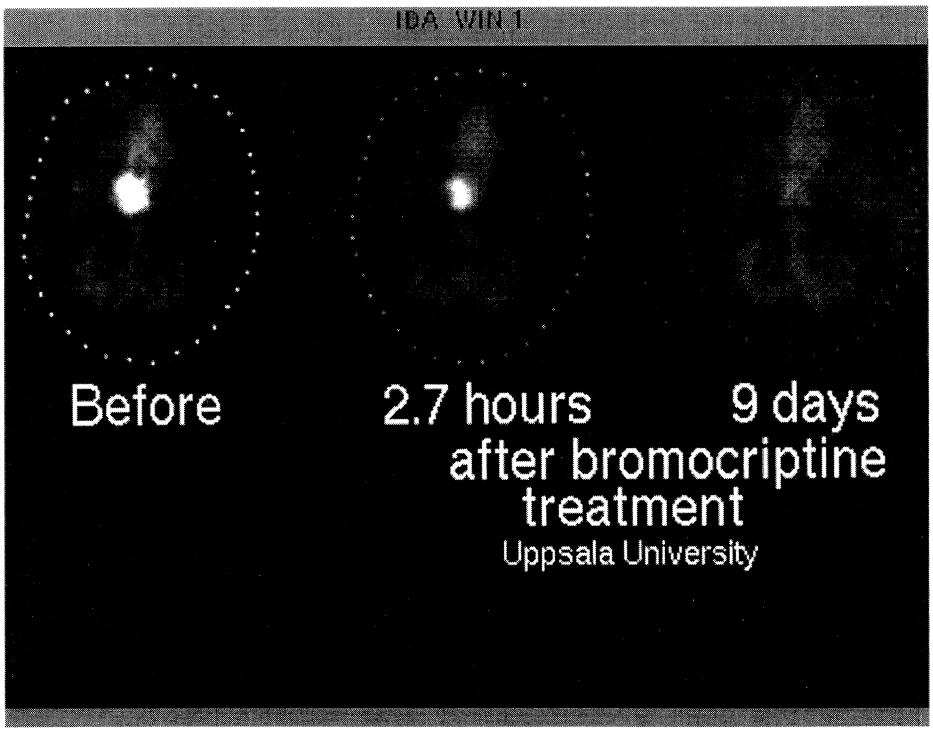
Positron Emission Tomography (PET) provides diagnostic information from tomographic measurements of the biochemistry and physiology of tissues and organs. If diseases are related to biochemical changes, these can be observed with PET long before any anatomical changes are detectable. This shows the results of carbon-11 methionine used in an investigation to estimate the effect of therapeutic drug treatment on a brain tumour. (Photo Uppsala University PET Centre, Sweden)

pharmaceutical companies are registering new products and procedures for cyclotron-produced isotopes.

From Dewi M. Lewis, Amersham International plc, Amersham, UK.



Positron emission tomography

Positron Emission Tomography (PET) is an advanced nuclear medicine technique used for research at major centres. Unique diagnostic information is obtained from tomographic measurements of the biochemistry and physiology of tissues and organs. In theory, diseases are related to biochemical changes and these can be observed with PET long before any anatomical changes are detectable.

In PET the radioactive component is a positron-emitting isotope or 'tracer'. The positrons annihilate with electrons in the body to produce two gamma rays 180° apart; coincidence detection of these gammas provides a very efficient method of determining the spatial distribution of the radioisotope tracer. Because physiological measurements are usually required in a single imaging session, very short-lived isotopes are used to label the tracer molecules; isotope production and labelling is usually carried out in situ. The most commonly used radionuclides are carbon-11 (half-life 20 minutes), nitrogen-13 (10 minutes), oxygen-15 (2 minutes), and fluorine-18 (110 minutes).

A PET system has three major components:

- a particle accelerator with targets for production of the positron-emitting isotopes;
- chemistry modules for synthesis and labelling of the desired tracers;
- and a PET camera for in-vivo measurements of the distribution of the tracer in the body.

Cyclotrons have become the standard accelerator for producing PET isotopes with typical protons energies of 10-18 MeV, and 5-9 MeV for deuterons with beam currents up to 75 microamps. Present-day PET cyclotrons are extremely compact, highly automated machines suitable for hospital environments and have little in common with the older laboratory-designed research machines.

All new PET cyclotrons are based on negative ion technology to facilitate beam extraction and minimize induced radioactivity build-up. Closed-loop computer control manages startup, tuning and irradiation, leaving only the choice of labelling compound and a few initial irradiation parameters to be determined by the user. With the exception of oxygen-15, the radioactivity level needed for a typical scan is 200 MBecquerel. A single production batch will be sufficient for two or more patient scans.

PET has expanded since the mid 1970s and there are now about 140 PET centres worldwide, half of them in North America. The PET procedure is similar to conventional isotope imaging but with improved sensitivity and spatial resolution. PET can image and measure quantitatively new biochemical parameters such as blood flow, fatty acid and glucose utilization, oxygen metabolism, amino acid transport, receptor densities and occupancy in the brain and other organs. The most com-

PET production

Radionuclide	Nuclear Reaction
C-11	$^{14}N(p,\alpha)^{11}C$
N-13	$^{16}O(p,\alpha)^{13}N$
O-15	$^{14}N(d,n)^{15}O$
F-18	$^{18}O(p,n)^{18}F$

monly used tracer is fluorine-18 deoxyglucose (FDG), a sugar analogue used in studying glucose metabolism in the brain and other organs. Researchers have been able to label more than 500 different PET compounds but kinetic biochemical models only exist for about 15 of these.

Promising applications exist in fields of oncology, neurology and cardiology. In oncology, PET is used to detect type and grade of primary tumours and metastases, the extent of tumours prior to surgery, to differentiate radiation necrosis from tumour, and to assess the degree of malignancy of lesions and their response to surgical or drug therapy.

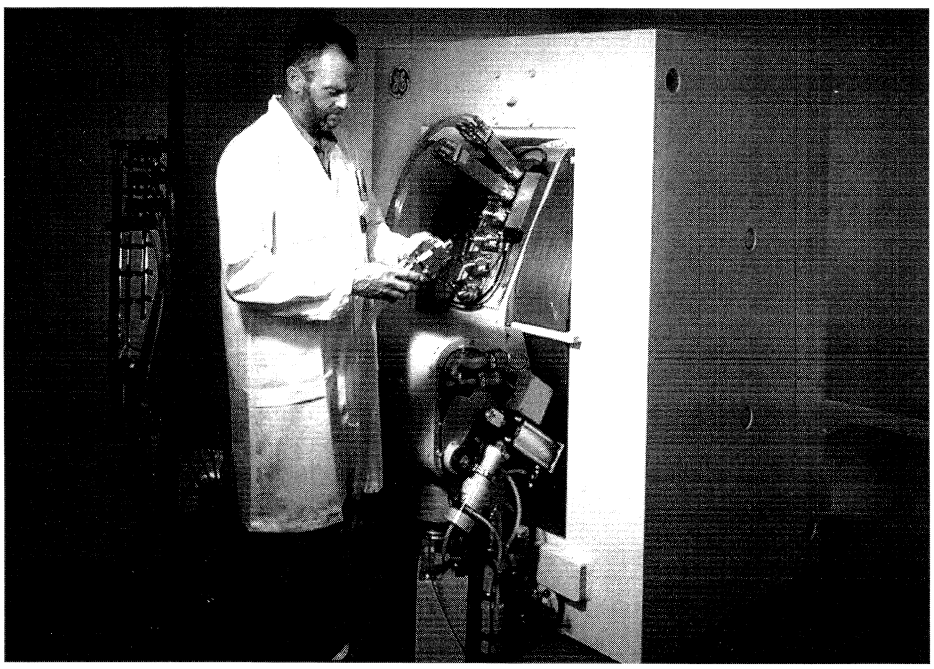
Applications in neurology include localization of seizure foci in epileptic patients, early detection of Alzheimer's disease, and differential diagnosis of movement disorders such as Parkinson's disease. In cardiology, PET is used for assessment of myocardial tissue viability, which is often a prerequisite for a bypass operation. Diagnosis by other methods often fails to identify tissue viability, possibly leading to unnecessary surgery. Assessment of coronary artery disease is another important PET application area in cardiology.

The world demand for new PET systems is estimated to be 15-20 units per year. Although it is not yet a routine clinical procedure, it is expected that once insurance companies start reimbursement for PET studies, then clinical use will grow rapidly. Recently the US Federal Drug Administration (FDA) approved the use of FDG as a diagnostic drug for the study of epilepsy.

General Electric and Siemens both supply complete PET systems, comprising cyclotron and camera, and enjoy around 90% of the market. Several smaller companies either manufacture cyclotrons (IBA and Oxford Instruments) or PET cameras (Positron Corporation and Shimadzu). Recently low energy linacs have been proposed for PET, but at the low linac energy of 4 MeV, high beam currents are needed to reach the required isotope yields.

Commercial manufacturers clearly face a challenge to expand the market for PET by reducing equipment capital costs and by designing systems that increase patient throughput.

From Stig Lindback, GEMS PET Systems AB, *Uppsala, Sweden*



A 11 MeV compact cyclotron with negative hydrogen ion extraction for generating very short-lived PET isotopes. Present-day PET cyclotrons are extremely compact, highly automated machines for hospital environments and have little in common with the older laboratory-designed research machines. (Photo GE Medical Systems, Uppsala, Sweden)