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Drugs Used in Radiological Investigations: A Comprehensive Review

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ABSTRACT :

Radiological procedures form an essential part of modern medicine, providing vital diagnostic information. The use of drugs during these procedures ensures clearer images, patient safety, and management of complications. This review discusses the pharmacological agents used in radiological investigations, with a focus on contrast agents, premedication strategies, emergency drugs, and supportive agents. Emphasis is placed on their mechanisms of action, clinical uses, and safety profiles to help practitioners achieve optimal outcomes while minimizing risks.

This review summarizes drugs commonly used in radiological investigations, including diagnostic contrast agents (iodinated contrast media, gadolinium-based contrast agents, ultrasound microbubbles, barium preparations), radiopharmaceuticals (diagnostic and therapeutic), and adjunctive medications used to optimize image quality or manage procedures (antispasmodics, sedatives, analgesics, local anaesthetics, anticoagulants). Pharmacology, indications, administration routes, dosing principles, special-population considerations (pediatrics, pregnancy, renal dysfunction), important adverse effects and emergency management are discussed. Practical recommendations, monitoring and safety measures are provided.

Keywords: Contrast agents; Radiopharmaceuticals; Iodinated contrast; Gadolinium; Ultrasound contrast; Procedural sedation; Interventional radiology; Safety

Introduction

Radiological investigations are essential tools in modern medicine for diagnosing and monitoring diseases. To improve image clarity and accuracy, certain drugs called contrast agents and radiopharmaceuticals are widely used. Contrast agents, such as iodinated compounds for CT and X-ray, gadolinium-based agents for MRI, and microbubble agents for ultrasound, help enhance the visibility of internal organs and blood vessels. Barium sulfate remains a traditional choice for gastrointestinal tract imaging.

Radiopharmaceuticals, including Technetium-99m, Fluorine-18 FDG, and Iodine isotopes, allow functional and molecular imaging through PET and SPECT. Some radioactive drugs like Iodine-131, Lutetium-177, and Yttrium-90 are also used therapeutically, especially in cancer treatment. While these agents greatly improve diagnostic accuracy, they may cause adverse effects such as allergic reactions, kidney injury, or radiation exposure. Therefore, careful selection and monitoring are necessary. This review summarizes the main drugs used in radiological investigations, their uses, safety issues, and future directions.

Drugs used in radiology serve two broad purposes: to generate or enhance diagnostic signal (contrast agents and radiopharmaceuticals) and to facilitate safe, tolerable procedures (sedation, analgesia, antispasmodics, local anaesthesia, periprocedural anticoagulation). Understanding their pharmacology, proper dosing and safety considerations is essential for radiologists, radiographers and clinical teams. This review consolidates contemporary guidance and evidence for clinical practice.

Classification and Overview

Major classes of drugs used in radiological practice:

1. Iodinated contrast media (intravenous and intra-arterial) for CT and angiography.
2. Gadolinium-based contrast agents (GBCAs) for MRI.
3. Ultrasound contrast agents (microbubbles) for CEUS.
4. Enteric contrast (barium and water-soluble agents) for fluoroscopic GI studies.
5. Radiopharmaceuticals for SPECT/PET diagnostics and radionuclide therapies (e.g., 99mTc agents, 18F-FDG, 177Lu, 90Y, 223Ra).
6. Adjunctive medications: antispasmodics (e.g., hyoscine butylbromide, glucagon), sedatives (midazolam, propofol), analgesics (fentanyl), local anaesthetics (lidocaine), anticoagulants and thrombolytics used in interventional radiology.

Iodinated Contrast Media (ICM)

Classification and physicochemical properties:
Iodinated contrast agents are categorized by ionic vs non-ionic and by osmolality (high-, low- and iso-osmolar). Modern clinical practice overwhelmingly uses non-ionic low- or iso-osmolar agents (e.g., iohexol, iopamidol, ioversol, iodixanol). Osmolality affects physiologic responses (flushing, heat, renal hemodynamics) and historically influenced adverse event rates.

Indications and common uses:
• Contrast-enhanced CT (body, angiography, CTA) and fluoroscopic angiography.
Administration, dosing and injection protocols:
• Dosing is determined by study type, patient weight and iodine concentration. Typical IV doses for adult body CT range from 50–150 mL of low-osmolar iodinated contrast (300–370 mg I/mL) administered at 1–6 mL/s depending on the scanner protocol and whether arterial/venous phase imaging is required.

Adverse effects and precautions:
• Immediate hypersensitivity-like (anaphylactoid) reactions—rare but potentially severe and unpredictable. Premedication protocols are reserved for patients with prior moderate–severe contrast reactions.
• Post-contrast acute kidney injury (PC-AKI), previously called contrast-induced nephropathy (CIN): risk increases with baseline renal impairment, intravascular volume depletion and intra-arterial administration. Strategies to minimize risk include judicious use of contrast, IV isotonic hydration for at-risk patients and avoidance of nephrotoxic co-medications when possible.[1,2]

Special considerations:
• Metformin: temporary withholding recommendations vary by guideline and renal function; many contemporary guidance documents reduce restrictions for low-risk exams but recommend individualized plans for eGFR <30 mL/min/1.73 m^2.[2]

Gadolinium-based Contrast Agents (GBCAs)

Types and chelate stability:
GBCAs are classified as linear or macrocyclic and by ionicity. Macrocyclic agents (e.g., gadoterate, gadobutrol, gadoteridol) are more stable chelates and have lower association with gadolinium retention and NSF than some linear agents.

Clinical use and dosing:
• Typical intravenous dosing for MRI is 0.1 mmol/kg for standard contrast-enhanced MRI; specific protocols and doses vary by indication (e.g., dynamic liver MRI, MR angiography may use different dose strategies).

Safety and deposition concerns:
• Nephrogenic systemic fibrosis (NSF) is a rare but serious condition historically linked to less-stable linear GBCAs in patients with severe renal impairment; modern practice preferentially uses group II (lower risk) agents in most settings and applies precautions for advanced CKD.
• Gadolinium retention in brain and other tissues has been demonstrated even in patients with normal renal function after repeated administrations; the clinical consequences remain uncertain, and guideline bodies recommend minimizing unnecessary GBCA use and preferring lower-risk agents when contrast is needed.[3-6]

Ultrasound Contrast Agents (Microbubbles)

Overview:
Intravenous microbubble contrast agents (e.g., perflutren microbubbles, sulfur hexafluoride microbubbles such as SonoVue/Lumason) improve vascular and tissue perfusion assessment in echocardiography and contrast-enhanced ultrasound (CEUS). They are not radiopaque agents but acoustically active gas-filled microbubbles.

Safety and precautions:
• Generally excellent safety profile; however, there have been rare reports of serious cardiopulmonary adverse events—manufacturers and regulatory agencies recommend screening for unstable cardiopulmonary status and ensuring resuscitation capability during administration.[7-9]

Enteric Contrast (Barium and Water-Soluble Agents)

Uses:
Barium sulfate suspensions and water-soluble iodinated agents are used for fluoroscopic GI studies (barium swallow, small bowel follow-through, enema). Barium provides excellent mucosal coating but is contraindicated if perforation is suspected due to risk of barium peritonitis; water-soluble

iodinated agents are used when perforation risk exists.

Complications:

• Aspiration pneumonitis and peritonitis with extravasation are known complications. Avoid barium in suspected bowel perforation and in patients at high risk of aspiration when safer agents exist.[10]

Radiopharmaceuticals: Diagnostic and Therapeutic

Diagnostic radiopharmaceuticals:

• SPECT tracers (commonly 99mTc-labeled agents for bone scan, myocardial perfusion, renal scans) and PET tracers (most commonly 18F-FDG) provide physiological and molecular imaging. Radiochemistry, half-life and biodistribution dictate tracer choice and imaging timing.[11,12]

Therapeutic radiopharmaceuticals:

• Targeted radionuclide therapies such as 177Lu-DOTATATE for somatostatin-receptor–positive neuroendocrine tumours and Y-90 radioembolization for hepatic tumours are in increasing clinical use; they require multidisciplinary care, dosimetry, and specific safety precautions for radiation and marrow toxicity.[3,13]

Adjunctive Drugs Used to Optimize Imaging and Procedures

Antispasmodics:

• Hyoscine butylbromide (Buscopan) and glucagon are commonly used to reduce bowel peristalsis in CT colonography and MR enterography; evidence suggests variable benefit and local practice varies. Contraindications (e.g., glaucoma, prostatic hypertrophy for antimuscarinics; insulinoma for glucagon use) must be considered.[14–16]

Sedation and analgesia:

• Midazolam is a commonly used benzodiazepine for conscious sedation; fentanyl is often paired for analgesia in painful procedures. Dosing must be weight-adjusted with continuous monitoring and personnel trained in airway management.[17]

Local anaesthesia:

• Lidocaine is widely used for local infiltration and local anaesthetic blocks. Maximum recommended doses are approximately 4.5 mg/kg (without epinephrine) and 7 mg/kg (with epinephrine) in adults; always calculate total milligram dose based on concentration and patient weight to avoid systemic local anaesthetic toxicity.[17]

Anticoagulation and antiplatelet management in interventional radiology:

• Periprocedural management of anticoagulants and antiplatelets should follow consensus guidance, balancing thrombosis and bleeding risk. Procedural heparinization dosing during angiography varies by indication; anticoagulation reversal strategies should be available in IR suites.[5]

Adverse Effects, Monitoring and Emergency Preparedness

Immediate hypersensitivity reactions (anaphylaxis):

• Radiology departments must be equipped and trained to manage anaphylaxis. Intramuscular adrenaline (epinephrine) is first-line for anaphylaxis (typical adult IM dose 0.3–0.5 mg of 1 mg/mL [1:1000], repeat as needed). Observation and escalation protocols should be in place.[18]

Contrast extravasation:

• Recognize early; management includes limb elevation, cold packs for iodinated contrast, and surgical input for large-volume extravasation or compartment syndrome risk.

Radiopharmaceutical safety:

• Radiation protection, contamination control and patient instructions for post-therapy radiation safety (e.g., 177Lu, 90Y, 223Ra) are essential; monitor for myelosuppression and organ toxicity per protocol.

Pediatric and Pregnancy Considerations

Pediatrics:

• Dose adjustments (weight-based) are essential for contrast agents, radiopharmaceuticals and sedatives. Protocol-driven sedation/analgesia policies and presence of pediatric-trained staff are recommended.

Pregnancy and lactation:

• Iodinated contrast crosses the placenta; use when benefits outweigh risks and counsel regarding potential fetal thyroid effects (especially in first

trimester). Gadolinium should be used only if essential and with informed consent; breastfeeding may often continue after contrast exposure per guideline advice, but institutional policies vary.[2,3]

Practical Recommendations

1. Use guideline-preferred contrast agents (ACR/ESUR recommendations) and limit exposure to what is clinically necessary.
2. Screen renal function (eGFR) in patients at risk; hydrate and follow local protocols to minimize PC-AKI risk; avoid unnecessary metformin interruption except in high-risk scenarios.
3. Prefer macrocyclic GBCAs and avoid legacy linear chelates in patients with severe renal impairment when feasible.
4. Ensure emergency medications (epinephrine, IV fluids, antihistamines, steroids) and resuscitation-capable staff are available during contrast administration and CEUS when appropriate.
5. For interventional procedures, follow SIR consensus and local IR protocols for anticoagulation, sedation and post-procedure monitoring.[1–5]

Conclusion

Drugs used in radiological investigations encompass a broad array of agents, diagnostic contrast materials, radiopharmaceuticals and adjunctive medications, each with unique pharmacology and safety profiles. Adherence to contemporary guidelines, careful patient selection, weight- and indication-based dosing, and preparedness for adverse events are the pillars of safe and effective imaging practice.

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