularly around the carotid

bifurcation. Calcium blooming and partial-volume effects can make the residual vascular lumen difficult to assess. Higher-resolution and spectral CT techniques may help reduce some of these limitations [4-5].

Coronary CT Angiography

Coronary CT angiography (CCTA) has become an important non-invasive technique for assessing coronary artery anatomy and coronary artery disease. Improvements in temporal resolution, ECG synchronization, prospective ECG triggering, retrospective ECG gating, motion correction, and contrast administration have improved the diagnostic performance of CCTA. CCTA permits evaluation of coronary artery lumen, stenotic lesions, calcified and non-calcified plaque, and overall coronary anatomy. The Society of Cardiovascular Computed Tomography has published recommendations for appropriate coronary CTA acquisition, emphasizing standardized protocols and optimization of image quality and radiation exposure. An important advantage of CCTA is that it can provide information beyond luminal narrowing. Coronary plaque can be assessed according to its morphology, distribution, and calcification characteristics, providing a more comprehensive evaluation of atherosclerotic disease [6,7]. Standardized reporting systems such as CAD-RADS were developed to improve communication of coronary CTA findings. CAD-RADS provides categories for coronary stenosis and incorporates additional information relevant to coronary disease assessment [8]. Computational techniques have further expanded CCTA. CT-derived fractional flow reserve (FFR-CT) can provide information regarding the physiological significance of selected coronary stenoses without invasive catheterization. This represents an important development toward combining anatomical and functional assessment within CT-based cardiovascular imaging.

CT Pulmonary Angiography

CT pulmonary angiography (CTPA) is widely used for evaluation of suspected pulmonary embolism. The examination requires rapid contrast-enhanced acquisition timed to achieve adequate pulmonary arterial enhancement. CTPA can directly demonstrate filling defects within the pulmonary arteries and can also reveal alternative thoracic abnormalities. Depending on image quality and acquisition parameters, assessment can extend from the main pulmonary arteries to segmental and subsegmental branches. Appropriate contrast timing and radiation optimization are important components of CTPA. Spectral CT can provide iodine distribution maps and low-energy virtual monoenergetic images, which may improve iodine conspicuity in the pulmonary circulation and provide additional information when conventional enhancement is suboptimal [8]. The increasing availability of spectral CT also provides opportunities for material-specific evaluation. Iodine maps can demonstrate contrast distribution, while virtual monoenergetic reconstructions can increase iodine attenuation at lower energy levels [9,10].

Aortic CT Angiography

CTA plays an important role in evaluation of the thoracic and abdominal aorta. Major indications include suspected aortic dissection, aneurysm, penetrating atherosclerotic ulcer, intramural hematoma, traumatic vascular injury, and assessment before and after endovascular treatment. In acute aortic disease, rapid acquisition and extensive anatomical coverage allow assessment of the aorta and its major branches. CTA can demonstrate the location and extent of dissection, identify true and false lumens, evaluate branch-vessel involvement, and assist with treatment planning. For abdominal aortic aneurysms, CTA provides information regarding aneurysm size, morphology, mural thrombus, renal and iliac artery anatomy, and relationships with surrounding structures. CTA is particularly important for preprocedural planning and follow-up after endovascular aneurysm repair. Advanced post-processing can provide multiplanar and three-dimensional visualization of complex aortic anatomy. Spectral CT may additionally provide material-specific information that can assist in selected vascular and postoperative applications [11].

Peripheral CT Angiography

Peripheral CTA is widely used for evaluation of arterial disease of the lower extremities. It can demonstrate stenosis, occlusion, collateral vessels, aneurysms, and distal arterial runoff. The ability to acquire a large anatomical region during a single contrast-enhanced examination makes CTA useful for mapping the distribution and severity of peripheral arterial disease. MIP and VR images can provide an overview of the vascular tree, whereas thin-section axial images remain essential for detailed assessment. Peripheral CTA can contribute to treatment planning by demonstrating the location and length of stenotic or occluded segments and the condition of vessels above and below the affected region. A major challenge is extensive arterial calcification. Calcium blooming can obscure the residual vascular lumen and may reduce confidence in stenosis grading. Higher spatial resolution and spectral techniques may help overcome some of these limitations [3].

Renal, Mesenteric and Visceral CTA

Renal CTA can be used to evaluate renal artery stenosis, aneurysm, dissection, vascular anomalies, and renal vascular anatomy before selected surgical or interventional procedures. Mesenteric CTA is useful for demonstrating stenosis or occlusion involving the celiac artery, superior mesenteric artery, and inferior mesenteric artery. It has an important role in suspected acute and chronic mesenteric ischemia because rapid acquisition allows assessment of both vascular abnormalities and associated bowel changes.CTA can also be used in the evaluation of gastrointestinal bleeding when an appropriately timed multiphasic protocol is performed. Spectral CT can provide iodine-specific information that may help identify active contrast extravasation or enhance visualization of vascularized lesions [9,10]. The ability to separate iodine from other materials is one of the major advantages of spectral CT. Iodine maps can therefore provide additional information beyond conventional CT attenuation measurements.

Role of Multiplanar and Three-Dimensional Reconstruction

The diagnostic value of CTA is not limited to axial images. MPR allows vessels to be followed along their longitudinal axis, while curved planar reformations can display tortuous vessels in a single plane.MIP emphasizes high-attenuation structures, including contrast-filled vessels, and is particularly useful for vascular mapping. VR provides three-dimensional anatomical representations and may be helpful for communicating complex vascular anatomy to surgeons and interventional specialists [1-3]. However, reconstructed images should complement rather than replace thin-section axial images. Post-processing can introduce artifacts or obscure overlapping structures. Therefore, comprehensive CTA interpretation should involve assessment of both source images and appropriate reconstructed datasets.

Dual-Energy and Spectral CT in Angiography

One of the major recent developments in CTA is the integration of dual-energy and spectral CT. DECT acquires information at different X-ray energy levels and uses material-decomposition techniques to differentiate materials according to their energy-dependent attenuation properties.Several useful image datasets can be generated from a single acquisition, including conventional-like images, virtual monoenergetic images, iodine maps, and virtual non-contrast images.

Low-energy virtual monoenergetic images increase iodine attenuation and can therefore improve visualization of contrast-enhanced vessels. This may be particularly useful when vascular enhancement is suboptimal and may allow reduction of iodine delivery in selected protocols. High-energy virtual monoenergetic images can reduce certain beam-hardening artifacts and may improve visualization near metallic structures [9-13]. Iodine maps provide visual and quantitative information regarding iodine distribution and can be useful in vascular and perfusion-related applications. Virtual non-contrast images may reduce the need for a separate true non-contrast acquisition in selected clinical situations. However, virtual non-contrast images should not automatically be considered equivalent to conventional non-contrast CT for every indication.

Photon-Counting CT: An Emerging Development

Photon-counting CT represents a major technological development in CT imaging. Conventional energy-integrating detectors convert X-ray photons into light before electrical signal generation, whereas photon-counting detectors directly register individual X-ray photons and categorize them according to energy .Potential advantages include higher spatial resolution, improved contrast-to-noise characteristics, reduced electronic noise, multi-energy imaging, and improved material discrimination .In cardiovascular imaging, PCCT may be particularly useful for evaluating small vessels, coronary arteries, calcified plaques, and vascular stents. Its high spatial resolution can improve visualization of small anatomical structures and may reduce some limitations caused by blooming from dense materials [14].A recent cardiovascular review described enhanced spatial resolution, improved signal and contrast characteristics, reduced electronic noise and artifacts, lower radiation exposure potential, and multi-energy capability as important advantages of PCCT . Nevertheless, implementation challenges, reconstruction requirements, scanner availability, and clinical standardization remain important considerations [15].

Artificial Intelligence in CT Angiography

Artificial intelligence is increasingly being incorporated into vascular CT workflows. AI-based algorithms can assist with image reconstruction, noise reduction, vessel segmentation, stenosis detection, plaque quantification, anatomical labelling, and automated reporting [16]. In coronary CTA, deep-learning approaches have been investigated for automated coronary artery segmentation and plaque analysis. AI may also support calcium scoring, stenosis detection, and extraction of quantitative imaging biomarkers [17].AI applications are also expanding into aortic and peripheral vascular imaging. Automated segmentation can reduce the time required for vessel analysis and potentially improve quantitative assessment. Despite promising results, AI should currently be considered a decision-support technology rather than a replacement for radiologists. Differences among scanners, patient populations, acquisition protocols, and disease prevalence may influence algorithm performance. External validation and prospective clinical evaluation are therefore essential before widespread implementation.

Radiation Dose Optimization

Radiation exposure remains an important consideration in CTA because CT uses ionizing radiation. Modern scanners provide several strategies for reducing dose while maintaining diagnostic image quality. These include automatic tube-current modulation, appropriate tube-voltage selection, ECG-triggered acquisition for cardiac CT, iterative reconstruction, and deep-learning reconstruction. Spectral CT may contribute to dose optimization by allowing virtual non-contrast images to be reconstructed from contrast-enhanced acquisitions in selected circumstances. However, this approach should be applied according to the clinical indication because virtual and true non-contrast images are not identical [5,18].Dose optimization should follow the principle of achieving adequate diagnostic information with the lowest reasonable radiation exposure. Patient body habitus, clinical indication, scanner technology, and the vascular territory being examined should all be considered when selecting the imaging protocol.

Contrast Media Considerations

Iodinated contrast material is essential for most CTA examinations because it produces strong differentiation between vascular structures and surrounding tissues. Contrast concentration, injection rate, volume, and timing should be optimized according to the vascular territory and scanner characteristics. Important considerations include renal function, previous contrast reactions, patient weight, intravenous access, contrast concentration, and circulation time. Spectral CT may permit lower iodine delivery in selected applications because low-energy virtual monoenergetic images can increase iodine attenuation. However, the objective should not simply be to minimize contrast volume. The primary goal is to achieve sufficient vascular enhancement for a diagnostic examination while minimizing unnecessary exposure. Appropriate patient assessment and institutional contrast-safety protocols remain essential.

Limitations of CT Angiography

Although CTA provides excellent anatomical information, it has several limitations. Radiation exposure remains an important consideration because the technique uses ionizing radiation. Iodinated contrast administration also requires appropriate patient assessment. Motion can significantly degrade vascular images, particularly coronary CTA. High heart rate and irregular cardiac rhythm can adversely affect coronary image quality. Severe vascular calcification can produce blooming artifacts and obscure the true vascular lumen. Metallic stents, prostheses, and surgical materials can introduce additional artifacts. Although newer spectral and photon-counting techniques may reduce some artifacts, they do not eliminate all limitations [14]. CTA has traditionally been predominantly anatomical, although CT-FFR, CT perfusion, iodine mapping, and quantitative spectral imaging increasingly provide functional or quantitative information. Another limitation is protocol variability. Different manufacturers may use different acquisition, reconstruction, and spectral imaging approaches. Standardization and appropriate interpretation are therefore important for consistent clinical practice.

Future Perspectives

The future of CTA is likely to involve increasing integration of high-resolution acquisition, spectral imaging, photon-counting detectors, artificial intelligence, automated post-processing, and quantitative analysis. Photon-counting CT may improve visualization of small vessels and complex vascular structures, while spectral CT may increasingly provide quantitative iodine and material-specific information. AI may automate repetitive tasks such as vessel segmentation, stenosis measurement, plaque quantification, and structured reporting [16,17]. Future CTA systems may increasingly combine anatomical and physiological information within a single examination. Integration of CT-derived functional measurements with clinical and laboratory information could facilitate more individualized assessment of vascular disease.

However, technological development must be accompanied by clinical validation, standardized protocols, quality assurance, cost-effectiveness assessment, and appropriate education of radiologists and radiographers. Successful implementation of advanced CTA will depend not only on scanner capabilities but also on optimized patient selection, acquisition technique, reconstruction, interpretation, and clinical integration.

Conclusion

CT angiography has evolved from a primarily anatomical vascular imaging technique into a sophisticated platform capable of providing high-resolution structural, quantitative, and increasingly functional information. Its applications include cerebral, carotid, coronary, pulmonary, aortic, peripheral, renal, mesenteric, and other vascular territories [1–7].MDCT and advanced reconstruction techniques have established CTA as a rapid and versatile vascular imaging modality. Dual-energy and spectral CT have added material-specific information, including iodine maps and virtual monoenergetic images [8–10]. Photon-counting CT represents a further technological development toward improved spatial resolution, spectral imaging, and vascular visualization [14,15]. Artificial intelligence is expanding the possibilities for automated segmentation, quantitative analysis, image reconstruction, and decision support [16,17]. Despite these advances, radiation exposure, contrast-related considerations, motion, calcification, artifacts, and technological variability remain important limitations. Future research should focus on standardized protocols, clinically validated AI systems, dose and contrast optimization, and integration of anatomical and functional information. Overall, continuing technological development is expected to broaden the clinical role of CTA. The combination of high-resolution CT acquisition, spectral information, photon-counting technology, and intelligent image analysis offers opportunities for increasingly comprehensive vascular assessment.

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Design to Print #9250671670

Angiography of the Intracranial Arteries using Magnetic Resonance

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Abstract
Assessment of the cerebral circulation may have an impact on patient care and offers important information for the diagnosis and prognosis of numerous intracranial disorders. Technological developments in magnetic resonance angiography (MRA) have increased the technique's accuracy in a number of clinical scenarios, including aneurysms, congenital vascular anomalies, inflammatory arterial disorders, arterial and venous steno-occlusive diseases, and preoperative evaluation of dural sinus patency.

Because MRA is non-invasive and non-ionizing, it has taken the place of traditional digital subtraction angiography in many locations for cerebral vascular disease screening. A number of MRA methods, including time-of-flight MRA (TOF MRA), phase-contrast MRA (PC MRA), and more recently contrast-enhanced MRA (CE MRA), have been developed for the imaging of the cerebral vascular system. The three-dimensional (3D) TOF-MRA technique is advised for arterial evaluation and the two-dimensional (2D) TOF or 2D PC-MRA technique for venous evaluation in the assessment of steno-occlusive disease.

Keywords: Cerebral arteries, stenosis and blockage, cerebral arteries, arteriovenous malformations; magnetic resonance, vascular research, Brain tumours, aneurysms, cerebral arteries, compression of the nerves.

Introduction:
For the screening of cerebral vascular disease, magnetic resonance angiography (MRA) has supplanted traditional catheter-based digital subtraction angiography (DSA) in many facilities. This is mostly because DSA is non-invasive; the probability of a neurologic event is estimated to be 4%, with a permanent disability occurring in 1% . Additionally, MRA provides excellent images of the cerebral vasculature with the ability to observe the veins from a variety of perspectives.

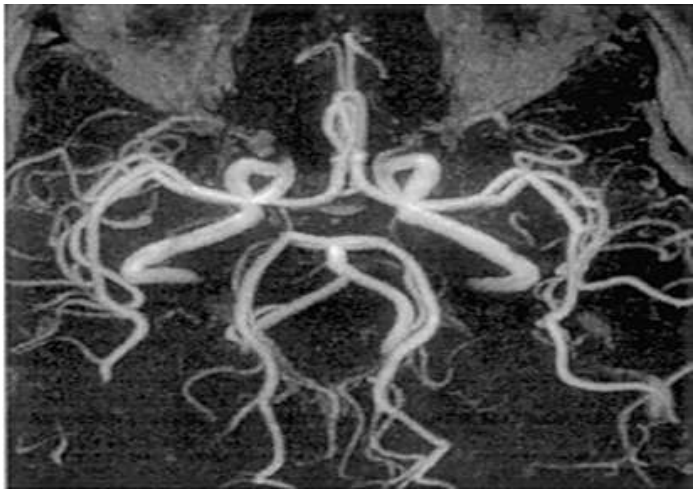
The integrated presentation of soft tissues and arteries is another benefit of MRA. Furthermore, intracranial flow may be somewhat quantified by MRA. Reduced visualization of extremely small distal cortical or deep branches, poor temporal information, poor selection, and reliance on flow or patient cooperation are some of MRA's drawbacks. This issue of EJR contains more detailed information on the technical elements of MRA of the intracranial vasculature. Here, we will restrict ourselves to a synopsis of a few key components. The superior quality of intracranial The modest volume of interest, the significant input influence throughout the cardiac cycle, and the negligible effects of the most frequent sources of MR are the foundations of MRA. artifacts like breathing, heartbeat, and variations in head sensitivity.

The intracranial arteries can be seen using both flow-dependent and flow-independent MRA techniques. The most popular sequence for studying intracranial arteries is the three-dimensional time-of-flight (3D TOF) MRA. Multiple overlapping thin slab acquisitions (MOTSA) to overcome saturation, "tilted optimized non-saturating excitation" (TONE) radiofrequency pulses, and the use of magnetization transfer (MT) prepulses to suppress the signal of stationary tissues or achieve fat suppression are all methods for improving image quality. Intravenous contrast enhancement can be utilized to improve the visibility of veins and minor artery branches, but it has drawbacks such as increased cost, vein superimposition, and enhanced soft tissues. Recently, ultrafast MRA of the intracranial arteries was obtained using dynamic three-dimensional MRA following bolus-injection of gadolinium. Without signal-intensity losses from turbulence or flow-saturation effects, it enables a highly accurate examination of the cerebral vasculature. The sequence is better suited for use with recalcitrant patients due to its extremely quick acquisition time. Through the sequential capture of pictures in the arterial and venous phases, dynamic information can be obtained in the MRA research of arteriovenous malformations. The intracranial vasculature can be beautifully shown with three-dimensional Phase-Contrast Acquisitions (3D PC). Benefits include the ability to investigate arteries and veins simultaneously, the absence of superimposition of enhancing soft tissues, and independence from the orientation of the acquisition volume. Therefore, patients with acute thrombosis and bleeding related to vascular diseases should use PC acquisitions.

2D TOF, contrast-enhanced MRA, and phase-contrast quisitions with suitable velocity-encoding can all be used to study the cerebral veins.

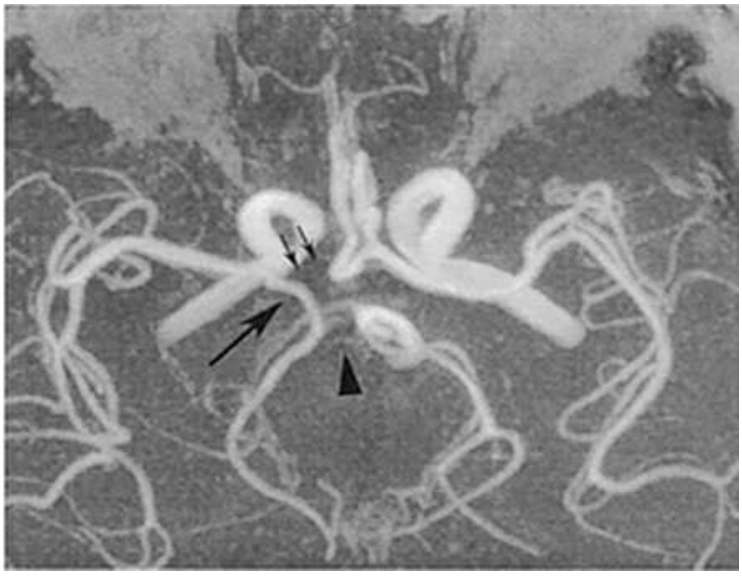
Normal variations and normal cerebral vascular anatomy:
On MRA, the cerebral veins and arteries are clearly visible. As people age, the distal intracranial arteries become less visible. As a result, children typically have superior MR angiograms than adults. Even in young adults, very small arteries like the anterior choroidal arteries and lenticulostriate arteries are rarely apparent, but they are frequently seen in youngsters.

It is easy to observe variations of the circle of Willis, such as a "fetal" origin of the posterior cerebral artery, hypoplasia or aplasia of one horizontal segment of the anterior cerebral artery, and hypoplasia of the posterior communicating artery.



Typical anatomy. MIP transverse of a 3D-TOF MRA. enhancement of the image using MT, MOTSA, and TONE. Take note of the superb illustration of normal intracranial vasculature, particularly the posterior and middle cerebral arteries' distal branches.

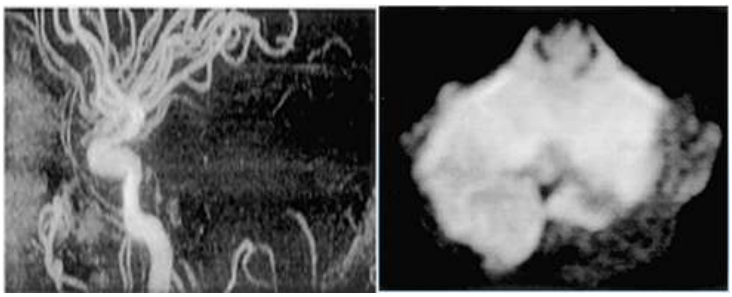
The persisting trigeminal artery and other fetal remains of anastomoses between the carotid arteries and the vertebral system are clearly seen. There are variations in the venous architecture, such as the presence of a midline occipital sinus or hypoplasia of one of the transverse sinuses.



Normal variations in anatomy. 3D-TOF transverse MIP "MRA" The right posterior cerebral artery's fetal origin (arrow) without the P1-segment (arrowheads). The anterior cerebral artery's A1-segment is absent in the same patient (small arrows).

Arterial occlusion and stenosis:

MRA can clearly demonstrate total blockage, most commonly of the basilar or middle cerebral arteries. Careful image analysis can also reveal occlusion of smaller arteries. It is necessary to correlate the clinical presentation with the spin-echo pictures. When choosing between neuroprotective medications or trombolysis, the quality of MR-angiograms is largely adequate. MRA can be used to screen for intracranial vascular disease because low to moderate stenoses are typically well demonstrated by MRA techniques . High-grade stenoses that produce significant local flow disruptions are typically exaggerated in both diameter and length due to saturation of the slow-flowing blood distal to the stenosis. Due to saturation, very severe stenoses might simulate complete blockage, especially on 3D TOF MRAs. Gadolinium injections or successive 2D acquisitions perpendicular to the poststenotic artery can be used to counteract this saturation. Only in the event that these techniques are unable to visualize any distal vessels can one draw the conclusion of occlusion. MRA can show stenoses caused by auto-immune arteritis in young individuals. vasospasm, dissection, or sickle cell anemia. The most notable characteristic of Moya-Moya illness, aside from basal occlusions, is the hypertrophy collaterals in the basal ganglia. However, conventional spin-echo scans frequently already show these



Basilar artery occlusion: (a) Sagittal MIP of 3D-TOF: the basilar artery is not visible; (b) The same patient's transverse diffusion weighted picture shows hyperintensity in both cerebellar hemispheres and the brain stem, suggesting a recent infarction.

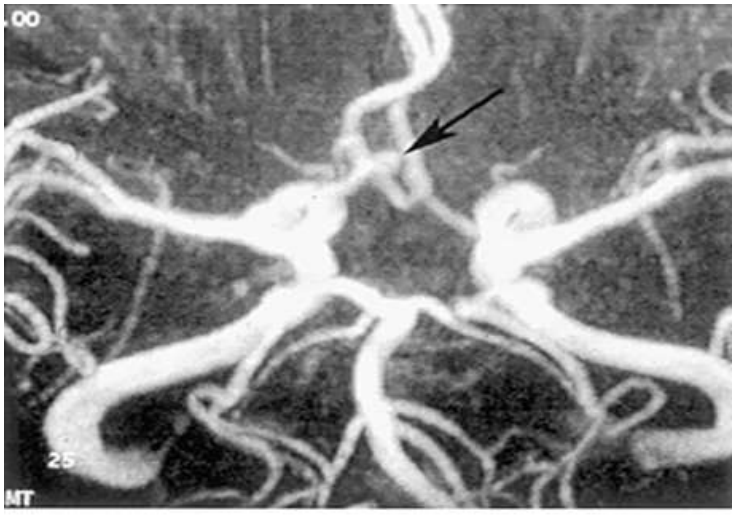
collaterals together with related infarcts in the cerebral parenchyma. Although the spontaneous hyperintense feature of the thrombus can resemble flowing blood on the MIP, intracranial dissection can be visualized with MRA. Consequently, phase-contrast sequences or correlation with the spin-echo pictures are required. While transcranial Doppler can identify vasospasm, morphological data can be used to identify patients who may benefit from interventional neuroradiological procedures, such as angioplasty, papaverine infusion, or selective underlying aneurysm embolization, as well as to determine the best time for intervention. When it comes to illustrating vasospasm of the internal carotid artery or the middle cerebral artery, MRA is less sensitive than DSA. Both reversible stenoses and signal alterations of the brain parenchyma are observed in patients with ecclampsia.

Aneurysms:

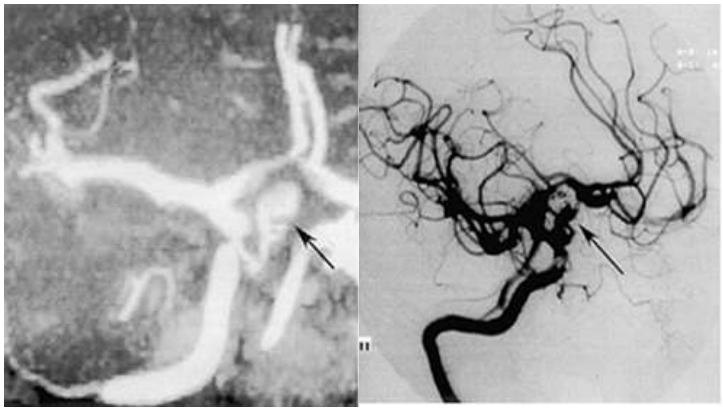
In the diagnostic work-up of a patient with a suspected intracranial aneurysm, MRA has to answer several questions. The aneurysm has to be detected or absence of aneurysm has to be confirmed with certainty. The exact topographic location has to be determined, including the vessel of origin, demonstration of the aneurysmal neck, and clarification of the relationship to neighboring vessels. The morphology and size of the aneurysm must be demonstrated. Finally, vasospasm has to be ruled out.

For aneurysms as small as 3–4 mm, MRA has a detection probability of about 90–95% . Consequently, patients with polycystic kidneys and those with a positive family history can be screened for cerebral aneurysms using MRA. To prevent the carrier vessels from being superimposed on the aneurysm, careful examination of the MRA in several projections and of the native pictures is required. In bigger aneurysms, local turbulence may mimic intraluminal thrombus or cause the lesion's volume to be underestimated. The signal in the distal vessels will be diminished by saturation due to slow flow in bigger aneurysms. Gadolinium injections enable the recovery of the vascular signal in this instance as well. On TOF angiograms, a high signal from partial thrombosis or hemorrhage results in an overestimation of the patent lumen or blurring of the aneurysm contour. The precise size of the aneurysm can be ascertained by correlation with the spin-echo pictures and/or phase-contrast data. Similarly, 3D TOF provides the best imaging for large unruptured aneurysms. 2D MRA with presaturation is used for hemorrhagic, thrombosed, or distant aneurysms as well as for the examination of the various aneurysm components, such as trombus, hemorrhage, or patent residual lumen more instructive. The anatomical implantation, the lesion's origin, and the aneurysm's neck can all be evaluated with extreme accuracy because to MRA's capacity to produce many projections. The transverse projections, which correspond to the traditional "Hirtz-incidence," are especially useful for studying anterior communicating aneurysms and in many cases of eccentrically developed aneurysms. As previously stated, consecutive MRA tests can be used to diagnose and monitor concomitant vasospasm. Due to susceptibility artifacts from the implanted material, it is not viable to follow up on an aneurysm with MRA following surgical clipping. Patients can be appropriately monitored with 3D TOF MRA following endovascular therapy with detachable coils since the platinum coils are not ferro-magnetic. Following parent vessel occlusion, spin-echo MRI and MRA will verify both the parent vessel's occlusion and the aneurysm's gradual elimination. Follow-up patients with

untreated aneurysms or those who have failed endovascular therapy are excellent candidates for MRA. Cerebral aneurysms can be detected even more accurately with dynamic gadolinium-enhanced three-dimensional MRA than with 3D TOF or PC MRA. Metens et al. claim a 100% identification rate of aneurysms with a mean size of 6 mm, the smallest measuring 2 mm in diameter. Of the 23 aneurysms, 3D TOF missed one and 3D PC seven. The region where the vast majority of saccular aneurysms are found is covered by a transverse venous phase acquisition, which comes after a coronal arterial phase acquisition in two perpendicular volumes. Even in agitated patients with subarachnoid hemorrhage, the extremely brief acquisition period enables excellent images. Dynamic gadolinium-enhanced three-dimensional MRA makes it simple to distinguish between mural trombus and sluggish flow in big aneurysms since a trombus is never hyperintense on the arterial pictures.



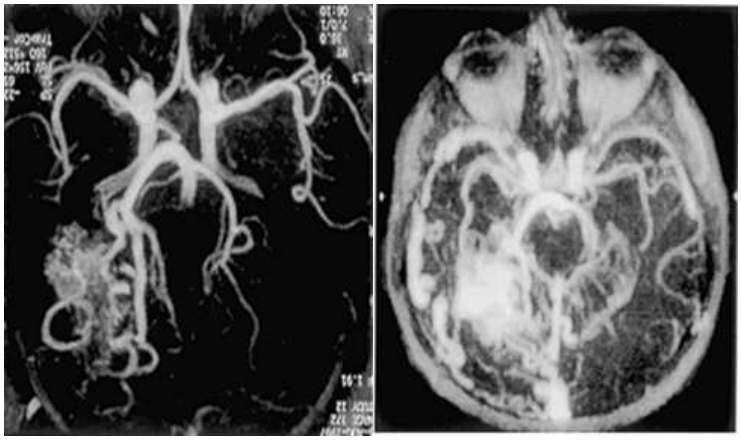
Shows a little anterior communicating artery aneurysm. 3D-TOF MRA's semi-coronal MIP. A little (3 mm) anterior communicating artery aneurysm (arrow).



Recurrent aneurysm following GDC coiling: (a) Coronal MIP of 3D-TOF MRA: recurrent aneurysm (arrow). Take note of the coils' lack of artifacts; (b) DSA: confirmation of recurrence (arrow).

Arteriovenous abnormalities:

On a standard spin-echo MRI, arteriovenous malformations (AVMs) are typically already apparent. The number, size, and position of the feeding arteries, the size of the nidus, the existence of intranidal arteriovenous shunts, and the size and direction of the draining veins are all shown by angiography. Aneurysms on the draining veins, feeding arteries, or nidus have significant prognostic implications. On 3-D TOF MRA or PC MRA, the feeding arteries with high flow are typically clearly visible. The feeding vessels' hyperdynamic flow can cause intense local turbulence, which might result in signal loss and the development of pseudostenoses. Small aneurysms on the feeding arteries are often overlooked due to this and spatial resolution issues. The nidus and the draining veins are often not fully visible due to saturation. Once more, gadolinium injection or the use of less saturating sequences like 2D TOF or 3D MOTSA can be quite beneficial. Exquisite venous anatomy can be shown using high-resolution 3D gradient-echo sequences with a lengthy echo-time. This makes it possible to identify tiny AVMs more effectively. Because of susceptibility artifacts, this approach is less appropriate for studying AVMs around the base of the skull or those have seen prior bleeding. mations after radiosurgery or embolisation . Developmental venous anomalies (DVAs) or the so called 'venous angiomas' are mostly incidental findings on gadolinium-enhanced MRI . They are consid ered to be congenital variants of the venous drainage of the brain. In rare cases they are seen in patients with intracerebral hemorrhage, mostly attribited to coinci dental cavernous angiomas. MRA can be useful to confirm the lesion and to study the confluence of the draining vein of the lesion in the dural venous sinuses. Stenoses at the confluence are believed to be at the origin of bleeding in these venous angiomas.



Occipital arteriovenous malformation on the right side (a) The feeding arteries and the AVM nidus are clearly visible in the transverse MIP of the 3D-TOF MRA. The veins that discharge are not visible; (b) MRA with dynamic gadolinium enhancement. improved venous drainage illustration.

Tumors:

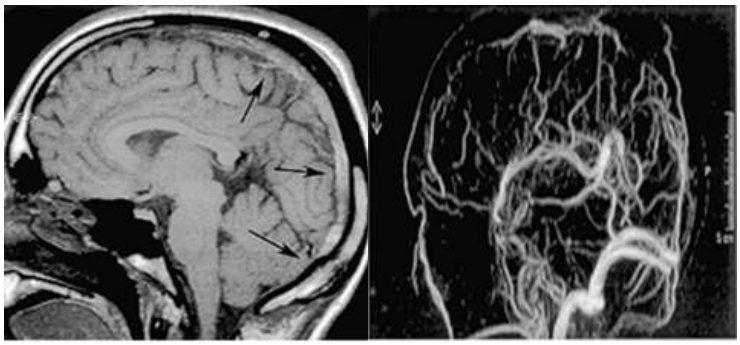
Angiography is utilized as a preoperative inquiry in the study of cerebral tumors to provide information about the brain's vascular structure, the tumor's vascularity, and the path of the cerebral veins so that a surgical strategy can be chosen. The external carotid artery supply must be seen in patients with extra-axial malignancies. Through the visualization of vessel displacement, MRA provides primarily indirect information. To assess tumoral vascularity, MRA resolution is inadequate. However, CE spin-echo MRI is similarly effective in diagnosing tumor size, location, and vascularity in the majority of patients. However, MRA is more useful for studying the venous anatomy, particularly following an adolinium injection. To choose the surgical strategy, it may be sufficient to see the superficial cortical veins and the cortical structure.

Lastly, MRI and MRA are combined in stereotactic procedures to determine the safest needle trajectory and approach, as well as to choose the target location, hence increasing treatment safety.

Venous pathology:

The majority of acute to subacute thromboses are already identified on unenhanced T1 SE images due to the hyperintense nature of the new clot. MRA is used to assess the degree of cerebral venous occlusion and confirm the spin-echo MR

diagnosis. Venous trombosis in MRA is identified by the presence of a filling defect in the lumen or the lack of dural venous sinus visualization. Because they increase the MIP, high intensity fresh thrombi can result in false-negative images on TOF sequences. Saturation in 2D TOF MRA sequences with dissappearance of the vascular signal is associated with false-positive results. Phase-contrast techniques and the use of saturation pulses may be required in these situations. On T1-weighed spin-echo pictures, the deep cerebral veins may appear hyperintense due to thrombosis. Both thalami will exhibit hyperintensity on T2-weighted spin-echo imaging. MRA shows that the deep veins are not filled. As previously stated, MRA can show venous compression and/or blockage in the investigation of brain malignancies.



Superior sagittal sinus thrombosis: (a) Sagittal T1-weighed image: hyperintense thrombus in the superior sagittal sinus (arrows); (b) Sagittal MIP of 3D-PC MRA: no visualization of the superior sagittal sinus.

Vascular compression:

Neuralgia may be caused by vascular loops that compress the cranial nerves. Loops of the anterior inferior cerebellar artery (AICA) can compress the facial nerve in the cerebellopontine angle, resulting in neuralgia, hemifacial spasms, or facial nerve palsy.

An elongated basilar artery may be the cause of trigeminal neuralgia. The tortuosity of the basilar artery and the AICA can be seen with MRA with the right methodology. Vascular compression can be diagnosed by connection with the spin-echo data. Accurate vessel identification at or near the root entry/exit zone is made easier by the simultaneous display of MRA and multiplanar reconstruction (MPR).

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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

Compliance Test and Quality Assurance of Medical Diagnostic Installations

Quality Assurance of diagnostic x-ray equipment means systematic actions necessary to provide adequate confidence that diagnostic x-ray equipment will perform satisfactorily in compliance with safety standards specified by the **Atomic Energy Regulatory Board (AERB).**

The AERB has published the National Safety Code on Medical Diagnostic X-ray Equipment and Installations, **Safety code # AERB/SC/MED-2 (Rev-1), dated : 05/10/2001**

The implementation of the provisions of the safety code ensures the protection from radiation of occupational workers, patients, and the public.

WHY QUALITY ASSURANCE OF DIAGNOSTIC MACHINES IS REQUIRED?

- **To Check:-**
  - Accuracy and Consistency of Radiation Equipment
  - Factors affecting X-Ray source equipment, surrounding area of the equipment, Safety of Patient's & Personnel Operating the equipment
  - Evaluation of potential exposure levels at various locations arising from the operations of the equipment
- **It helps :-**
  - Reduces the down time of the machine
  - Accurate & Timely diagnosis
  - Minimize radiation dose levels tc patients, technicians & general public
  - Cost effective
  - Complies to regulatory requirements
  - Professional & Public reputation of Diagnostic clinics
- **Compulsory Requirements as per :-**
  - AERB Regulations (Every Two years)
  - NABH Regulations (Every One years)
  - ISO Certification



Quality Assurance & Area Surveillance tests is compulsory requirements to register / renew your diagnostic equipment with AERB.

- **Diagnostic Installations, include:-**
  - X-Ray with fluoroscopy (Fixed and Mobile)
  - CT Scan
  - Mammography
  - C Arm Machines
  - Cath Lab
  - Dental X rays
  - Orthopentogram (OPG)
  - Cone beam CT (CBCT)
  - Bone Densitometry (BMD)
- **Quality Assurance Tests to be performed Include:-**
  - Congruence of radiation and optical field
  - Central beam alignment
  - Focal spot size & Timer check
  - Accelerating voltage reproducibility
  - Linearity of Timer and mA station
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Non-Contrast Computed Tomography in Urinary Stone Disease:
Association of Stone Size, Location, and Hounsfield Units with Hydronephrosis — A Narrative Review

Raghvendra, Bachelor of Radiology Student, NIMT Institute of Medical and Paramedical Science, Greater Noida

Abstract

Background: Urinary stone disease, also known as urolithiasis, is a common condition that can interfere with the normal flow of urine and cause obstruction of the urinary tract. One of the important imaging findings associated with obstruction is hydronephrosis, characterized by dilatation of the renal collecting system. Non-contrast computed tomography (NCCT) is widely used to evaluate urinary calculi because it provides detailed information about stone size, anatomical location, attenuation, and associated changes in the urinary tract.

Objective: This narrative review examines the role of NCCT in evaluating urinary stones, with particular emphasis on the relationships between stone size, anatomical location, Hounsfield unit (HU) measurements, and associated hydronephrosis.

Methods: Four selected research articles were considered to explore the available evidence. Three studies focused primarily on the relationship between urinary stone characteristics and hydronephrosis, while an additional study examined stone size and CT attenuation in relation to clinical outcomes, including spontaneous stone passage and extracorporeal shock wave lithotripsy (ESWL) success. The findings were reviewed qualitatively and organized according to their relevance to radiological assessment and treatment planning.

Results: The reviewed evidence suggests that increasing stone size is associated with a greater likelihood of more severe hydronephrosis. Stone location may also influence the severity of collecting system dilatation, although the strength of this association can vary between studies. A retrospective CT study involving 128 patients reported a significant association between increasing stone size and hydronephrosis severity, with proximal and middle ureteral stones associated with greater severity than distal ureteral or ureterovesical junction stones. CT attenuation measurements provide complementary information about stone density and may help predict the response to ESWL. However, the selected evidence does not establish a direct relationship between HU values and hydronephrosis severity.

Conclusion: NCCT is an important imaging modality for the comprehensive evaluation of urinary stone disease. Assessment of stone size, location, attenuation, and associated hydronephrosis can provide clinically useful information about urinary obstruction and support treatment planning.

Further research is needed to determine whether combining these CT parameters improves the prediction of hydronephrosis severity and clinical outcomes.

Keywords: Non-contrast computed tomography, urinary calculi, urolithiasis, hydronephrosis, Hounsfield units, CT-KUB, ureteral obstruction, extracorporeal shock wave lithotripsy.

Introduction

Urinary stone disease, commonly referred to as urolithiasis, is a condition in which mineral crystals accumulate and develop into calculi within the kidneys or other parts of the urinary tract. These stones may remain within the renal collecting system or migrate into the ureters, where they can partially or completely obstruct the passage of urine. The clinical presentation varies considerably, ranging from incidentally detected asymptomatic stones to severe flank pain, nausea, vomiting, urinary obstruction, and complications requiring urgent medical attention.

Hydronephrosis is an important radiological finding associated with impaired urinary drainage. It refers to dilatation of the renal pelvis and calyces and may occur when a urinary stone obstructs the normal flow of urine. The degree of dilatation varies depending on several factors, including the size and location of the obstructing stone, the degree and duration of obstruction, and the patient's underlying urinary tract anatomy. Persistent or severe obstruction may compromise renal function, particularly when accompanied by infection or other complications. Nevertheless, hydronephrosis alone does not provide a complete measure of renal function or establish the duration of obstruction.

Accurate imaging is therefore essential for identifying urinary stones, determining their anatomical location, and evaluating associated changes in the urinary tract. Ultrasonography is frequently used as an initial imaging examination because it does not involve ionizing radiation and can demonstrate collecting system dilatation. However, its ability to directly visualize ureteral calculi may be limited, particularly for small stones or stones located in certain portions of the ureter. The visibility of a stone can also be affected by bowel gas, body habitus, and technical factors.

Non-contrast computed tomography of the kidneys, ureters, and bladder (NCCT KUB) provides detailed cross-sectional images of the urinary tract without requiring intravenous contrast material. It is particularly useful for identifying urinary calculi, measuring their dimensions, determining their location, and detecting secondary signs of obstruction. NCCT can also demonstrate findings such as perinephric fat stranding and other changes that may accompany ureteral obstruction. These features make it a valuable examination in the assessment of suspected urinary stone disease.

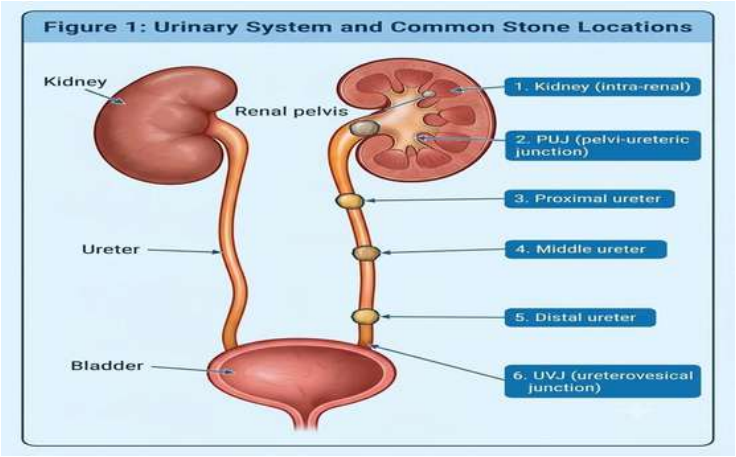
Three CT parameters are particularly relevant to the present review. First, stone size may influence the likelihood of spontaneous passage and the degree of obstruction. Second, stone location determines the anatomical level at which urinary drainage may be impaired. Third, stone attenuation, expressed in Hounsfield units, provides an estimate of radiographic density and may contribute to predicting stone composition and treatment response. These parameters provide different types of information and should not be considered interchangeable.

Previous research has investigated the association between stone characteristics and hydronephrosis severity. A retrospective study published in 2026 involving 128 patients reported a significant relationship between increasing ureteral stone size and greater hydronephrosis severity. It also identified an association between proximal or middle ureteral location and more advanced hydronephrosis compared with distal ureteral or ureterovesical junction stones [2]. Such findings support the

importance of assessing stone characteristics alongside secondary signs of obstruction.

However, the relationship between stone attenuation and hydronephrosis remains less clearly established in the selected literature. Although HU measurements may help characterize stones and inform treatment planning, their independent contribution to predicting hydronephrosis severity requires further investigation

Accordingly, this narrative review discusses the role of NCCT in urinary stone evaluation, focusing on stone size, anatomical location, HU measurements, and their potential clinical relevance in the assessment of hydronephrosis.



Review Methodology

This paper was prepared as a narrative review of four selected research articles concerning the NCCT evaluation of urinary calculi and their associated clinical or radiological findings.

The articles were selected according to their relevance to the following themes:

1. The relationship between urinary stone size and hydronephrosis.
2. The association between stone location and the severity of collecting system dilatation.
3. The use of HU measurements to characterize urinary stones.
4. The relevance of stone size and attenuation to spontaneous passage and ESWL outcomes.

Three selected studies primarily addressed the relationship between urinary stone characteristics and hydronephrosis, while the fourth examined stone size and HU measurements in relation to clinical outcomes.

The findings were organized thematically and interpreted in relation to the radiological assessment of urinary stone disease. Particular attention was given to the distinction between evidence directly addressing hydronephrosis and evidence concerning treatment outcomes.

As this was a narrative review based on a limited number of selected articles, it was not intended to provide an exhaustive systematic review or a pooled statistical estimate. A formal database search strategy, eligibility criteria, and independent quality assessment were not available in the supplied material. Consequently, the findings should be interpreted as a qualitative synthesis of the selected literature rather than as definitive evidence of causation.

Discussion

Role of NCCT in the Evaluation of Urinary Stones

NCCT plays an important role in the radiological assessment of urinary calculi because it provides information about both the stone itself and the surrounding urinary tract. Unlike imaging techniques that primarily demonstrate collecting system dilatation, NCCT can directly identify most urinary calculi and accurately describe their size and anatomical position.

Stone size is generally measured in millimetres using axial and multiplanar CT images. Depending on the study protocol, the maximum stone diameter or other dimensional measurements may be recorded. Consistent measurement methods are important when comparing findings across patients or research studies.

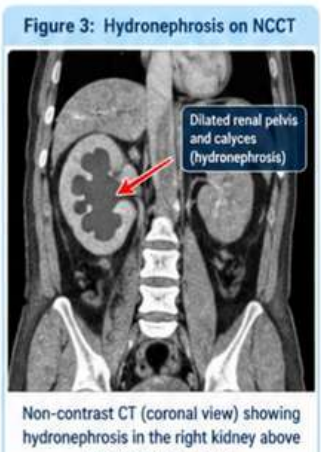
Stone location should also be documented precisely. Renal calculi may be present within the renal calyces or pelvis, whereas ureteral calculi can be classified according to their position in the proximal, middle, or distal ureter. Stones located at the ureteropelvic junction or ureterovesical junction may be described separately, depending on the classification system used.

In addition to identifying the calculus, NCCT can demonstrate secondary findings associated with obstruction. These include hydronephrosis, hydroureter, and perinephric or periureteral fat stranding. The presence and extent of these findings may help the radiologist describe the possible consequences of a stone on urinary drainage.

Nevertheless, CT findings must be interpreted in conjunction with clinical information. The absence of marked hydronephrosis does not necessarily exclude acute obstruction, and the degree of dilatation does not always correspond directly to the degree of renal functional impairment. Therefore, NCCT findings should support, rather than replace, clinical assessment.



Non-contrast CT (coronal view) showing a hyperdense stone in the ureter.



Non-contrast CT (coronal view) showing hydronephrosis in the right kidney above the obstructing stone.

Relationship Between Stone Size and Hydronephrosis

Stone size is an important characteristic in the evaluation of ureteral calculi. A larger stone may be more likely to impede urinary drainage, particularly when its diameter approaches or exceeds the effective calibre of the ureter at the site of impaction. Continued obstruction may increase pressure within the collecting system and lead to progressive dilatation.

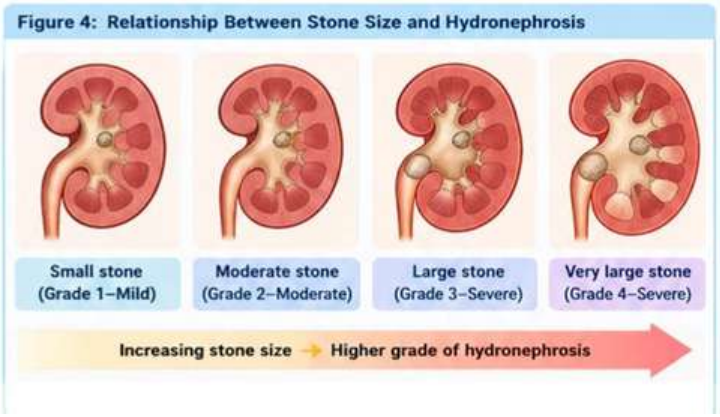
Khan et al. [1] investigated the prevalence of hydronephrosis associated with urinary tract calculi on NCCT. According to the supplied summary of their study, 137 of 196 patients (69.9%) had hydronephrosis. The authors also reported a statistically significant relationship between stone size and hydronephrosis severity ($p < 0.001$). These findings suggest that stone dimensions may provide useful information when assessing the likelihood of associated collecting system dilatation.

Similarly, Öztepe and Gülmez [2] evaluated 128 patients with single unilateral ureteral stones identified on non-contrast CT. Hydronephrosis was present in 116 patients (90.6%), and moderateto-severe hydronephrosis was reported in 58 patients (45.3%). Their analysis demonstrated a positive association between stone size and hydronephrosis grade (Spearman's rho = 0.422, $p < 0.001$). In their multivariable ordinal regression model,

each 1 mm increase in stone size was associated with higher odds of a more severe hydronephrosis grade (odds ratio 1.20, 95% confidence interval 1.07–1.33; p = 0.001) [2].

The findings of these studies are consistent with the possibility that larger ureteral calculi are associated with more pronounced urinary obstruction. However, the relationship should not be interpreted as absolute. Small stones can produce significant obstruction, while some larger stones may be associated with limited dilatation. The duration of obstruction, stone impaction, ureteral anatomy, and the degree of partial or complete blockage may all influence the observed imaging appearance.

From a radiological perspective, documenting the maximum stone diameter together with the presence and grade of hydronephrosis provides a more complete description than reporting stone size alone. Such combined assessment may assist clinicians in evaluating the potential significance of the finding, although treatment decisions require additional clinical information.



Relationship Between Stone Location and Hydronephrosis

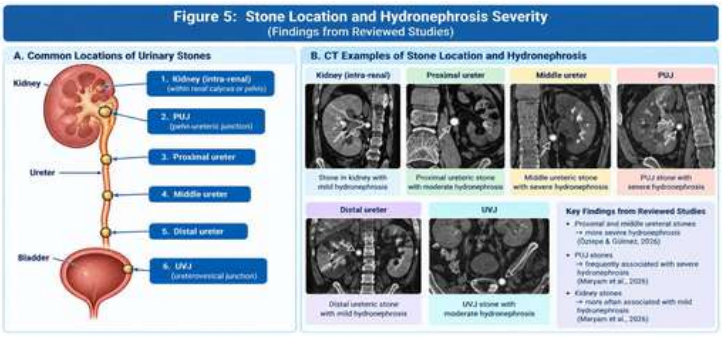
The anatomical position of a urinary stone may influence the pattern and severity of obstruction. Ureteral stones are commonly classified as proximal, middle, or distal, with the ureteropelvic junction and ureterovesical junction serving as important anatomical landmarks.

A stone located in the proximal or middle ureter may be associated with substantial upstream urinary dilatation. However, location alone does not determine the severity of obstruction, and distal stones can also cause marked hydronephrosis when urinary drainage is significantly impaired.

Öztepe and Gülmez [2] reported that proximal and middle ureteral stones were associated with greater hydronephrosis severity than distal ureteral or ureterovesical junction stones. In their study, moderate-to-severe hydronephrosis was observed in 61.5% of patients with proximal ureteral stones, 75.0% of those with middle ureteral stones, and 29.4% of those with distal ureteral or ureterovesical junction stones. Their adjusted ordinal regression analysis also identified an association between proximal or middle ureteral location and a higher hydronephrosis grade (odds ratio 2.40, 95% confidence interval 1.14–5.07; p = 0.022) [2].

These results suggest that anatomical location may contribute information beyond stone size alone. However, only eight patients in this study had middle ureteral stones, which limits the precision of the estimate for that subgroup. In addition, differences in patient selection, symptom duration, stone impaction, and location classification may explain why associations vary across studies.

Consequently, stone location should be interpreted alongside stone dimensions and the observed degree of urinary tract dilatation. Further research using standardized anatomical categories and hydronephrosis grading systems would help establish whether the relationship is consistent across different populations.



Role of Hounsfield Units in Stone Characterization

Hounsfield units are quantitative measurements of CT attenuation that describe how strongly a tissue or material attenuates X-rays relative to water. In urinary stone assessment, HU measurements can provide an estimate of stone density and may help predict stone composition or response to particular treatment methods.

Stone attenuation is influenced by several factors, including mineral composition, stone structure, measurement technique, and CT acquisition parameters. Therefore, HU values should be interpreted as an imaging-based estimate rather than as a definitive identification of chemical composition.

A region of interest can be placed within the stone on CT images to measure attenuation. To improve reliability, the region of interest should be positioned carefully within the calculus, avoiding adjacent soft tissues and partial-volume effects where possible. Stone size, image noise, reconstruction settings, and the use of small or irregular regions of interest can affect the measurement.

Mittal [4], according to the supplied reference and study summary, examined stone size and HU values in relation to clinical outcomes, including spontaneous stone passage and ESWL success. The reported findings indicated that ESWL success decreased as stone attenuation increased. This is clinically relevant because denser stones may be more resistant to fragmentation and may require a different treatment approach.

However, the relationship between HU and hydronephrosis must be distinguished from the relationship between HU and treatment response. A stone's density may influence its susceptibility to fragmentation without directly determining the degree of urinary collecting system dilatation. Hydronephrosis is more directly related to the effect of obstruction on urinary drainage, whereas attenuation describes the stone's CT characteristics.

The selected evidence therefore supports discussing HU as a complementary parameter for stone characterization and treatment planning. It does not establish that higher HU values are independently associated with more severe hydronephrosis. This question requires studies that measure stone attenuation and hydronephrosis grade in the same patient population.



Integrated Assessment of Stone Size, Location, HU, and Hydronephrosis

The main advantage of NCCT is its ability to demonstrate several relevant imaging features during a single examination. Stone size, anatomical location, attenuation, and the presence of hydronephrosis provide complementary information about urinary stone disease.

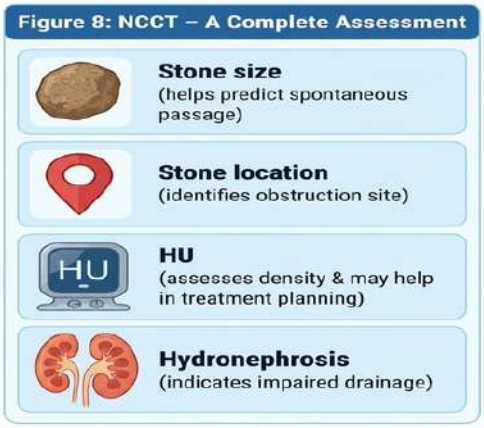
Stone size may indicate the likelihood of spontaneous passage and the potential for obstruction. Anatomical location helps identify the level at which urinary drainage may be impaired. HU measurements provide information about attenuation and may contribute to treatment selection. Hydronephrosis demonstrates dilatation of the collecting system and provides evidence of a possible obstructive effect.

These parameters should be evaluated together rather than interpreted independently. For example, a relatively large proximal ureteral stone accompanied by substantial hydronephrosis may raise greater concern for significant obstruction than a small stone without collecting system dilatation. Nevertheless, this comparison is illustrative and does not constitute a validated prediction rule.

Similarly, a high HU measurement may be relevant when considering ESWL, but it should not be interpreted as a direct measure of obstruction severity. The clinical significance of each parameter depends on the patient's symptoms, renal function, presence of infection, and other relevant findings.

A structured NCCT report should therefore include the stone's location, maximum diameter, number of calculi, relevant attenuation measurements when appropriate, and the presence and severity of hydronephrosis. Associated findings such as hydroureter and perinephric changes should also be documented when present.

Such a systematic approach can improve the completeness and consistency of radiological reporting and provide clinicians with information relevant to further assessment and management.



Research Gap and Future Scope

Although the selected studies provide useful information about urinary stone characteristics and hydronephrosis, several questions remain unresolved.

First, the association between stone size and hydronephrosis requires further evaluation in larger and more diverse populations. Existing findings suggest that increasing stone size is associated with greater hydronephrosis severity, but the relationship may vary according to the duration of obstruction, stone impaction, anatomical differences, and clinical presentation.

Second, the influence of stone location remains incompletely established. Studies have used different anatomical categories and patient-selection criteria, making direct comparison difficult. Future research should use standardized location classifications and reproducible hydronephrosis grading systems.

Third, the relationship between HU measurements and hydronephrosis severity is an important area for further investigation. The supplied study summary from Mittal [4] concerns clinical outcomes such as ESWL success and spontaneous passage rather than a direct association between attenuation and hydronephrosis. Therefore, it remains uncertain whether HU measurements contribute independent predictive information about the severity of urinary obstruction.

Fourth, the combined predictive value of stone size, location, and attenuation has not been established by the limited evidence reviewed here. Prospective studies could measure all three parameters in the same patient population and assess their associations with hydronephrosis grade, renal function, spontaneous passage, and treatment outcomes.

Such studies should account for potentially important confounding factors, including age, sex, symptom duration, infection, baseline renal function, stone composition when available, and previous urinary tract disease. Multivariable statistical models could then determine whether HU measurements provide additional predictive value after accounting for stone size and location.

Finally, future research could examine the reproducibility of HU measurements across different CT scanners and acquisition protocols. Standardized measurement methods would help improve comparisons between studies and clarify the practical value of attenuation measurements in routine radiological reporting.

Limitations of the Review

This review has several limitations. First, it is based on four selected research articles, which limits the breadth of the available evidence. Second, the review follows a narrative approach rather than a systematic methodology; therefore, the possibility of selection bias cannot be excluded. Third, differences in study populations, imaging methods, stone-location categories, and hydronephrosis grading systems may limit comparisons across studies.

In addition, the evidence concerning HU measurements and treatment outcomes does not necessarily establish a relationship between stone attenuation and hydronephrosis severity. The limited number of selected studies prevents a reliable conclusion regarding the independent contribution of HU values to predicting urinary obstruction.

The bibliographic details and full texts of all four references should also be verified before submission. The findings summarized in this manuscript should be checked against the original articles to ensure that the numerical results and interpretations are accurate.

Conclusion

Non-contrast computed tomography is a valuable imaging modality for evaluating urinary stone disease because it provides detailed information about stone size, anatomical location, attenuation, and associated changes in the urinary tract. These findings are particularly relevant when assessing hydronephrosis, an important imaging sign of impaired urinary drainage.

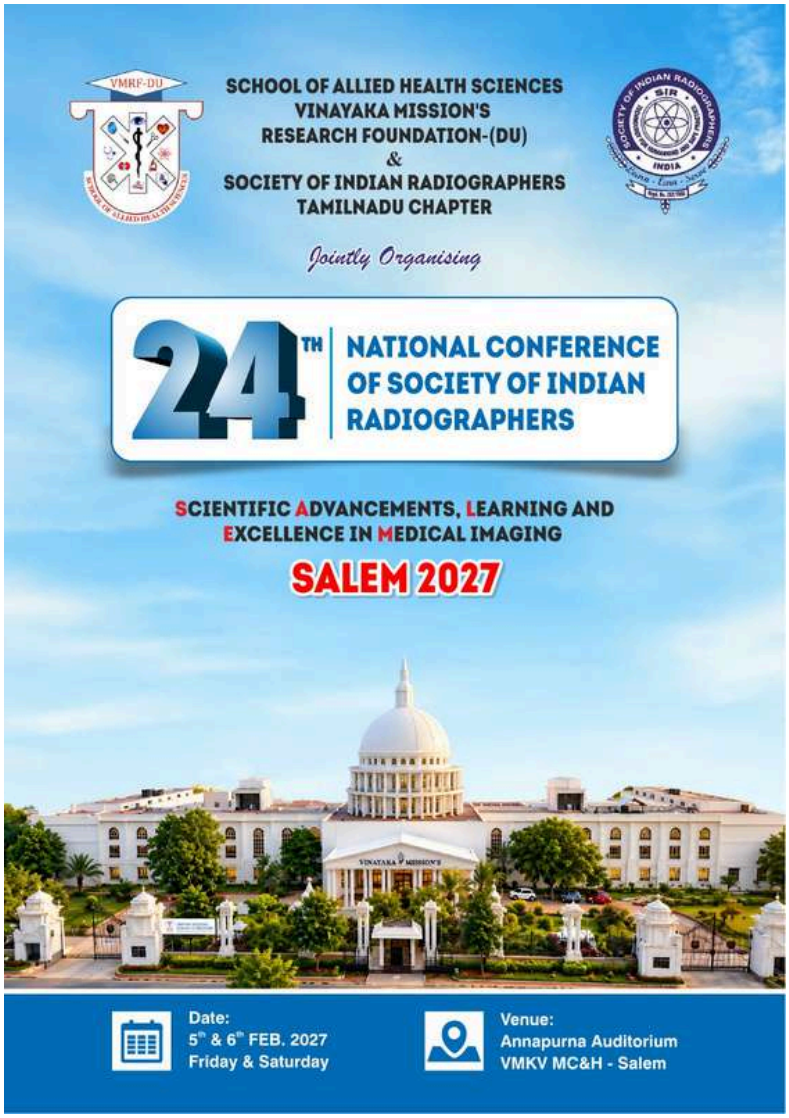
The reviewed evidence suggests that larger ureteral stones are associated with more severe hydronephrosis. Stone location may also influence the degree of collecting system dilatation, although this relationship requires confirmation across larger populations and standardized study designs.

HU measurements provide additional information about stone density and may help predict treatment outcomes, particularly the response to ESWL. However, their direct relationship with hydronephrosis severity remains insufficiently established in the selected literature.

Overall, a combined assessment of stone size, location, attenuation, and hydronephrosis can improve the descriptive completeness of NCCT examinations. Future studies evaluating these parameters together may clarify their independent and combined predictive value and further strengthen the role of NCCT in the radiological evaluation and management of urinary stone disease.

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Advances in SPECT /CT Imaging

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Abstract

A sophisticated imaging technique, single photon emission tomography/computed tomography (SPECT/CT) plays a vital role in the monitoring and diagnosis of numerous illnesses. The technological developments, clinical implications, and future prospects of SPECT and SPECT/CT imaging are reviewed in this study. This review focuses on detector materials, camera head and collimator designs, signal amplifier devices, image reconstruction methods, and quantitative approaches. Position-sensitive PMTs (PSPMTs), avalanche photodiodes (APDs), and silicon PMs are replacing bulky photomultiplier tubes (PMTs) in order to increase detection efficiency and improve energy and spatial resolution. New SPECT cameras have most recently been developed for cardiac imaging. The new design uses an L-shaped camera head that uses semiconductor detector materials like Cd Zn Te (CZT: cadmium–zinc–telluride) or specialized collimators in conjunction with traditional sodium iodide detectors (NaI(Tl)). The practical benefits of the new design include quicker scanning durations, increased picture quality, enhanced patient comfort, reduced claustrophobic effects, and decreased overall size, particularly in specialised healthcare centres. Moreover, this study provides clinical examples in oncology, neurology, cardiology, musculoskeletal, and infection, highlighting the influence of these breakthroughs on clinical practice in radiology and molecular imaging departments.

Keywords: SPECT: collimator design, solid state detector, reconstruction algorithm, artificial intelligence

Introduction

A three-dimensional (3D) distribution of the gamma rays released by radionuclides is produced using photon emission computed tomography (SPECT). Before physical changes take place, functional abnormalities can be identified thanks to the pictures' functional information about organs and tissues. Since 1999, hybrid SPECT/CT scanners have been widely placed throughout the world thanks to the combination of SPECT and computed tomography (CT). A non-invasive hybrid method called SPECT/CT directly combines functional and morphological data from the CT and SPECT components, respectively. Despite continuous advancements in specialized SPECT cameras, CT pictures demonstrate diagnostic accuracy and localization, improving reader trust and clinical outcomes in various clinical applications. The competitiveness of SPECT/CT among contemporary diagnostic imaging modalities has been greatly increased by recent technological developments. Better image quality, increased diagnostic precision, and more trustworthy quantitative analysis are the results of advancements in both hardware and software. In terms of hardware, traditional photomultiplier tubes (PMTs) have developed into sophisticated signal amplification devices like position-sensitive PMTs (PSPMTs), avalanche photodiodes (APDs), and silicon photomultipliers (SiPMs), while semiconductor detectors are gradually replacing conventional NaI(Tl) scintillation detectors. Additionally, for both dedicated and multipurpose SPECT systems, advances in collimator and camera head designs have enhanced detector sensitivity, spatial resolution, and imaging efficiency. By developing sophisticated iterative reconstruction algorithms, image correction methods (attenuation, scatter, and resolution correction), and quantitative imaging approaches, software advancements have supplemented these hardware breakthroughs. These technologies provide precise assessment of radiotracer uptake for clinical decision-making, optimize photon use, and enhance image quality. All of these developments have made SPECT/CT a more precise, effective, and quantitative molecular imaging method by extending its clinical applications in cardiology, cancer, neurology, musculoskeletal imaging, and infection/inflammation imaging.

1. Advancement of SPECT Technology

Conventional systems, however, have a number of drawbacks, such as large photomultiplier tube (PMT)-based camera heads, low detector sensitivity, longer collection times, restricted photon energy and spatial resolution, and the requirement for greater radiopharmaceutical doses. Additionally, these restrictions lessen patient comfort, especially for pediatric and immobile patients. Recent developments in both hardware and software have greatly enhanced SPECT technology. Conventional PMTs have been supplanted by advanced read-out systems including avalanche photodiodes (APDs) and silicon photomultipliers (SiPMs), as well as solid-state semiconductor detectors, especially cadmium–zinc–telluride (CZT) detectors. Higher sensitivity, better energy and spatial resolution, faster scan times, reduced radiation exposure, and increased image quality are all offered by these technologies.

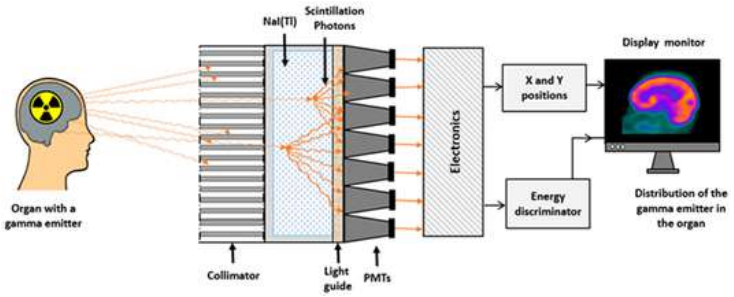


Figure 1. Schematic representation of basic components of the Anger scintillation camera.

1.1advance in Hardware Technology

The current research focuses on investigating a more compact design for gamma cameras intended for small-animal imaging, scintimammography or molecular breast imaging, myocardial perfusion imaging, and small-organ imaging. Significant advancements in the Anger scintillation camera hardware, such as novel detector materials and signal amplifying devices, as well as advances in the design of collimators and the camera head, have resulted in the smaller and more compact imaging systems.

1.2 Detector Material

The physical characteristics of the γ-ray detector, including its density, detection efficiency, energy resolution, and spatial resolution, have a significant impact on the quality of SPECT imaging. Conventional Anger cameras with NaI(Tl) scintillation detectors offer continuous sampling and strong inherent efficiency, but they operate poorly close to detector edges and have modest spatial and energy resolution. Because of their excellent detection efficiency and comparatively low manufacturing cost, scintillation materials including NaI(Tl), CsI(Tl), CsI(Na), and $LaBr_3$:Ce have been widely employed. $LaBr_3$:Ce is ideal for high-count-rate and small-animal SPECT

applications because of its high light output, quick reaction, and enhanced energy resolution. Cadmium–zinc–telluride (CZT) semiconductor detectors have become more significant in SPECT and SPECT/CT in recent years, especially in cardiac imaging. CZT eliminates the requirement for photomultiplier-based amplification by directly converting γ-rays into electrical impulses. This offers excellent inherent spatial resolution, compact detector construction, and improved energy resolution. CZT detectors are appropriate for quantitative and multi-radionuclide imaging, and they can function at room temperature.

Semiconductor technology has improved significantly despite rising manufacturing costs and constraints for high-energy γ-rays. The use of CZT detectors in contemporary SPECT imaging is demonstrated by systems like D-SPECT® and VERITON®. In general, better picture clarity, spatial resolution, energy resolution, and compact SPECT system design have been made possible by the advancement of scintillation and semiconductor detectors.

1.3 Design of Collimators

Large active area detectors and acquisition techniques that effectively catch emitted γ-rays are necessary to reduce statistical uncertainty in SPECT. While preserving or enhancing image quality, new technologies seek to lower prescribed radiation dose and scan time.

IQ.SPECT is an ultra-fast cardiac SPECT method that combines advanced iterative reconstruction, cardio-centric acquisition, and a unique SMARTZOOM multifocal collimator. The SMARTZOOM collimator reduces truncation and increases sensitivity to the heart by using near-parallel holes at the periphery and focussed holes at the center. Compared to traditional LEHR collimation, it can offer sensitivity that is up to four times higher. In addition to increasing sensitivity and enabling a somewhat comfortable detector distance, the cardio-centric orbit places the heart within the magnification region. Additionally, IQ.SPECT offers a variety of imaging procedures, such as 4-minute standard-dose, 8-minute half-dose, and 16-minute quarter-dose protocols. Collimator geometry, detector motion, gantry deflection, attenuation, and scatter are all taken into consideration by its sophisticated reconstruction. With shorter acquisition durations or lower radiation doses, this improves image quality by reducing artifacts.

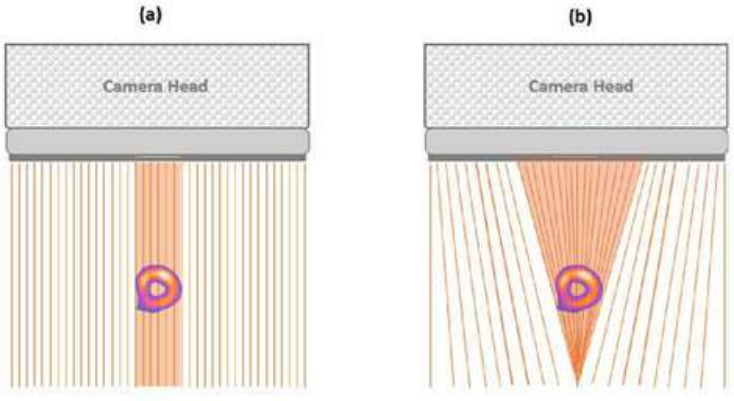


Figure 2. Camera head with a conventional LEHR collimator (a) and a SMARTZOOM collimator (b).

1.4Developments in Signal Amplification

- Tubes for Photomultipliers

The scintillation light generated by NaI(Tl) crystals has historically been amplified using photomultiplier tubes. Nevertheless, the size and weight of the detector assembly are increased by the comparatively large size of typical PMTs. Detector design and spatial resolution are also constrained by their physical attributes.

- **Photomultiplier tubes that are sensitive to position**

Scintillation event localization is enhanced using position-sensitive photomultiplier tubes. They are a technological step in between more sophisticated solid-state reading devices and traditional PMTs.

- **Photodiodes Avalanche**

Compact semiconductor devices called avalanche photodiodes are able to transform scintillation light into electrical signals. Because of their lower size, camera-head design is more flexible.

- **Photomultipliers made of silicon**

Another new technology for signal amplification is silicon photomultipliers. They can be integrated into contemporary detecting systems and have small dimensions. Thus, the shift to more compact and effective SPECT detector systems has been aided by the development of PSPMTs, APDs, and SiPMs.

1.5 The Camera Head's Design

Only a small percentage of the NaI(Tl) detector is efficiently exploited, traditional dual-head gamma cameras have limitations when it comes to cardiac imaging. Additionally, pain and claustrophobia may result from their close detector-to-patient location. In order to enhance sensitivity, picture quality, acquisition speed, and patient comfort, specialized SPECT systems as D-SPECT, Discovery NM/Alcyone, Cardius 3 XPO, and VERITON have been created. Utilizing CZT detectors, D-SPECT offers far more sensitivity than traditional systems, enabling shorter acquisition times and dosage administration. Additionally, the open-gantry design enhances patient comfort. To increase sensitivity, Discovery NM/Alcyone integrates 3D reconstruction, stationary acquisition, focused collimation, and CZT detectors. While VERITON uses 12 independent CZT detector arms to provide 360° coverage and enable quantitative 3D dynamic SPECT, Cardius 3 XPO uses a triple-head solid-state detector arrangement.

1.6 Advancements in Software Techniques

In order to increase diagnostic picture quality, decrease image noise, and improve spatial resolution, modern SPECT and SPECT/CT systems increasingly use sophisticated software. With particularly significant applications in cardiac SPECT, current advancements primarily concentrate on image reconstruction algorithms, data-correction strategies, and quantitative imaging techniques.

1.7 Reconstruction Algorithms

The quality of SPECT images has been greatly enhanced by developments in computation and iterative reconstruction. Compared to traditional filtered back projection (FBP), Maximum Likelihood Expectation Maximization (MLEM) and Ordered-Subsets Expectation Maximization (OSEM) offer superior noise management. Nevertheless, repetitive approaches may result in spatial blurring and noise amplification, which prompts the creation of resolution-recovery and noise-reduction strategies. Attenuation, dispersion, detector response, and distance-dependent spatial resolution are all taken into account by contemporary reconstruction methods like Astonish, Flash3D, Evolution, and Wide-Beam Reconstruction (WBR).

Astonish: Improves signal-to-noise ratio and image quality while possibly cutting acquisition time by using OSEM with resolution recovery and noise reduction.
Flash3D: Integrates 3D resolution recovery, attenuation, scatter, and detector response corrections with iterative OSEM. It can significantly shorten the acquisition time of cardiac SPECT.
Evolution: Achieves resolution recovery while managing noise amplification by integrating collimator and detector response into OSEM reconstruction.
Wide-Beam Reconstruction (WBR): In order to improve resolution and image quality while enabling faster acquisition times and possibly lower radiation exposure, models the geometric and physical properties of the imaging equipment and detector–patient distance.

When compared to traditional reconstruction techniques, these sophisticated reconstruction techniques often enhance spatial and contrast resolution, noise control, quantitative correctness, and acquisition efficiency.

1.8 Data Correction Methods

SPECT picture quality and quantitative accuracy can be diminished by attenuation, dispersed radiation, poor spatial resolution, and image noise. For this reason, scatter correction is a crucial part of contemporary SPECT reconstruction. More sophisticated computational algorithms have been developed as a result of the limits of traditional correction methods in terms of accuracy and increased image noise. Mathematical modeling or additional energy windows can be used to estimate scatter. Scatter correction can be directly incorporated into the reconstruction process using contemporary iterative reconstruction techniques however this takes more processing power. Subtracting counts from off-peak energy windows is a straightforward method for myocardial perfusion imaging, although it may increase image noise. When compared to subtraction techniques, model-based scatter correction has been shown to improve image contrast by roughly 10% to 20%. Additionally, more sophisticated correction methods are used in fields like brain imaging and radionuclide dosimetry.

Overall, scatter correction has become more feasible due to advancements in computer power and reconstruction approaches, enhancing SPECT's image quality, contrast, and quantitative reliability.

1.9 Quantitative Methods

The goal of quantitative SPECT is to differentiate aberrant radiotracer uptake from incidental or physiological uptake. Relative and semi-quantitative measures of SPECT have given way to absolute quantification, which is represented as activity concentration (kBq/cc) or standardized uptake value (SUV). By using resolution-recovery-based reconstruction and camera calibration, contemporary software has enhanced quantitative SPECT. Radiotracer distribution can be measured more precisely thanks to technologies like xSPECTTM and SUV SPECTTM. During reconstruction, SPECTTM combines SPECT and CT data to enhance quantitative evaluation and anatomical localization. Standardized uptake measurements for tracking the course of the disease and the effectiveness of treatment are made possible by the xSPECT QuantTM software that goes along with it. SUV-SPECT allows for an absolute evaluation of radiotracer uptake by converting voxel counts into activity concentration and SUV.

The use of SPECT in bone imaging, cancer, radionuclide therapy, and cardiac perfusion imaging is generally growing due to advancements in quantitative software, with ongoing development focused on enhancing quantitative correctness and clinical usability.

2. Advances in SPECT Animal Imaging

The majority of preclinical SPECT imaging uses small animal models, especially rodents, for which the spatial resolution, sensitivity, and tissue contrast of traditional clinical SPECT systems are restricted. Through specialized instruments, recent technical advancements have concentrated on addressing these constraints. Advanced scintillation materials like CsI(Tl), CsI(Na), and $LaBr_3$(Ce) further improve detector performance, while pinhole and multi pinhole collimation increase spatial resolution and image sensitivity. Improved energy discrimination is offered by semiconductor detectors like CdTe and CZT, especially for dual-isotope imaging and low-energy radionuclides. Contemporary micro-SPECT systems are capable of detecting extremely low radiotracer concentrations and achieving submillimeter spatial resolution (about 0.5–0.7 mm). Preclinical studies on cardiovascular illness, cancer, neurological conditions like Parkinson's and Alzheimer's disease, and medication development can all benefit from the use of micro-SPECT. Signal localization, contrast, and spatial resolution are all improved when micro-SPECT is combined with micro-CT or micro-MRI to offer additional functional and anatomical information. As a result, these hybrid systems are becoming crucial instruments for preclinical studies and contemporary medication development. Nuclear medicine is rapidly utilizing artificial intelligence (AI), especially machine learning (ML) and deep learning (DL). AI has the ability to reduce imaging time, administered activity, and effort in SPECT and SPECT/CT by supporting patient setup, dosimetry, quality assurance, picture reconstruction, image analysis, and pre-reporting. AI applications include automated lung nodule segmentation and quantification as well as automated cardiac assessment, such as endocardial border tracking and polar plot analysis. For the reconstruction of SPECT images, deep learning techniques have also been studied. When compared to traditional OSEM-based reconstruction, SPECT Net, an early deep-learning reconstruction method, showed less susceptibility to noise. Clinical implementation is still difficult despite these developments. Data quality and structure, model applicability, standardization, explainability, transparency, and possible algorithmic bias are all significant issues. Reliable AI model creation and assessment require sizable validated databases and registries. In addition to ethical and legal frameworks, standardized imaging techniques, external validation, and suitable AI training, successful deployment necessitates cooperation between physicians, medical physicists, technologists, data scientists, and other healthcare professionals. With the potential to enhance quantitative SPECT imaging, workflow efficiency, and diagnostic accuracy, AI is generally anticipated to assist rather than replace nuclear medicine specialists.

3. Clinical Implications of Recent Advances in SPECT AND SPECT/CT

By integrating functional radiotracer data with anatomical localization, SPECT/CT has increased the practical value of nuclear medicine and improved diagnostic confidence in a number of therapeutic disciplines.

Cardiology

To assess myocardial perfusion and inducible ischemia, SPECT myocardial perfusion imaging is frequently utilized. The use of

CT-based attenuation correction enhances interpretation and lessens attenuation artifacts. IQ. Rapid cardiac imaging is further supported by SPECT while preserving diagnostic image quality.

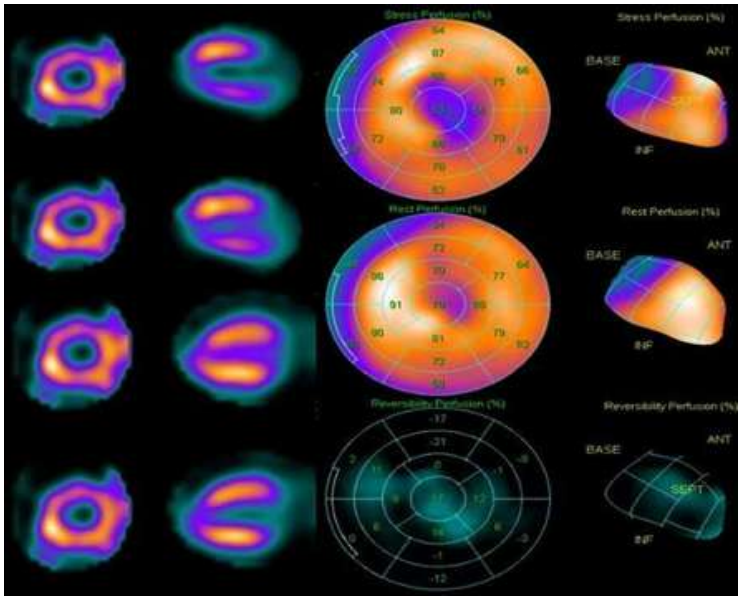


Figure 3. Stress and rest myocardial perfusion SPECT images showing partially reversible perfusion defects involving the apical, apico-anterior, apico-lateral, and apico-inferior segments. The corresponding polar maps and 3D-rendered images demonstrate the regional perfusion abnormalities and segmental perfusion scores according to the 16-segment model.

Oncology

SPECT/CT is especially helpful for imaging thyroid cancer and offers precise anatomical localization of radiotracer uptake. It helps with disease staging and treatment evaluation and can differentiate between metastatic disease and residual thyroid tissue.

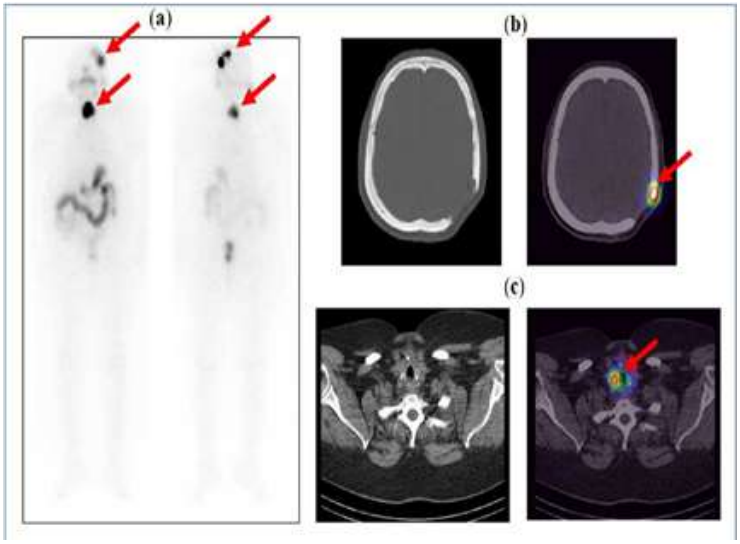


Figure 4. Post-therapy iodine SPECT/CT imaging demonstrating residual and metastatic iodine-avid disease. (a) Anterior and posterior whole-body images showing iodine uptake in the neck and left parietal region, with physiological tracer distribution in the salivary glands, stomach, bowel, and urinary bladder. (b) CT and fused SPECT/CT images demonstrating an osteolytic iodine-avid lesion in the left parietal bone along the postoperative margin. (c) CT and fused SPECT/CT images showing focal iodine uptake in residual thyroid tissue in the neck.

Musculoskeletal Imaging

SPECT/CT enhances the identification and description of anomalies found on planar bone scans. It can assist in identifying diseases like bone metastases and differentiating regions of aberrant osteoblastic activity.

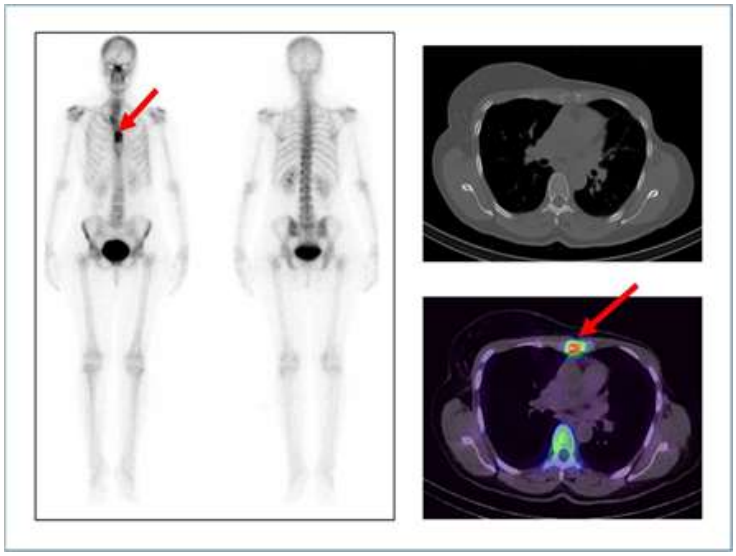


Figure 5. Anterior and posterior whole-body bone scintigraphy demonstrating abnormal radiotracer uptake in the sternum (left). CT and fused SPECT/CT images of the chest (right) demonstrate focal tracer uptake corresponding to an osteolytic lesion in the sternum (arrow), indicating an iodine-avid skeletal lesion.

Neurology

SPECT/CT can enhance the identification and anatomical localization of disorders in the nervous system. For instance, it can help with surgical planning and confirmation by localizing cerebrospinal fluid leaking in radionuclide cisternography.

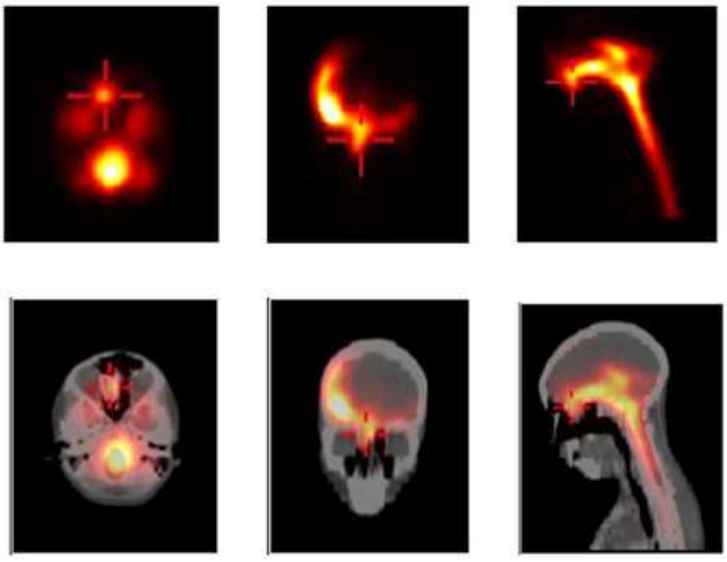


Figure 6. Planar static images (top row) in axial (left), coronal (middle), and sagittal (right) views demonstrate focal radiotracer uptake in the frontal skull region (cross). SPECT/CT images (bottom row) localize the uptake to the right ethmoid bone.

Infection and Inflammation

Current high-sensitivity SPECT/CT systems can aid in the detection and localization of infection, especially in situations like diabetic foot, suspected bone or soft-tissue infection, fever of unclear cause, and vascular graft infection. Tc-99m-labeled white blood cell imaging with SPECT/CT discovered an intra-abdominal abscess in the reported clinical example that had not been found by earlier studies. Anatomical localization, image interpretation, quantitative evaluation, and diagnostic applications in cardiology, cancer, musculoskeletal imaging, neurology, and infection imaging have all been enhanced by technology advancements in SPECT/CT.

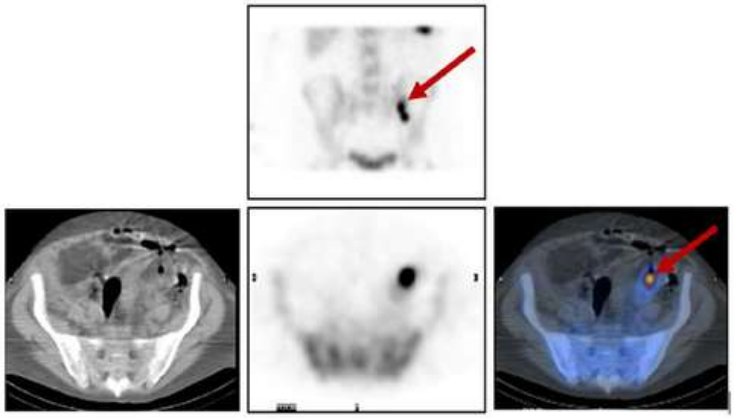


Figure 7. Top row: Planar static image (anterior view). Bottom row: SPECT/CT axial images (CT slice—left; SPECT slice—middle; and fused images—right) that localise the abnormal uptake to an intra-abdominal abscess in the peritoneum.

Conclusion

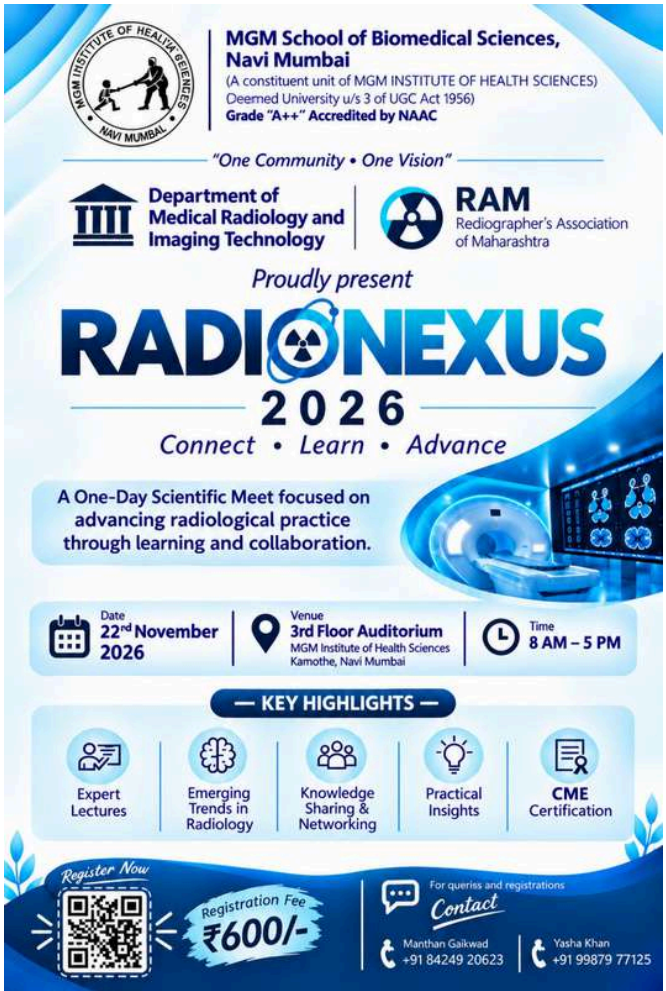
By enhancing picture quality, acquisition efficiency, and quantitative evaluation, recent developments in SPECT and SPECT/CT hardware and software have reinforced their position in diagnostic imaging. In addition to optimized reconstruction techniques that incorporate count statistics and system-specific calibration, future research should concentrate on enhancing quantitative accuracy through improved correction of scatter, attenuation, and spatial-resolution losses. Particularly in cardiac imaging, sophisticated software may further enhance organ segmentation and illness assessment. Automated segmentation, radiomic feature extraction, diagnosis, and treatment outcome prediction could all be improved by combining machine learning and deep learning. All things considered, it is anticipated that further technological advancement will enhance clinical results while promoting patient-centered, economical, and sustainable imaging treatment.

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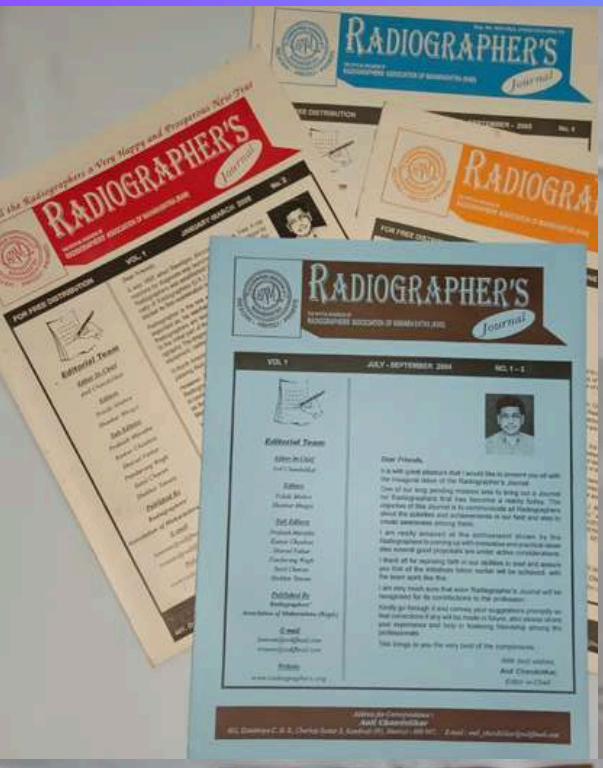


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