The appropriate use of diagnostic services: (ix) Nuclear medicine

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Introduction

As part of the diagnostic services which should be available to all patients Nuclear Medicine may be defined as the use of radioactive materials as tracers to elucidate pathophysiological processes[1,2]. It is therefore a service which primarily throws light on *function* as opposed to, say, clinical chemistry which typically provides information on the chemical profile of a body fluid from which functional *inferences* can be made. Since a large proportion of the information derived from Nuclear Medicine studies is presented in pictorial form the notion is widespread that the use of radioactive materials is but another method of producing anatomical images.

Anatomical information can often be usefully obtained. If, for example the functional state of the biliary system is being studied the radiopharmaceutical chosen for its property of being rapidly extracted by the liver from the blood will first clearly demonstrate the whole liver and from this image the size, shape, and position of that organ can be determined. But this is incidental to the fact that this particular study measures the speed and efficiency with which the liver extracts an appropriate material from the circulation, concentrates it in the biliary tree, and then excretes it into the duodenum.

This is in contrast to purely anatomical information obtained by radiological means in confirming obstruction at, say, the ampulla of vater. In such a case radiology will show the biliary tree to be greatly distended. If the obstruction is surgically relieved a repeated radiological study shortly afterwards will demonstrate an equally distended and abnormal system of biliary channels. If a radionuclide functional study is carried out before and after such an operation the degree of *functional* relief can be assessed.

Numerous examples can be quoted but this misunderstanding is so widespread that a further one may not be superfluous. Examination of a damaged wrist may lead to a suspicion of a fractured scaphoid but radiological examination may not confirm the suspicion. A bone-seeking radiopharmaceutical will be concentrated in areas of increased skeletal metabolism. However fine a fracture line the bony repair process will massively increase bone metabolism compared with the undamaged contralateral side and will show up on the image as a patch of highly increased radioactivity in an area corresponding to the position of the scaphoid, although that particular bone cannot be delineated on a Nuclear Medicine Image.

For similar reasons invasion of organs[3] by metastatic cancer can often be demonstrated by the use of radiopharmaceuticals. In certain cases such invasion can also be demonstrated by radiological procedures, or by ultrasound, and sometimes such a method is the one of choice. The lack of a sharp edge in such a lesion or the similarity to the host organ in opacity to X-rays may make these faster diagnostic methods ineffective while changed function in the tumour area may make it easily demonstrable by use of an appropriate radiopharmaceutical.

An outstanding example of this is where it is desired to establish the absence of skeletal metastases. Even very early metastases, not demonstrable radiologically, can be demonstrated using a bone seeking radiopharmaceutical[4]. A range of metabolic bone diseases each show characteristic skeletal changes when studied using a bone-metabolism-related radionuclide[5].

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Examples of diagnostic use

Common examples of proved diagnostic usefulness of nuclear medicine are tabulated below. This is not an exhaustive list, and procedures are continuously being proved of diagnostic usefulness and transferred from the development stage to availability as a routine diagnostic procedure.

Examples of functional parameters which can be numerically assessed with Nuclear Medicine techniques

Kidneys:	Glomerular filtration rate (GFR) and parenchymal transit times (PTT);
Thyroid:	Various radioimmunoassays and in-vivo assessment of thyroid functional status;
Heart:	Ventricular ejection fraction, ventricular volume, systolic and diastolic volume, cardiac output;
Circulation:	Plasma volume, red cell mass, spleen cell mass;
Body Composition:	Total body water, total exchangeable sodium and potassium, total body potassium;
Brain:	Oxygen extraction rate (OER), glucose uptake, regional cerebral blood flow, phosphate uptake.

Examples of functional studies displayed pictorially and also giving anatomical information.

Skeleton:	Primary bone tumours, skeletal metastases, metabolic bone disease, injury not confirmed radiologically, bony reaction to loosening of, or infection around, a prosthesis, degenerative joint disease;
Thyroid:	The nature of a goitre;
Lungs:	The presence of pulmonary emboli, sarcoidosis;
Liver:	Size, shape and position of the organ, rare variations of the normal eg situs inversus, primary tumours, metastatic invasion, biliary function;
Kidneys:	Blood supply, parenchymal function, drainage, developmental anomalies, renograms computer derived from image data;
Bladder:	Ureteric reflux;
Heart:	Rest and stress ischaemic areas, anomalous wall motion, presence of an aneurysm, phase relationships of contractile tissue.

One of these uses, the investigation of the skeleton, is discussed in more detail below.

Malignant disease

Skeletal imaging is used to detect bony metastases and is the most sensitive indicator of the early spread of disease to the skeleton. This method should be used in the staging of newly diagnosed tumours which characteristically metastasise to the skeleton (eg breast and prostatic cancer). Following treatment serial studies reveal the regression or otherwise of known metastases and hence the treatment can be monitored. Patients thought to have disseminated disease have a rate of positive bone images of up to 85% while X-ray examination is positive in only 50% of patients. In early disease X-ray examination is unlikely to demonstrate any abnormality.

In primary bone tumours the image only occasionally shows the lesion to extend beyond the limits demonstrable by X-rays and because of reactive hyperaemia giving rise to increased concentration of tracer the image is not reliable as a guide to the optimum level of amputation. In lymphomas bone imaging is preferable to X-ray study in staging and in vague bone pain as the nuclear medicine study is often positive while the X-ray study is negative or equivocal. In multiple myeloma the majority of lesions lead to very little new bone formation and skeletal imaging is not suited to staging and establishing the extent of disease.

Benign bone disease

The main areas of clinical application are in the early recognition of a pathological process, in the assessment of the extent of the disease, in the assessment of the severity of the disease by quantitative analysis of tracer uptake, and in the monitoring of the efficacy of therapy. Sometimes the use of radioactive tracers is applied to assist clinical evaluation where the pathology is known: for example, to throw light on whether an

inflammatory process is old and metabolically quiescent, or acute and giving rise to active bony metabolic reaction. Tracers can be helpful in assessing avascular necrosis, in monitoring graft healing, and in diagnosing the probable cause of pain in the follow-up of total hip replacement.

Paget's disease is occasionally clearly evident on a skeletal image obtained for some other reason. The appearance has typical features not often confused with those caused by other conditions. In metabolic bone disease there are image appearances typical of specific types but measured tracer concentration is becoming an important diagnostic index.

In sacroilitis and ankylosing spondylitis the bone image shows abnormalities of tracer uptake prior to the appearance of X-ray changes. These abnormalities can be quantified and used not only in confirming early disease but in monitoring treatment.

Fractures of small bones, such as the scaphoid and ribs, and stress fractures, are often difficult to assess radiologically but such damage leads to locally raised bone metabolism which is immediately obvious on a nuclear medicine image. The bone scan is thus a valuable method for both diagnosis and monitoring progress in such cases.

In arthritis bone seeking radiopharmaceuticals will concentrate round affected joints before the appearance of radiological changes. In osteoarthritis the uptake pattern on the image tends to be focal and in rheumatoid arthritis the abnormal uptake typically diffusely involves the whole joint. Imaging is therefore useful in the diagnosis of early disease and in monitoring the efficacy of treatment.

Optimum use of a nuclear medicine service

The introduction of new radiopharmaceuticals, and improvements in instrumentation, as well as progressively developing computer soft-ware, all make Nuclear Medicine one of the most rapidly developing of the diagnostic specialities. This continuous growth in its diagnostic potential has also meant a non-uniform distribution of resources throughout the country. As a matter of economy in the use of radiopharmaceuticals, or for other local reasons it is often advantageous to group investigations of a similar type all on one day. For certain tests to produce meaningful results preparation of the patient is essential: a typical example is the withholding of antithyroid drugs before thyroid functional testing.

For all of these reasons it is essential to make personal contact with the local Nuclear Medicine Consultant before making a new demand on his diagnostic service. It is also necessary to consider carefully the strategy of investigation for each individual patient. Careful thought will usually show that if a Nuclear Medicine study is among the series of tests concerned likely to be necessary it should be carried out early as this may render unnecessary other much more expensive tests.

For example a simple renogram with associated functional images may tell the urosurgeon all he wishes to know[6]. The test uses ancillary staff for less than an hour of the patient's time (as an outpatient), and about ten minutes of a Nuclear Medicine Consultant's time. An even more time and expense saving is in Nuclear Cardiology[7]. A whole series of parameters of cardiac function can be quantitated and other important qualitative data such as defining areas of akinesis, localizing an aneurysm, showing which areas of the myocardium are ischaemic at rest and whether the affected areas are modified by exercise, can all be obtained by an outpatient test extending over two to three hours. If the cost of this is compared with that of admission for cardiac catheterisation from which less data may well be obtained it is obvious which studies should be arranged first.

Two other points should be remembered. Nuclear Medicine tests are remarkably safe, by far the majority of adverse reactions being minor[8]. A further point, often never considered by the referring doctor is that of radiation dose to the patient. Although the information derived from Nuclear Medicine tests cannot usually be obtained by other methods radiological procedures may often provide data sufficient for decisions to be taken. These often deliver a much higher radiation dose to the patient and every doctor should question whether the radiation dose is justified by the information to be obtained

in every individual submitted to investigation. This is morally vital if sufficient data, or even more data, can be obtained at the expense of a fraction of the radiation dose. Multiple testing is unjustified except when essential to the best management of the patient. No-one should be irradiated at all unless the data to be obtained are essential for the correct clinical decisions to be made.

Rules for the efficient use of a nuclear medicine service.

1. Maintain frequent personal contact with the Nuclear Medicine Consultant: results are often not clear-cut and need to be discussed.

2. Consider the sequence of investigations of every patient and terminate the sequence as soon as sufficient results have been obtained to allow taking a firm clinical decision.

3. In requesting an investigation state clearly the question to be answered on which a clinical decision will be based.

4. Give all relevant information when making a written request. The interpretation of a result can be profoundly influenced by the clinical data.

5. Clinical feed-back to the Nuclear Medicine Consultant is essential to improving future accuracy of interpreting test results.

References

1. Maisey MN, Britton KE, Gilday DL, eds. Clinical nuclear medicine. London: Chapman and Hall, 1983.

2. Ell PJ, Williams ES. Nuclear medicine: an introductory text. Oxford: Blackwell Scientific, 1981.

3. Larson SM, Carrasquillo JA. Nuclear oncology 1984. Semin Nucl Med 1984; 14:268-276.

4. McNeill BJ. Value of bone scanning in neoplastic disease. Semin Nucl Med 1984;14:277-286.

5. Ell PJ, Dash J, Raymond J. Bone scanning: a review on purpose and method. Skeletal Radiol 1976;1:33-45.

6. O'Reilly PH, Shields RA, Testa HJ. Nuclear medicine in neurology and nephrology. Sevenoaks: Butterworth, 1979.

7. Ell PJ, Walton S. Jarritt PH. Radionuclide ventricular function studies: correlation with E.C.G., echo and X-ray data. The Hague: Nijhoff, 1982.

8. Keeling DH. Adverse reactions to radiopharmaceuticals: United Kingdom 1977-1983. Br J Radiol 1984; 57:1091-1096.