Practical PET/CT: reflections and skills development

For nine months, Marc Griffiths undertook a placement within a clinical PET/CT environment in order to gain a greater understanding of the service. Over the next two issues of *Synergy*, he reflects on his experience, starting with time spent on a mobile scanner.

Overview

An opportunity arose in April 2007 for a secondment into the clinical PET/CT field. It came at a transitional period for PET, because the Government had announced plans for the increased provision of PET scans through managed service agreements with medical imaging companies, such as Alliance Medical Ltd (AML) – the result of an initial consultation document undertaken by the Department of Health in 2005, assessing the overall delivery of PET services in England, compared to other countries[1]. Although I was a practicing diagnostic radiographer and nuclear medicine practitioner, this was a journey through uncharted waters, in terms of the patient groups encountered, handling a Beta emitting radioisotope, and appreciating the various facets of a modern PET/CT practice. A constructivist model of emotional learning[2] was adopted throughout the clinical placement and, although the prospect of working alongside clinical practitioners was an exciting thought, it was also very daunting.

The training received before and during the clinical placement was essential to the provision of a safe and effective PET/CT service. This included a series of competency based practical assessments, probationary reports, and undertaking a College of Radiographers approved injection course. Being able to transfer academic knowledge and understanding of PET/CT into the clinical field required personal adjustment and cognitive skill development.

It soon became apparent that the use of PET/CT within practice was evolving. The referral of patients for scans now covers a wide range of clinical pathologies, including the most current cancers, such as lung, colon, lymphoma and melanoma. In line with diagnostic and treatment pathways identified by the National Institute for Clinical Excellence (NICE), PET/CT was being utilised as a diagnostic staging and monitoring tool for patients. In a number of cases, its use was impacting on the overall staging of patients and providing crucial information for surgeons and other healthcare professionals at multi-disciplinary team (MDT) meetings.

Physical working environment

PET/CT practitioners arrive at mobile clinical sites around 7 to 7.30am to prepare for the working day and undertake the various quality control checks – because the mobile units are transported around the country, it is crucial to check for any issues which could have a detrimental effect on the overall quality of the patient scans. This included ensuring that the crystals are fully operational (ie, coincidence mean, gain values and singles test) and that there are no alignment issues. Being able to recognise and problem-solve hardware and software faults requires knowledge, understanding, good training and the employment of transferrable skills. A good working relationship with the trailer drivers and equipment engineers also helped!

In addition, the paperwork is collected from site, referral forms are checked, and a signature from the clinician who holds the Administration of Radioactive Substances Act Committee (ARSAC)[3] licence is ensured. This is crucial, because the introduction of a radioactive substance into a patient's bloodstream induces a radiation risk. Obviously, the risk benefit analysis is carried out (Ionising Radiation (Medical Exposure) Regulations 2000) for each patient to ensure the PET/CT examination provides beneficial results.

The initial reaction to being on board a mobile PET/CT scanner is one of space, or lack of it to be precise – it is unfortunately small

Figure 1: A mobile PET/CT scanner environment. Note the close proximity of the trailer walls, which are lead-lined to minimise radiation dose to the outside public and workers.

Figure 2: External view of a mobile PET/CT unit. The oval shows the scanner environment; the square, the control console; and the triangle, the patient injection/uptake area.

(figure 1) and weighs approximately 46 tons due to the lead shielding required. The 'pop out' sections (figure 2) enable additional space for operators, but this is limited compared to a static PET/CT environment.

Practical working skills had to be developed in terms of distance and shielding, something that radiographers and nuclear medicine practitioners are taught very early on in their training. Issues related to potential 'crossfire' from having radioactive patients either side of the control area means that consideration is needed for patients' overall safety on entering and exiting the environment. Standing at the side of the scanner whilst the table is moving up and down generally protects the operator, and the composite material is Kevlar which offers some form of practical radiation protection.

Patient experience

It was important to appreciate the patient 'journey' before, during and after a PET/CT scan. Patients demonstrate various emotional states after receiving potentially life-changing information within the oncology setting. Some were informed of their clinical diagnosis literally days before their scan and I hadn't previously encountered such intensity of feelings. The scans were also used to evaluate treatment, post-chemotherapy, and I was fortunate enough to witness numerous cases where it had made a substantial difference to the overall management of patients. It was at these moments that the true potential and diagnostic value of PET/CT became clear and felt more personal than reading about sensitivity and specificity values in a journal article!

Patient preparation is paramount for any examination or treatment procedure. In addition to verbal discussions, patients also receive a booklet relaying information about their scan, preparation requirements, aftercare considerations and how the procedure may be utilised in their particular case. However, it became apparent early on that some patients receive very little information prior to their scan – mainly due to the fact that some referrers (eg, consultant oncologists) request PET/CT scans within a very short time frame. The reason is two fold: firstly, to be in line with the Department of Health's Cancer Plan[4] initiative that waiting times of patients must be minimised and, secondly, the efficacy of PET/CT defines the individual treatment a patient receives. Also, the amount of patients who did not read the information or chose to ignore it was concerning at times.

There is a considerable amount of patient preparation, more than

Figure 3: An anxious patient who demonstrated symmetrical 'brown fat' uptake within the neck.

I had considered from initial theoretical experience. Although the standard preparation is relatively straightforward (see appendix on *http://synergy.sor.org/january2009*) and generally includes fasting for a minimum of six hours prior to a scan, there appears to be potential issues for patients who are either type I or type II diabetic, chemotherapy patients, and patients who have undergone some form of lymphatic drainage (eg, breast cancer). Individual alterations are also needed depending on the specific requirements of the examination or the patient. For example, patients should avoid any strenuous exercise before the scan – recent muscle usage and/or patient tension/anxiety may lead to the uptake of FDG-18 post-injection, known as 'brown fat' uptake (figure 3).

Large patients sometimes faced difficulties in being comfortable within the actual PET/CT scanner (figure 1). Although the imaging bore is relatively generous, the limited attenuation correction field of

Figure 4: Specialised containers that house a lead-lined case.

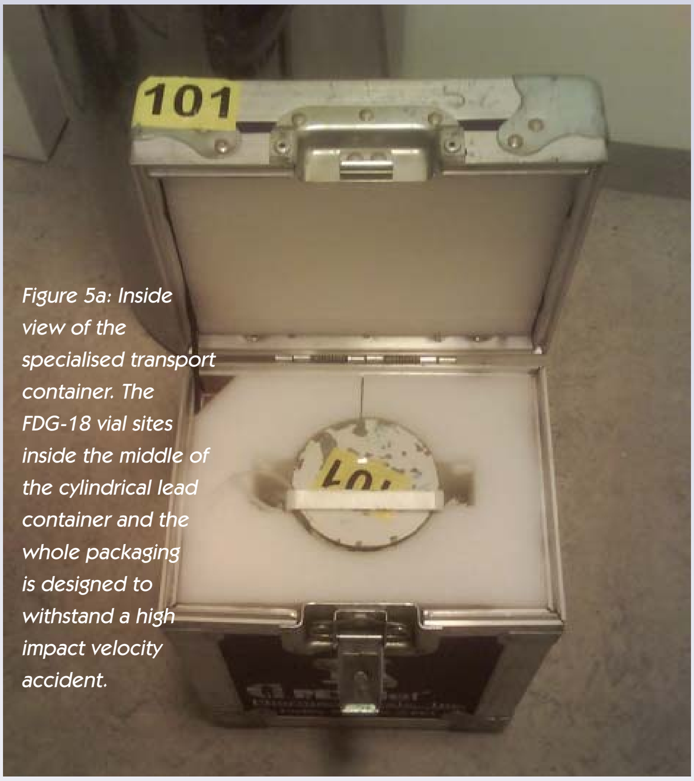

Figure 5a: Inside view of the specialised transport container. The FDG-18 vial sites inside the middle of the cylindrical lead container and the whole packaging is designed to withstand a high impact velocity accident.

Figure 5b: Housing 'pig' of the FDG-18 vial. Note the thickness of the 'pig' and the lead glass screen.

view (FOV) (50 cms) within the GE Discovery PET/CT scanner resulted in some larger patients not having a full attenuation correction FOV algorithm applied to the raw PET data. This was inevitable in larger patients and was subsequently documented within the specific patient's paperwork.

Similar to other nuclear medicine procedures, patients and their carers (if required) are informed of the radioactive nature of the PET procedure, via the patient information booklet and during the actual imaging procedure. Due to the relatively higher linear energy transfer (LET) of beta particles, compared with gamma and x-ray energy sources, the importance of time, distance and shielding became apparent very early on. For example, judging some patients' ability to help themselves off the scanner took some practice, rather than assistance being given and personal dose being increased.

FDG-18 production, delivery and management

The FDG-18 radioisotope is produced within a cyclotron unit, a specialist machine where the bombardment of a target element (eg, oxygen) by particles occurs at a very high speed. This ultimately creates an unstable element (eg, Fluorine-18), which is attached to a glucose solution, to create FDG-18. This solution has a very short physical half-life (110 minutes) and needs to be transported to both mobile and static PET/CT facilities very quickly.

Licenced road vehicles transport the FDG in specialised containers to clinical sites and the amount of paperwork is extensive in terms of ensuring the hand-over of this licenced medical product. Strict regulations, such as the Radioactive Substances Act[5] have to be adhered to when transporting any radioactive material. Each container holds a single vial of FDG-18 radioisotope solution (figures 4 and 5a & 5b).

Taking into account the short half-life of FDG-18 is vital: each patient's arrival would be built into the overall management of the service. Sometimes an accident on the motorway would result in late delivery, causing concern in relation to the provision of sufficient FDG-18 activity and booked patients. A number of incidents involving the FDG-18 solution failing the strict quality control procedures also occurred. It was sometimes difficult to re-organise patients, especially if some of them had not eaten for a considerable amount of time, or if they were diabetic.

It was apparent that effective communication and problem solving skills were two of the fundamental attributes of a PET/CT practitioner. All healthcare professionals utilise these skills, but it was clear that, in order to manage a PET/CT service, particularly in a mobile environment, practitioners had to be able to foresee problems and effectively manage them. Support was available through various facets and managerial roles, but the dedication and drive to ensure minimal disruption to the provision of the PET/CT service by the practitioners I worked alongside was clear. It was as upsetting for them as for the patients when a scan had to be cancelled for reasons totally beyond their control. I can't recall ever seeing such dedication and commitment from a workforce and the feeling of complete empathy for the patients.

Injecting skills and protocols

FDG-18 controlled the working day. Without this radiopharmaceutical agent, it wasn't possible to achieve anything. Every PET/CT practitioner has a level of respect for the solution, in terms of its cost, potential diagnostic properties and biological damage to patients if injected incorrectly, but gaining confidence in its administration was, personally, a relatively slow process.

It is routine protocol for the areas in the south of England to utilise blue venflons for the administration of FDG-18. Working closely with clinical colleagues and appreciating the importance of good venous access is probably one of the most fundamental factors of being a PET/CT practitioner. This was probably over-stressed frequently by colleagues, but with valid reason.

Sometimes the venous access for patients who have undergone chemotherapy treatment is poor and the team approach to injecting patients with difficult veins demonstrated the true meaning of teamwork, professional trust and commitment to obtaining quality diagnostic results. A number of patients have to be injected in their feet, because lymph node clearance precludes venous access in the affected side of a patient with breast cancer. This is due to the poor clearance of the FDG-18 radioactive tracer and inaccessible veins in the opposite arm of the patient. Sometimes, patients who had experienced a large number of chemotherapy cycles would present with an expression of worry and stress, mainly because venous access would be a problem. However, the clinical composure, compassion and concern for patient safety was always demonstrated by my colleagues, sometimes under immense pressure to administer the FDG-18 solution within a certain time limit.

On one particular scanning day, a patient had to be cancelled because of problems with venous access, a rare occurrence. There is a finite time slot within the working day for patients to have venous access organised and any delay has a 'knock on' effect with the timings for other patients. Because the FDG-18 solution has a relatively short physical half-life, a decision was made to cancel the patient, following numerous attempts by a range of skilled professionals and even an anaesthetist. This decision was a difficult one to make and the fact that two patients had flown from Scotland to have their scan at the site had an influencing factor. Decision-making formulates an important aspect of a practitioner who may work within an advanced area of nuclear medicine such as PET/CT[6], but it is important to adhere to policies within any NHS Trust.

As much of the procedure as possible has to be explained to the patient before the injection of FDG-18, because the radiation dose received by the practitioner is directly proportional to the time spent with the patient, the distance from the source of radiation and the degree of secondary shielding that exists. Strict adherence to the ARSAC[3] limits is paramount. The maximum dose limit for a half-body PET/CT scan (which typically includes orbits to upper femora) is 400 MBq[3]. This value may be increased if the patient's weight is in excess of 100kg, but this is at the discretion of the clinical site's ARSAC licence holder.

Measurement of the FDG-18 radioisotope is undertaken by the practitioner, who is also responsible for the administration and post assay recording of the 'empty' vial. Documentation of the values and times is crucial, because the calculation of standard uptake values (SUVs) cannot be accurately undertaken otherwise. Reporting radiologists may wish to assess SUVs in patients who have undergone chemotherapy treatment and are reviewing the tumour uptake of FDG-18.

The preparation of consumables, sharps bins, patient documentation, patient dose calculation sheets and overall documentation/record keeping is paramount to the overall fluid running of a PET/CT service. In addition, obtaining the patient's height and weight is crucial to the calculation of SUVs within the scan, along with the pre- and post-injection dose values and times. All this was vital first hand experience in drawing up, measuring, safely injecting and disposing of FDG-18.

A three-way tap is an essential piece of kit in terms of being able to 'flush' the FDG-18 (contained in a vial, encased in a tungsten/lead case) with a sufficient amount of saline fluid. All syringes are leur-lock design to prevent any accidental spillage of the radioactive solution. A 3ml syringe is also used to draw off a sample of blood from the patient, prior to the administration of the FDG-18 solution, in order to measure the blood sugar level (BSL). A high BSL (greater than 10mmol/L) constitutes the potential for a poor scan, in terms of image quality, because the patient's body already possesses sufficient amounts of glucose, which then prevents the maximum uptake of FDG-18 within the patient's cells. This scenario may affect the overall sensitivity of a PET/CT scan.

Cold winter days may also potentially cause image quality problems. Cold patients may shiver and cause false uptake to occur within their spinous processes and various muscle groups within their bodies. So it is crucial that patients are kept as warm as possible, through blankets and an on-board heating system, as soon as they come on board the scanner. In addition, a lot of patients fail to drink any water prior to their attendance, which also affected overall scan quality.

Personal dosimetry

All PET/CT practitioners are issued with electronic personal dosimeters (EPDs), which provide an instantaneous readout of a cumulative dose received during a working day. It is important that the classified annual radiation dose of 6mSv[7] is not exceeded, which can constitute additional health checks and a scoping exercise being conducted. Roberts[8] and Benatar et al[9] identified the increased dose from PET/CT examinations compared to conventional nuclear medicine procedures for clinical practitioners and the use of an EPD unit is considered crucial in order to monitor personal dose limits.

Strict adherence to clinical protocols and audit monitoring of staff ensure that all PET/CT practitioners within AML are not classified workers.

In addition to the personal EPD, a finger thermoluminescent dosimeter (TLD) and a body TLD are also worn by PET/CT practitioners and replaced on a monthly basis. Handling the tungsten/lead composite syringe shields took some practice and I was fortunate enough to receive excellent hands-on training from the staff I worked with. Trying to draw up 0.6ml of FDG-18 with a 25G butterfly in a fragile vein of a chemotherapy patient in a confined space, with the knowledge of the associated decay factor requires skill, confidence and competence.

A colleague once told me that "you don't find PET/CT, it finds you…" This reminded me of the development required within all areas of medical imaging and the necessity to always engage with change, professionalism and competency.

NEXT MONTH: Marc recounts the clinical experiences of his placement.

About the Author

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References for this article can be found under 'Synergy resources' at *http://www.sor.org/members/pubarchive/synergy.htm*