(^{99m}Tc)); V09HA03 (technetium antigranulocyte antibody (^{99m}Tc)); V09HA04 (technetium sulesomab (^{99m}Tc)); V09IA01 (technetium antiCEA antibody (^{99m}Tc)); V09IA02 (technetium antimelanoma antibody (^{99m}Tc)); V09IA03 (technetium pentavalent succimer (^{99m}Tc)); V09IA04 (technetium votumumab (^{99m}Tc)); V09IA05 (technetium depreotide (^{99m}Tc)); V09IA06 (technetium arcitumomab (^{99m}Tc)).

ATC Vet — QV09AA01 (technetium exametazime (^{99m}Tc)); QV09AA02 (technetium bicisate (^{99m}Tc)); QV09BA01 (technetium oxidronate (^{99m}Tc)); QV09BA02 (technetium medronate (^{99m}Tc)); QV09BA03 (technetium pyrophosphate (^{99m}Tc)); QV09BA04 (technetium butedronate (^{99m}Tc)); QV09CA01 (technetium pentetate (^{99m}Tc)); QV09CA02 (technetium succimer (^{99m}Tc)); QV09CA03 (technetium mertiatide (^{99m}Tc)); QV09CA04 (technetium gluceptate (^{99m}Tc)); QV09CA05 (technetium gluconate (^{99m}Tc)); QV09DA01 (technetium disofenin (^{99m}Tc)); QV09DA02 (technetium etifenin (^{99m}Tc)); QV09DA03 (technetium lidofenin (^{99m}Tc)); QV09DA04 (technetium mebrofenin (^{99m}Tc)); QV09DA05 (technetium galtifenin (^{99m}Tc)); QV09DB01 (technetium nanocolloid (^{99m}Tc)); QV09DB02 (technetium microcolloid (^{99m}Tc)); QV09DB03 (technetium millimicrospheres (^{99m}Tc)); QV09DB04 (technetium tin colloid (^{99m}Tc)); QV09DB05 (technetium sulfur colloid (^{99m}Tc)); QV09DB06 (technetium rhenium sulfide colloid (^{99m}Tc)); QV09DB07 (technetium phytate (^{99m}Tc)); QV09EA01 (technetium pentetate (^{99m}Tc)); QV09EA02 (technetium technegas (^{99m}Tc)); QV09EA03 (technetium nanocolloid (^{99m}Tc)); QV09EB01 (technetium macrosalb (^{99m}Tc)); QV09EB02 (technetium microspheres (^{99m}Tc)); QV09FX01 (technetium pertechnetate (^{99m}Tc)); QV09GA01 (technetium sestamibi (^{99m}Tc)); QV09GA02 (technetium tetrofosmin (^{99m}Tc)); QV09GA03 (technetium teboroxime (^{99m}Tc)); QV09GA04 (technetium human albumin (^{99m}Tc)); QV09GA05 (technetium furifosmin (^{99m}Tc)); QV09GA06 (technetium stannous agent labelled cells (^{99m}Tc)); QV09GA07 (technetium apcitide (^{99m}Tc)); QV09HA01 (technetium human immunoglobulin (^{99m}Tc)); QV09HA02 (technetium exametazime labelled cells (^{99m}Tc)); QV09HA03 (technetium antigranulocyte antibody (^{99m}Tc)); QV09HA04 (technetium sulesomab (^{99m}Tc)); QV09IA01 (technetium antiCEA antibody (^{99m}Tc)); QV09IA02 (technetium antimelanoma antibody (^{99m}Tc)); QV09IA03 (technetium pentavalent succimer (^{99m}Tc)); QV09IA04 (technetium votumumab (^{99m}Tc)); QV09IA05 (technetium depreotide (^{99m}Tc)); QV09IA06 (technetium arcitumomab (^{99m}Tc)).

HALF-LIFE. 6.02 hours.

Adverse Effects and Precautions

Hypersensitivity reactions have been reported with technetium-99m preparations.

Breast feeding. The American Academy of Pediatrics has stated[1] that temporary cessation of breast feeding is required after exposure to technetium-99m since radioactivity has been reported to be present in breast milk for 15 to 72 hours.

1. American Academy of Pediatrics. The transfer of drugs and other chemicals into human milk. *Pediatrics* 2001; **108:** 776–89. Correction. *ibid.*; 1029. Also available at: http://aappolicy.aappublications.org/cgi/content/full/pediatrics%3b108/3/776 (accessed 01/07/04)

Uses and Administration

Technetium-99m is a daughter of molybdenum-99 (^{99}Mo, half-life 66.2 hours) and because of its short half-life is normally prepared just before use by elution from a sterile generator consisting of molybdenum-99 adsorbed onto alumina in a glass column. Technetium-99m as pertechnetate ($^{99m}TcO_4^-$) is obtained by elution with a sterile solution of sodium chloride 0.9%. Radiopharmaceuticals of technetium-99m are prepared shortly after elution to reduce loss by decay.

Because it has a short half-life and can be given in relatively large doses, and because the energy of its gamma-emission is readily detected, technetium-99m is very widely used, either as the pertechnetate or in the form of various labelled compounds, particles, and colloids for scanning bone and organs such as the brain, heart, kidney, liver, lung, spleen, and thyroid.

Sodium pertechnetate (^{99m}Tc) is used intravenously for angiography and for imaging blood pools, brain, salivary glands, and thyroid gland; the oral route may also be used for brain and thyroid imaging. Topical application to the eye is used for studying nasolachrymal drainage and the intraurethral route for imaging the urinary tract. Potassium perchlorate may be given before the pertechnetate to prevent uptake in the thyroid or choroid plexus and thus enhance visualisation in other organs.

Macroaggregates of human albumin labelled with technetium-99m [macrosalb (^{99m}Tc)] are used in lung scanning for the detection of abnormal lung perfusion patterns; after intravenous injection of a suspension of suitable particle size, usually 10 to 100 micrometres, the particles become trapped in the lung capillaries enabling ischaemic areas to be defined. Labelled albumin microspheres of particle size 10 to 50 micrometres are used similarly. Labelled macroaggregates of albumin have also been used in venography for the detection of deep-vein thrombosis of the legs. Technetium (^{99m}Tc) apcitide is a labelled peptide that binds to the glycoprotein IIb/IIIa receptor of activated platelets, and is also used for imaging of deep-vein thrombosis.

When technetium-99m bound to human serum albumin is given intravenously it becomes evenly distributed in the circulation and highly vascular organs or pools of blood may be readily located. Such a preparation is used in the examination of the heart.

Technetium-99m in the form of a colloid, such as albumin, sulfur, antimony sulfide, or tin, is used intravenously for the examination of the liver, spleen, and bone marrow. Sulfur colloid (^{99m}Tc) may be given orally for oesophageal and gastrointestinal imaging. Albumin colloid (^{99m}Tc) may be given subcutaneously for scanning of the lymphatic system. Colloidal rhenium sulfide (^{99m}Tc) has been used for sentinel lymph node detection in patients with malignancies.

Technetium-99m complexes of iminodiacetic acid derivatives, such as disofenin, etifenin, lidofenin, and mebrofenin are used intravenously in the investigation of hepatic function and in the imaging of the hepatobiliary system.

Agents used intravenously in both brain and renal imaging are technetium-99m-labelled gluconate, gluceptate, and pentetate. Other technetium-99m-labelled compounds are used in brain and kidney scanning; for instance, labelled bicisate and exametazime have been used in brain imaging and betiatide, mertiatide, and succimer have been used in kidney studies. The pentetate is also given by inhalation for lung ventilation imaging, and orally for studies of gastro-oesophageal reflux and gastric emptying.

For bone scanning various labelled phosphate compounds may be used and include medronate, oxidronate, and pyrophosphate, all given intravenously. Technetium-99m as the pyrophosphate is also used in cardiac scintigraphy. Technetium-99m as the medronate and pyrophosphate are also used to label red blood cells for use in blood pool scintigraphy, cardiac scintigraphy, detection of gastrointestinal bleeding, and testicular scintigraphy.

Compounds used intravenously in cardiac imaging include technetium-99m-labelled sestamibi, teboroxime, and tetrofosmin. Technetium (^{99m}Tc) sestamibi is also used for breast imaging.

Technetium-99m-labelled leucocytes (prepared using exametazime) are used for localisation of sites of inflammation or infection.

Monoclonal antibodies labelled with technetium-99m, such as arcitumomab and nofetumomab merpentan, are used for the detection and localisation of malignant neoplasms. Labelled sulesomab is used in the detection of osteomyelitis. Labelled fanolesomab was used in the diagnosis of appendicitis but was withdrawn from the market due to severe adverse effects. Technetium (^{99m}Tc) depreotide is a labelled peptide used intravenously for imaging of pulmonary malignancy.

Many other technetium-99m-labelled compounds have been prepared and used in different clinical studies for the examination of different organs or systems. Use with other radionuclides includes subtraction scanning with thallium-201 to detect parathyroid tumours.

Preparations

Ph. Eur.: Sodium Pertechnetate(Tc) Injection (Fission); Sodium Pertechnetate(Tc) Injection (Non-fission); Technetium(Tc) Bicisate Injection; Technetium(Tc) Colloidal Rhenium Sulphide Injection; Technetium(Tc) Colloidal Sulphur Injection; Technetium(Tc) Colloidal Tin Injection; Technetium(Tc) Etifenin Injection; Technetium(Tc) Exametazime Injection; Technetium(Tc) Gluconate Injection; Technetium(Tc) Human Albumin Injection; Technetium(Tc) Macrosalb Injection; Technetium(Tc) Medronate Injection; Technetium(Tc) Mertiatide Injection; Technetium(Tc) Microspheres Injection; Technetium(Tc) Pentetate Injection; Technetium(Tc) Sestamibi Injection; Technetium(Tc) Succimer Injection; Technetium(Tc) Tin Pyrophosphate Injection;
USP 31: Sodium Pertechnetate Tc 99m Injection; Technetium Tc Fanolesomab Injection; Technetium Tc 99m (Pyro- and trimeta-) Phosphates Injection; Technetium Tc 99m Albumin Aggregated Injection; Technetium Tc 99m Albumin Colloid Injection; Technetium Tc 99m Albumin Injection; Technetium Tc 99m Apcitide Injection; Technetium Tc 99m Arcitumomab Injection; Technetium Tc 99m Bicisate Injection; Technetium Tc 99m Depreotide Injection; Technetium Tc 99m Disofenin Injection; Technetium Tc 99m Etidronate Injection; Technetium Tc 99m Exametazime Injection; Technetium Tc 99m Gluceptate Injection; Technetium Tc 99m Lidofenin Injection; Technetium Tc 99m Mebrofenin Injection; Technetium Tc 99m Medronate Injection; Technetium Tc 99m Mertiatide Injection; Technetium Tc 99m Nofetumomab Merpentan Injection; Technetium Tc 99m Oxidronate Injection; Technetium Tc 99m Pentetate Injection; Technetium Tc 99m Pyrophosphate Injection; Technetium Tc 99m Red Blood Cells Injection; Technetium Tc 99m Sestamibi Injection; Technetium Tc 99m Succimer Injection; Technetium Tc 99m Sulfur Colloid Injection; Technetium Tc 99m Tetrofosmin Injection.

Proprietary Preparations (details are given in Part 3)
Austral.: Cardiolite; Ceretec; Myoview; Neurolite; ***Austria:*** Cardiolite; Ceretec; Myoview; TechneScan HDP; TechneScan LyoMAA; TechneScan MAG3; ***Belg.:*** Cardiolite†; Neurolite†; ***Cz.:*** 6-MDP, 8-MDP; Amerscan DMSA†; Amerscan Hepatate; Amerscan Medronate; Amerscan Pentetate†; Amerscan Pulmonate†; Amerscan Stannous; Amertec†; Anti-Granulocyte BW†; Brain-Spect; Cardio-Spect; Cardiolite; CEA-Scan†; Ceretec; DTPA; Hibida; HM-PAO Kit; Leuco-Scint; LeukoScan; Lymphoscint†; Macro-Albumon; Macrotec; Mag 3; Myoview; Nano-Albumon; Nanocoll; Neospect; Neurolite; Neuroscan; Osteocis†; Pulmocis; Rotop Mag-3†; Scintimun; Senti-Scint; TechneScan DMSA; TechneScan DTPA; TechneScan HDP; TechneScan HIG; TechneScan HSA; TechneScan Lyomaa; TechneScan MAG3; TechneScan PYP; TechneScan Q12†; Trimetyl-HIDA; Ultra Technekow FM; UltraTag RBC; ***Fr.:*** Cardiolite†; Myoview; Neurolite†; ***Irl.:*** Cardiolite†; ***Ital.:*** Cardiolite; CEA-Scan; Ceretec; LeukoScan; Myoview; Neospect; Neurolite; TechneScan MAG3; ***Neth.:*** Amerscan DMSA†; Amerscan Hepatate; Amerscan Medronate; Amerscan Pentetate†; Amerscan Stannous; Bridatec; Cardiolite; Ceretec; Choledíam; DraxImage MAA; DraxImage MDP; Drytec; Elumatic; LeukoScan; Maasol; Myoview; NeoSpect; Neurolite; Osteocis; Osteosol†; Phytacis; Pulmocis; Pulmotec; Teceos; TechneScan DMSA; TechneScan DTPA; TechneScan HDP; TechneScan HSA; TechneScan LyoMAA; TechneScan MAG3; TechneScan PYP; Ultra TechneKow; UltraTag; Venticoll; ***Port.:*** Angiocis; Bridatec; Cardiolite; Ceretec; Elumatic; LeukoScan; Macrotec; Mertioscan; Myoview; Nanocoll; NeoSpect; Neurolite; Osteocis; Pentacis; Phytacis; Pulmotec; Renocis; TechneScan DTPA; TechneScan HDP; TechneScan MAG3; Ultra TechneKow FM; ***Spain:*** Cardiolite; CEA-Scan; Ceretec; Drytec; Macrotec; Myoview; Neospect; Neurolite; TechneScan HDP; TechneScan Lyomaa; TechneScan MAG3; ***UK:*** Amerscan DMSA; Amerscan Hepatate; Amerscan Medronate; Amerscan Pentetate; Amerscan Pulmonate; Amerscan Stannous; Amertec; Angiocis; Cardiolite; CEA-Scan; Ceretec; Cholecis; Medrocis†; Myoview; Nanocoll; Osteocis; Pentacis; Pulmocis; Renocis; ***USA:*** AcuTect; Cardiolite; CEA-Scan; Choletec; Miraluma; NeoTect; NeutroSpec†; TechneScan HDP.

Thallium-201

Talio 201.
CAS — 15064-65-0.
ATC — V09GX01 (thallium chloride (^{201}Tl)).
ATC Vet — QV09GX01 (thallium chloride (^{201}Tl)).

HALF-LIFE. 73.1 hours.

Profile

Thallium-201, in the form of thallous chloride (^{201}Tl), is given by intravenous injection for scanning the myocardium in the investigation of acute myocardial infarction. It is also used for myocardial perfusion imaging in cardiac stress testing of patients with ischaemic heart disease. Adenosine (see Ischaemic Heart Disease, p.1203), dipyridamole (see Myocardial Imaging, p.1268), or dobutamine (see Diagnosis and Testing, p.1272) may be used to induce pharmacological stress in those patients unable to tolerate exercise.

Other uses include muscle perfusion scintigraphy in peripheral vascular disorders, visualisation of brain and thyroid tumours and metastases, and the localisation of parathyroid adenomas and hyperplasia by thallium-201 and technetium-99m subtraction scanning.

Preparations

Ph. Eur.: Thallous(Tl) Chloride Injection;
USP 31: Thallous Chloride Tl 201 Injection.

Proprietary Preparations (details are given in Part 3)
Austria: DRN 8103.

Tritium

Hydrogen-3; Tritio.
CAS — 10028-17-8.

HALF-LIFE. 12.3 years.

Profile

Tritium, in the form of tritiated water, has been used to determine the total body water by a dilution technique.

Preparations

Ph. Eur.: Tritiated(H) Water Injection.

Xenon-127

Xenón 127.
CAS — 13994-19-9.
ATC — V09EX02 (xenon gas (^{127}Xe)).
ATC Vet — QV09EX02 (xenon gas (^{127}Xe)).

HALF-LIFE. 36.41 days.

Profile

Xenon-127 has similar physical properties to those of xenon-133 (see below) and is also used by inhalation for pulmonary function studies and lung imaging.

Preparations

USP 31: Xenon Xe 127.

Xenon-133

Xenón 133.
CAS — 14932-42-4.
ATC — V09EX03 (xenon gas (^{133}Xe)).
ATC Vet — QV09EX03 (xenon gas (^{133}Xe)).

HALF-LIFE. 5.25 days.

Profile

Xenon-133 is an inert gas with relatively low solubility in plasma. In the gaseous form, it is mixed with air or oxygen in a bag or in a closed or open circuit spirometer. When the gas is stopped, xenon-133 is excreted promptly and completely through the lungs. It is used by inhalation in pulmonary function studies and lung imaging as well as in cerebral blood flow studies. It has also been used for these purposes in the form of an injection in sodium chloride 0.9%.

Preparations

Ph. Eur.: Xenon(Xe) Injection;
USP 31: Xenon Xe 133; Xenon Xe 133 Injection.