Physics and Technical Aspects of PET-CT Scanning for Radiotherapy Planning

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Radiation therapy is a fast moving field which is working towards personalised, targeted treatment for which functional imaging (PET/CT) is likely to play an important role. PET/CT is currently being used in pre-therapeutic staging and therapy response assessment. It has been recognised as a useful tool to help define the treatment fields for accurate radiotherapy treatment planning.

The introduction of IMRT, stereotactic RT, dose painting and volumetric modulated arc therapy have enabled accurate delivery of radiation to target tissues with tight margins. This requires precise planning prior to radiation treatment which helps to maximise radiation to tumour while minimising normal tissue dose, thereby increasing treatment efficacy to the target tissue. PET/CT provides a target volume for radiotherapy planning based on functional/metabolic properties of the tumour which in some cases may be detected sooner compared to anatomical changes seen on CT or MRI. PET also has access to a wide range of tracers that reveal different aspects of tumour metabolism and function, e.g. tissue hypoxia which is known to reduce effectiveness of radiation therapy and may require higher doses in the hypoxic areas. The PET based volumes are therefore often clinically more relevant than anatomical volumes based on CT or MRI alone. Moreover, routinely, Clinical Target Volume (CTV) has a margin placed around it to account for physiological motion while this is already accounted for in a PET volume as PET scans last 15-30 minutes, thus incorporating physiologic motion in the final image. On the other hand, targeting tissues that move a significant amount due to respiratory or cardiac motion has been a challenge in radiotherapy treatment planning. In PET/CT, respiratory motion can cause a decrease in the uptake of the lesion and can increase the apparent size of the lesion, decreasing the sensitivity of PET. It can also lead to mis-registration between the PET and CT. The effects of motion have the greatest influence on lesions of smaller size and low contrast. Respiratory motion correction of the PET/CT datasets can help in restore these changes influenced by motion, increasing the accuracy of the therapy planning provided by PET/CT.

For the PET/CT scan to be used for precise tumour delineation and planning, it is essential that the patient is in the same position as for the radiotherapy treatment session. This requires high standards of absolute accuracy and reproducibility, above the standard positioning requirements for PET/CT and is usually achieved by a combination of identical immobilisation devices and tattoos that identify the location of the reference isocentre. The equipment of most primary importance is a flat therapy couch made of carbon fibre (lightweight) to achieve the same geometry as a radiotherapy couch. All immobilisation devices can be attached to this couch if required. The same positioning and fixation systems used in radiotherapy planning should be used during the PET scan. During the process, training, regular quality control of the PET/CT system and external laser alignment system, good communication between the patient and radiotherapy and nuclear medicine staff, accurate documentation of the patients positioning and skin marks are vital to ensure that a reproducible treatment schedule chart can be maintained. At the treatment sessions the patient is positioned and aligned to the same position as outlined in the pre-treatment documentation. In cases where the reference isocentre from the PET/CT scan is not accurate, the couch may be moved and the distance (in mm) noted on the final treatment plan. Both the PET/CT scan and radiotherapy sessions need to be within a short time interval to avoid changes to target tissue morphology from disease.

In summary, four elements are essential to define PET-CT target volumes for radiotherapy. These are accurate patient positioning and image registration algorithms, a minimum time difference between the PET/CT and the radiotherapy, a robust IT system to allow transfer of data between different equipments, and an interdisciplinary approach with good communication between imaging and radiation oncology departments. Integrating functional imaging with various PET tracers into the radiotherapy planning process may help to define accurate functional tumour margins, reducing dose to normal tissue and thereby enabling the target tissue dose to be increased. Implementing a specific respiratory gated PET/CT protocol for patients referred with known lung cancer may help improve the accuracy of the therapy response assessment.

Further Reading:

1 Paulino A.C., Teh B.S. 2008. *PET-CT in Radiotherapy Treatment Planning*. Philadelphia USA, Saunders Elsevier.

2 BIR Report 23. 2011. *Molecular Radiotherapy in the UK: Current Status and Recommendations for Further Investigation*. The British Institute of Radiology, UK.

3 EANM Publications. *PET/CT Radiotherapy Planning Part 3 A Technologists Guide.* EANM.

4 Sattler B, Lee JA, Lonsdale, Coch E. 2010. *PET/CT (and CT) instrumentation, image reconstruction and data transfer for radiotherapy planning.* Radiotherapy and Oncology 96: 288-297.

5 Coffey M., Vaadering A. . 2010. *Patient setup for PET/CT acquisition in radiotherapy planning.* Radiotherapy and Oncology 96: 298-301.

6 Bettinardi V., Picchio M., Di Muzio N., Gianolli L., Gilardi M.C., Messa C. 2010. *Detection and compensation of organ/lesion motion using 4D-PET/CT respiratory gated acquisition techniques.* Radiotherapy and Oncology 96: 311-316.