

## Isotope scan in surgical diseases: Part 5

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*In this concluding issue of the series on the use of radioisotopes in surgery, the authors present a few miscellaneous applications of radio-nuclides in bone and other minor organ systems.*

### Salivary scintigraphy

As mentioned in the previous issue,  $^{99m}\text{TcO}_4^-$  (pertechnetate ion) is distributed like  $\text{Cl}^-$  and is concentrated in the salivary glands. Therefore sodium pertechnetate ( $\text{Na}^{99m}\text{TcO}_4$ ) is used to ; (a) scan the salivary glands, especially the parotids; and (b) assess salivary gland function.

**Salivary tumours:** All salivary tumours produce a 'cold' spot on  $^{99m}\text{Tc}$  (technetium) scan except adenolymphoma (Warthin's tumour), which is a form of monomorphic adenoma. The latter takes up more isotope than the rest of the gland to give a 'hot' spot on scan, so that a definite pre-operative diagnosis can be made without biopsy.

**Xerostomia:** Dry mouth (xerostomia) occurs in; (a) Sjogren's syndrome (keratoconjunctivitis sicca, xerostomia and rheumatoid arthritis / SLE / scleroderma); (b) sicca syndrome (first 2 components of Sjogren's syndrome); (c) Mikulicz syndrome (leukaemic infiltration) or disease (Sjogren's variant); and (d) post-radiation. In these conditions  $^{99m}\text{Tc}$  is used to quantify salivary gland function. Sequential salivary scintigraphy with  $^{99m}\text{Tc}$  pertechnetate confirms lack of salivary secretion and xerostomia.

### Meckel's diverticulum scan

Approximately half of the patients with Meckel's diverticulum (MD) have ectopic gastric mucosa. If the quantum of gastric mucosa is  $> 2 \text{ cm}^3$  (as in less than half of symptomatic patients), it can be demonstrated by  $^{99m}\text{Tc}$  pertechnetate scan. The ectopic gastric mucosa traps  $^{99m}\text{Tc}$  just like it does  $\text{Cl}^-$ . In acute situations (Meckel's perforation, haemorrhage, diverticulitis), 30-100  $\mu\text{Ci}$  of  $^{99m}\text{Tc}$  IV may localise the gastric mucosa in 90% of cases. The uptake can be increased by administering pentagastrin  $0.6 \mu\text{g kg}^{-1} \text{ SC}$ . Administration of potassium perchlorate prior to injection of technetium reduces uptake of the latter by the ectopic mucosa by virtue of competitive inhibition.  $^{99m}\text{Tc}$  scanning may thus be a promising diagnostic aid for MD, but instances of false-positive and false-negative results have been reported.

### Carotid body scan

Carotid body tumour (CBT) in the neck is the most common chemodectoma (nonchromaffin paraganglioma) among those encountered from the base of skull to the thorax. It is situated in the arterial adventitia (tunica media is hardly ever involved) at the carotid bifurcation (causing their separation), and is fed by the external carotid artery. The differential diagnosis includes; (a) carotid aneurysm; (b) branchial cyst; (c) neurofibroma; and (d) metastatic node.

**$^{99m}\text{Tc}$  pertechnetate scan:** Peters et al described CBT scanning in 1979. It involves perfusion of  $^{99m}\text{Tc}$  pertechnetate, accompanied by dynamic angioscanning, that depicts blood flow through the tumour. It is a useful screening procedure to differentiate it from the other lesions

mentioned above, and is usually performed prior to angiography. The latter and spiral CT are the most important diagnostic modalities.

## Bone scan

Radio-nuclide skeletal scan is usually done to; (a) diagnose specific diseases of bone and joints; and (b) elucidate the skeletal manifestations of disease elsewhere.

### Isotopes

**Technetium:**  $^{99m}\text{Tc}$ -{etidronate, methylene-diphosphonate(MDP), pyrophosphate(PYP)} are all stannous (tin) chelates of  $^{99m}\text{Tc}$  and the corresponding phosphorus-bearing compound (table 1). The first two are diphosphonates and the last is a linear polyphosphate. The first is not hydrolysed by enzymes, unlike polyphosphates. All have high affinity for  $\text{Ca}^{2+}$  and are highly specific bone-seeking compounds, selectively localising in bone with kinetics similar to  $\text{PO}_4^{3-}$ .  $^{99m}\text{Tc}$ -pertechnetate ion also localises in joints.

**Miscellaneous:**  $^{87m}\text{Sr}$ (strontium) and  $^{18}\text{F}$ (fluorine) have been used for detecting skeletal metastases from breast cancer and  $^{131}\text{I}$ (iodine) for detecting same from thyroid cancer.  $^{87m}\text{Sr}$  ( $T_{1/2}$ =2.8 hours) is suitable for clinical scanning. The importance of  $^{85}, ^{89}, ^{90}\text{Sr}$  ( $T_{1/2}$ =65 days, 51 days and 28 years, respectively) lies in bone accumulation and cumulative toxicity following nuclear fall-out.

**Specificity:** Any process associated with increased bone metabolism, vascularity, osteogenesis or high bone turnover, increases tracer accumulation. Therefore, except multiple myeloma, all neoplastic {benign, malignant (primary or secondary)}, traumatised and inflamed areas (osteomyelitis, arthritis, infarction, Paget's disease) non-specifically take up increased quantities of the tracer and appear as 'hot' spots. This lack of specificity of bone scan makes it essential to correlate the same with x-ray images.

**Sensitivity:** Scan is highly sensitive, being able to detect bone changes (except multiple myeloma) much before they are visible in x-ray. The calcium content of bone must be altered by about 50% before a lesion is apparent on x-ray. Thus the latter is highly insensitive in detecting early metastases to the bone.

### Skeletal manifestations

**Bone metastases:** Radio-nuclide scanning is particularly useful in detecting metastases from carcinoma of prostate, breast, lung, kidney, stomach and thyroid to the bones. However, excretion of isotope in the urinary bladder should not be confused with a 'hot' spot of a secondary deposit.

- Scanning frequently diagnoses skeletal metastases at the time of initial diagnosis of the primary itself.
- The extent of metastases documented by scan frequently exceeds the involvement suggested by symptoms.
- Scanning often diagnoses metastases when x-rays are normal or detects more deposits than by x-rays.

These facts enable selection of the appropriate treatment at an early stage and also guide the surgeon to the optimum site to take a biopsy.

**Thyroid cancer:** The sites of metastases, total body scan with  $^{131}\text{I}$ , skeletal scan with  $^{99m}\text{Tc}$ -PYP and the therapeutic aspects have been detailed in the previous issue.

**Breast cancer:** A lot of isotope studies ( $^{87m}\text{Sr}$ ,  $^{18}\text{F}$ ,  $^{99m}\text{Tc}$ ) of bone metastases from breast cancer have been conducted and they have been correlated with clinical and x-ray findings.

- The risk of occult bone disease has been correlated with clinical bone disease, based on scan findings.
- $^{87m}\text{Sr}$  studies have shown that 10% of women with otherwise operable (early) breast cancer have occult bone disease (i.e. not detected by x-rays and not producing skeletal symptoms) at the time of first diagnosis.

- ❑ A significant correlation has been found between positive bone scans and the presence of > 6 involved axillary nodes.
- ❑ Superiority of scan over x-ray notwithstanding, the latter should be done when scan is positive, to avoid erroneous interpretation due to benign disease.
- ❑ The accuracy of <sup>99m</sup>Tc-PYP scan is highest (99%) and twice that of 18F scan, and the latter is twice as accurate as x-ray in detecting bone metastases.

**Multiple myeloma:** It is the only malignancy in which scan is less sensitive than x-ray. The multiple lytic myeloma lesions are missed by the scanning isotopes because there are very few reactive cells surrounding the lesions which can take up the isotope.

**Osteomyelitis:** This is not apparent in x-ray before 3 weeks after onset. Bone scan is very useful in detecting early osteomyelitis (OM), several weeks before x-ray.

**MPUO:** The sensitivity of tracer accumulation in areas of increased bone metabolism (Paget's disease, OM, trauma, arthritis etc) has made bone scanning a useful procedure in cases of musculoskeletal pain of uncertain origin (MPUO).

### **Scanning in osteoporosis**

**Osteoporosis:** Whether senile, post-menopausal or steroid-induced, this is characterised by; (a) generalised reduction in bone mineral density and content (BMD, BMC); (b) increased incidence of 'fragility fractures' (spinal compression, femoral neck, Colles etc); and (c) non-specific features (reduction in height, skeletal pain ).

**Diagnosis:** The investigations are; (1) quantitative computed tomography (100-300 m rads of exposure); (2) bone densitometry. This is the best method for diagnosing osteoporosis, assessing the risk of osteoporotic fractures and evaluating the response to treatment by the exact gain in BMD. Densitometry can be performed by; (a) ultrasound (non-ionising, safe, inexpensive but with low precision and reproducibility); and (b) dual photon absorptiometry (x-ray or <sup>153</sup>Gadolinium (Gd)  $\gamma$  emission).

**Gadolinium:** Gd is a rare element (AN=64, AW=157.25) whose chelated form is used as a paramagnetic contrast in MRI scan (see "Brain scan"). <sup>153</sup>Gd is an artificial isotope ( $T_{1/2} = 241.6$  days), it decays by electron capture and emission of 70, 97 and 103 keV  $\gamma$  rays, and is used in dual photon absorptiometry (DPA). Absorptiometry is the measurement of the degree to which the radiation is completely dissipated within a tissue, and DPA is the measurement of the BMC in the axial skeleton (especially lumbar spine), by comparing the transmission through both soft tissue and bone of 2 separate photoelectric energy peaks emitted by <sup>153</sup>Gd.

**Principle of DPA:** It requires (a) a dual energy-producing photon source (<sup>153</sup>Gd or dual-energy x-ray machine); (b) photon detector; and (c) interface with a computer system for imaging the scanned area and for calculating the BMC and BMD. After photon beams of 2 different energies are passed through the site their differential absorption by bone and soft tissue is analysed. From the amount of reduction in the intensity of the dual-energy photon rays, one can calculate the amount of soft tissue, fat and BMD without the need to have constant body part thickness. This allows determination of whole body composition and BMC of multiple skeletal sites.

**Application:** Primary fracture sites may be evaluated by DPA. The BMD is determined a 2-dimensional (A-P) image of; (a) the lumbar spine, (L1-4 including the discs, most commonly); or (b) other sites (femoral neck, forearm, whole body and skeletal segments). The time interval of BMD measurements are variable; (1) post-menopausal osteoporosis: 1-2 year intervals; (2) steroid-induced osteoporosis: ½-1 year intervals, because of rapidity of bone loss; and (3) senile osteoporosis (>65 years): single measurement of the femoral neck.

**Results:** The results of DPA are quantitative and are expressed as; (1) *T-scores* (patient's BMD compared to the peak bone mass of the normal young adult reference population, using standard deviation; table 2); and (2) *Z-scores* (patient's BMD compared to mean BMD of

people of same age; table 3). A Z-score within one standard deviation of normal indicates no bone loss beyond that anticipated for the patient's chronological age.

**BMD in IBD:** Patients with inflammatory bowel disease (IBD) are at risk of developing metabolic bone disease. Using DPA it has been found that Z-scores are significantly lower in patients with Crohn's disease than in those with ulcerative colitis (UC) and healthy subjects. The BMD are similar in the latter two groups. Use of corticosteroids is the single most important factor responsible for the reduction in BMD in Crohn's disease. Body mass index and sex are also significant predictor variables of BMD in both Crohn's disease and UC. Disease localisation and small bowel resection have no influence on BMD in Crohn's disease.<sup>1</sup>

**<sup>153</sup>Gd vs. x-ray:** Both are examples of DPA because both use ionising photon radiation ( $\gamma$  or x-rays). Dual energy x-ray absorptiometry (DEXA) is more expensive than <sup>153</sup>Gd DPA. However, DEXA is considered the gold standard for the diagnosis of osteoporosis. It is more precise (detects minute BMD changes), versatile and reproducible (making it useful in assessing therapeutic response). It gives; (a) far better image resolution (due to much better photon flux); (b) faster scan (5 minutes instead of 20 for lumbar spine; due to high beam intensity); and (c) low radiation (1-3 m rad / sec). These characteristics make it very safe.

## Venous scan

This pertains to deep vein thrombosis (DVT). The investigations include; (a) invasive tests {contrast phlebography (ascending, exercise, cine and intra-osseous phlebography; ortho-/retrograde catheterisation and direct injection)}; and (b) non-invasive tests (Doppler sonography, impedance plethysmography, and <sup>125</sup>I-fibrinogen scan). The sensitivity and reliability of the last two combined are equal to that of contrast phlebography.

### **<sup>99m</sup>Tc-MAA radio-nuclide phlebography**

Labelled macro-aggregated albumin (MAA) is injected into a distal lower limb vein as a preliminary screening examination prior to lung scan for pulmonary embolism (PE). An obstructing thrombus is indicated in the gamma image of the proximal deep veins. It is not as accurate as contrast phlebography.

### **<sup>125</sup>I-fibrinogen scan**

**Principle:** Once injected IV, <sup>125</sup>I ( $T_{1/2}=60$  days; only  $\gamma$  emission) is progressively incorporated into a developing thrombus. Daily measurements of  $\gamma$  emissions over selected sites on the lower limb, using a hand-held  $\gamma$  detector and rate meter, indicate; (a) asymmetry in the  $\gamma$  emissions of the two limbs; or (b) rising  $\gamma$  emission at one point compared to the praecordial count.

**Sensitivity:** This test is extremely sensitive in detecting a new lower limb thrombus, reveals many clinically non-apparent thrombi and shows excellent correlation with contrast phlebography and is also non-invasive, unlike the latter. However, it is only applicable to thrombi below the mid-thigh level. Its low accuracy in detecting iliofemoral thrombi is due to background radioactivity in the urinary bladder and also due to relatively poor penetration of <sup>125</sup>I. Thus, in situ iliofemoral thrombus (rather than one that has propagated from the calf) may remain undetected.

**Evolution of DVT:** <sup>125</sup>I-fibrinogen testing has revealed that 50% of calf DVT actually commence in the OT, and the remainder develop in the first few post-operative days. Prospective studies with the isotope have shown that only 20% of calf DVT propagate variably along the axial leg-thigh veins, cause fatal PE or, more commonly, permanent vein damage, and thus require treatment. The rest 80% either lyse spontaneously or remain localised in the soleal venous sinuses.

## Mediastinal scan

Radio-nuclide mediastinal scanning is done for 3 purposes; (a) to evaluate the cause of mediastinal masses (e.g. intra-thoracic thyroid); (b) to localise and study mediastinal organs (e.g. thymus, intra-thoracic parathyroid, heterotopic marrow); and (c) for diagnostic work-up of PUO and malignancies (Hodgkin's disease, malignant lymphoma, lung cancer).

**Thyroid:**  $^{131}\text{I}$  scanning for mediastinal thyroid is important because; (a) it may be the only functioning thyroid tissue present; (b) its continuity (or otherwise) with the cervical thyroid may be demonstrated; (c) it may be non-functioning thyroid tissue in a mediastinal mass; and (d) the surgical technique for its removal may be decided (see "Thyroid scan" in previous issue).

**Parathyroid:**  $^{75}\text{Se}$ -methionine scan has been used for mediastinal parathyroid and other mediastinal masses (e.g. thymus) and also to localise intra-thymic parathyroid. The role of selective venous sampling and radioimmunoassay of parathormone have been elaborated under "Parathyroid scan" in a previous issue.

**Heterotopic marrow:** *Haemolytic anaemia* causes compensatory normoblastic marrow hyperplasia with the extension of red marrow in the mid-shafts of long bones and occasionally with extramedullary haematopoiesis, at times leading to the formation of radiographically visible paravertebral masses. *Some tumours* can also stimulate intra-thoracic extramedullary haematopoiesis. Techniques have been reported for radioisotope scanning of heterotopic marrow in the mediastinum though they are not in routine clinical use.

**Malignancy:**  $^{67}\text{Ga}$  citrate is a soft tissue-specific gamma emitting radio-nuclide (see "Liver scan"; 2<sup>nd</sup> issue). Following IV injection it demonstrates a special affinity for inflammatory and neoplastic tissues and is thus invaluable in detecting these pathologies in the lungs and mediastinal lymph nodes.  $^{67}\text{Ga}$  scan is used in; (a) Hodgkin's disease and malignant lymphoma (clinical staging and follow-up); (b) lung cancer, where it is very sensitive and specific; and (c) 'metastatic work-up' of malignancies for most sites.

**Myasthenia gravis:** Acetyl choline (ACh) receptor antibodies are found in the serum of 90% of patients with myasthenia gravis (MG), with a concomitant reduction in the number of functioning receptors. The antibodies are measured by radioimmunoassay with  $^{125}\text{I}$ -labelled  $\alpha$ -bungarotoxin. This snake venom\* binds specifically to the ACh receptor antigen in muscle preparations, usually obtained from human donors. When serum from the patient is added to the labelled antigen preparation, ACh receptor antibodies, if present in the serum, bind to the receptor antigens, but at a different locus from the  $^{125}\text{I}$ -labelled  $\alpha$ -bungarotoxin. The addition of anti-human globulin antibody results in precipitation of the  $^{125}\text{I}$ - $\alpha$ -bungarotoxin-receptor antigen-receptor antibody complex. The amount of ACh receptor antibody can then be calculated as a function of the radioactivity in the precipitant. There is a tendency for the ACh receptor antibodies to decrease following thymectomy.

*[\*Use of labelled snake venom is not a unique concept.  $^{131}\text{I}$ -labelled snake venom has been used by Snyder in experimental animals to show that uptake of venom is reduced by 2/3 after the application of a tourniquet.]*

## Isotopes in GIT

**Gastro-oesophageal reflux:**  $^{99\text{m}}\text{Tc}$  dissolved in water is swallowed by the patient. Gamma images are taken to detect gastro-oesophageal reflux (GER) while abdominal pressure is increased stepwise to 35 mm Hg. It is simple and non-invasive (unlike manometry or pH recording which require endoscopy or intubation), but requires costly equipment and radioisotope for a relatively straightforward clinical situation. It is specially suitable for children. One minute of study with  $0.74 \times 10^7 \text{ Bq } ^{99\text{m}}\text{Tc}$  delivers a radiation dose equal to minute of fluoroscopy.<sup>2</sup>

**H. pylori:** This bacteria, known for its association with dyspepsia, gastritis, peptic ulcer, gastric cancer, MALT (Mucosa-Associated Lymphoid Tissue) lymphoma etc., produces

urease in large amounts which converts urea into carbon dioxide and ammonia. Thus:  $\text{CO}(\text{NH}_2)_2 + \text{H}_2\text{O} = \text{CO}_2 + 2\text{NH}_3$ . The  $\text{CO}_2$  is absorbed in the body and excreted via the lungs. This is the basis of *urea breath test* for *H. pylori* in the stomach. A solution of  $^{13}$  or  $^{14}\text{C}$ -urea is given orally. In *H. pylori* infected patients the labelled  $\text{CO}_2$  appears in the breath within 20 minutes and remains for > 100 minutes (normally  $^{14}\text{CO}_2$  does not appear in the breath). Studies have shown that this is a powerful predictor of the presence of underlying ulcer disease in a dyspeptic patient, especially in smokers, and that a negative test is a powerful predictor of absence of same. It also indicates that a negative upper GI investigation does not preclude the subsequent presentation with ulcer disease.<sup>3</sup>

**GI bleeding:**  $^{99\text{m}}\text{Tc}$ -labelled RBC is used in scintigraphy to detect gastrointestinal (GI) bleeding. In the technique called sequential subtraction scintigraphy (SSS), following IV administration of  $^{99\text{m}}\text{Tc}$ -RBC, 5-minute interval images are subtracted from each other using a digital camera. Compared to conventional non-subtraction scintigraphy (CNS) this technique detects bleeding site and calculates bleeding rate earlier. The minimum detectable rate by SSS is  $0.05 \text{ ml min.}^{-1}$  and the minimum detectable activity volume within 10 minutes is 0.5 ml (vs. 3 ml by CNS).<sup>4</sup>

**Malabsorption:** Vitamin  $\text{B}_{12}$  deficiency is almost always due to malabsorption and its pathogenesis can be delineated by the Schilling test.  $^{57}$  or  $^{58}\text{Co}$ - $\text{B}_{12}$  is given orally followed shortly thereafter by IM injection of unlabelled  $\text{B}_{12}$ . The next 24-hour urine is measured for its radioactive content (1<sup>st</sup> stage Schilling test). The whole procedure is repeated with labelled  $\text{B}_{12}$  bound to intrinsic factor (IF), the other steps remaining the same (2<sup>nd</sup> stage Schilling). In pernicious anaemia (or some other type of IF deficiency) urinary radioactivity is low in the 1<sup>st</sup> stage but normal in the 2<sup>nd</sup>. If the latter is also abnormal it indicates; (a) bacterial overgrowth; (b) ileal resection or disease; or (c) even an ileal absorptive defect secondary to  $\text{B}_{12}$  deficiency.

**Biliary reflux:** In order to measure the reflux of bile into the stomach or oesophagus, especially after gastric surgery,  $^{99\text{m}}\text{Tc}$ -labelled HIDA (synthetic bile salt derivative) is injected IV as the patient lies prone under a 90 cm field of view gamma camera for 90 minutes. The data from the gamma camera are fed into a computer that uses correction formulae to account for the degradation of the isotope and radioactive scatter from without and within the area of interest. A typical computer printout of the area under the camera, 30 minutes after the injection, in a case of post-Billroth II gastrectomy with extensive bile reflux into the gastric remnant will show a dense area of radioactivity between the oesophageal and small bowel areas of radioactivity. The other areas that are marked in the printout are the lungs (reference area), liver and gallbladder, urinary bladder areas. Since bile reflux is intermittent, a negative test during the course of 90 minutes does not rule out nocturnal biliary reflux.<sup>5</sup>

**Miscellaneous:** Gastric emptying studies are useful in assessing the results of surgery on the gastric outlet. A gamma camera can effectively follow the emptying of a semi-solid meal of  $^{99\text{m}}\text{Tc}$ -labelled scrambled eggs. Salivary scintigraphy to assess *salivary gland function* and scanning for *Meckel's diverticulum* have been described earlier. Many authors have described radioisotope scintigraphic techniques for demonstrating; (a) Barrett's oesophagus; (b) inflamed oesophageal mucosa resulting from GER; and (c) oesophageal motor dysfunction (by radio-nuclide transit techniques).<sup>2</sup>

## Scanning in PUO and malignancy

A deep-seated abscess or an occult malignancy may be the cause of pyrexia of unknown origin (PUO). Tables 4 and 5 summarise some radio-nuclide scans for fever and malignancy. They have been elaborated throughout the series. *Liver/spleen scan* is the single most useful diagnostic test. A mildly enlarged non-palpable spleen or a clinically occult metastasis in the liver may be identified by scan. *Bone scan* can detect metastases before they are

radiologically evident, with the exception of multiple myeloma. Ten percent of women with breast cancer, who are eligible for potentially 'curative' mastectomy by all other criteria, have been found to have skeletal deposits in bone scans. The value of <sup>67</sup>gallium scans (whole body and tomographic cuts of various sections) have been described under "Mediastinal scan", though for metastatic lesions to the brain, CT scan is more sensitive.

## Isotopes in haematopoiesis

**Erythropoiesis:** The use of radioactive iron (Fe) such as <sup>55</sup>Fe (T<sub>1/2</sub>=4 years) or <sup>59</sup>Fe (T<sub>1/2</sub>=47 days) provides a quantitative assessment of erythropoiesis. The rate at which <sup>59</sup>Fe-labelled transferrin (the circulating iron-binding protein) disappears from the plasma enables calculation of plasma iron turn-over, which in turn is proportional to the total developing erythroid cell mass. The extent to which circulating RBC acquires the <sup>59</sup>Fe label provides an index of the efficiency or effectiveness of erythropoiesis.

**Polycythaemia vera:** <sup>32</sup>P(phosphorus) (T<sub>1/2</sub>=14.3 days; pure β emitter), in doses of 2.3 mCi metre<sup>-2</sup> IV, gets incorporated in bone and thus suppresses the marrow in *polycythaemia vera* (PV). Treatment may be repeated within 3 months with a 25% increase in dose. Leukaemic transformation (due to cumulative dose effect) and thrombocytosis (platelets > 4 lakhs mm<sup>-3</sup> temporarily) may occur with this treatment. *Primary thrombocythaemia* {autonomous growth of megakaryocytes, excessive platelet production (sustained elevation > 8 lakhs mm<sup>-3</sup>)}, which may occur as part of PV, is also treated by <sup>32</sup>P.

**Blood volume/flow estimations:** A known quantity of <sup>131</sup>I-labelled serum albumin (for plasma volume) or <sup>55,59</sup>Fe or <sup>51</sup>Cr-labelled RBC (for red cell volume) is injected IV. After allowing time for even distribution, a measured volume of the mixed sample is examined in the scintillation counter to give the dilution of the amount originally injected. This gives the whole of the diluting volume (plasma or red cells). Clearance rates of the radioisotopes after IM injection of <sup>133</sup>Xe or <sup>24</sup>Na are sometimes used in blood flow measurement studies.

**Miscellaneous:** Radioisotopes are also used in; (a) pernicious anaemia (vide supra); (b) hypersplenism, splenic sequestration and T<sub>1/2</sub> of blood cells (see "Splenic scan"); and (c) marrow studies (see "Hepatic scan", "Splenic scan", "Mediastinal scan").

Table 1		
Bone isotopes		
<sup>99m</sup> Tc		Others
With phosphorus	Without phosphorus	
Etidronate Pyrophosphate Methylene-diphosphonate	Na pertechnetate	<sup>87m</sup> Strontium <sup>18</sup> Fluoride <sup>131</sup> Iodide <sup>153</sup> Gadolinium

Table 2	
<i>T-scores of osteoporosis in adult women (W.H.O.)</i>	
Normal	BMD within 1.0 SD of the YARM
Osteopaenia	BMD >1.0 SD but < 2.5 SD below the YARM
Osteoporosis	BMD = or >2.5 SD below the YARM
Severe osteoporosis	BMD = or >2.5 SD below the YARM, one or more fragility fractures
<i>BMD = bone mineral density; SD = standard deviation; YARM = young adult reference male</i>	

<b>Table 3</b>	
<b>Normal BMD of Western women at L<sub>2-4</sub></b>	
Age (years)	BMD (Gm cm <sup>-2</sup> )
20	1.051
25	1.072
30	1.079
35	1.073

<b>Table 4</b>	
<b>Scanning in PUO</b>	
<i>Organ scan</i>	<i>Cause of PUO</i>
Lung	Pulmonary emboli
Lung and liver	Small subphrenic abscess
Bone	Occult osseous metastases
Kidney	Hypernephroma
<sup>67</sup> Gallium scan	Cryptic focus of infection or infiltration

<b>Table 5</b>			
<b>Scanning (evaluation and staging) for tumours of certain organ systems</b>			
<i>Organ system</i>	<i>Presenting lesion(s)</i>	<i>Routine clinical scan</i>	<i>Staging/special procedure</i>
Lung	Multiple masses	Thyroid scan	Brain scan
	Single mass		<sup>67</sup> Gallium scan
Thyroid	Nodule, goitre	Thyroid scan	Scan total body ( <sup>131</sup> I), skeletal ( <sup>99m</sup> Tc-PYP)
Breast	Single lump		Liver, bone, brain scans
Lymphoid	Adenopathy, splenomegaly		<sup>67</sup> Ga scan, liver, spleen, bone scans
GIT	Gastric mass		Liver scan
	Pancreatic mass		Liver scan
	Liver mass(es)	Liver scan	<sup>131</sup> I-anti AFP scan
	Gallbladder, biliary tract mass, stricture	Liver scan	
	Colon stricture, mass		Liver scan, <sup>131</sup> I-anti CEA scan
Urinary system	Kidney mass		Liver, bone scans
Male genital system	Testicular mass		Liver scan, <sup>131</sup> I-anti (AFP, βHCG) scans, <sup>67</sup> Ga scan (seminoma metastases)
	Prostate		Bone scan
Gynaecological	Ovarian mass		Bone, liver scans
	Uterine mass		Bone, liver scans, <sup>131</sup> I-anti βHCG scan
	Cervical lesions		Bone, liver scans

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