The impact of PET/CT in modern radiation therapy – a dosimetrist's perspective

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The benefit of using PET/CT imaging in the diagnosis and staging of many cancers is well established. PET scanning has the capability of showing metabolic changes in disease states, allowing the radiation oncologist to optimise his/her contouring of tumours on imaging scans, keeping treatment volumes as accurate as possible, potentially reducing radiation doses to adjacent healthy tissue structures. PET/CT helps in differentiating between malignant and benign cells, reducing the risk of treating non-cancerous tissue and better insuring the detection of disseminated disease. It also provides earlier diagnosis of cancer and better tracking of tumour activity after treatment is complete.

PET/CT scanning is not useful for all cancer diagnosis. Cancer cells vary in the normal metabolism of glucose resulting in increased glucose uptake and decreased glucose clearance. Glucose can be bound to the positron 18-F to make a compound 18 F-fluorodeoxyglucose, or FDG, currently the most commonly used tracer in PET scanning. When FDG is introduced into a patient's blood stream, it is taken up by the cancer cells at a more rapid rate than normal cells therefore allowing cancerous tissue to be visualized as "hot spots" on a PET scan. Tumour size and cell type are factors that effect PET scan accuracy. Although accuracy in detecting tumours larger than 2 cm is high, PET may miss approximately one third of invasive cancers smaller than 1 cm.

The implementation of PET/CT scanning has revolutionized treatment planning in radiotherapy. PET/CT scanning can detect more accurately than conventional CT scanning tumour size and location, allowing the radiation oncologists to more precisely define the area being treated, likely reducing the volume of surrounding healthy tissue being irradiated. The constant struggle in radiation therapy planning is to treat the tumour to a full dose while avoiding high radiation doses to neighbouring healthy tissues and organs at risk. One example is with primary brain tumours. For the most part, these are aggressive cancers that require a high dose of radiation to eradicate the tumour entirely. The dose required to abolish the tumour can be upwards of 60 Gray while the maximum dose the brainstem can tolerate before serious complications are encountered is 54 Gray. We must be very careful to keep the dose to the brainstem, eyes, chiasm and hippocampi low while still delivering enough radiation to hopefully cure the patient. PET/CT scanning helps us determine precisely where the tumour is and its growth pattern in the brain so that our radiation oncologists and radiologists can work together to delineate the area to be irradiated as accurately as possible.

Another cancer type that benefits from PET/CT scanning is lymphoma. One type of lymphoma is Hodgkin lymphoma. This is a disease of the lymph nodes, usually occurring in the mediastinum, often diagnosed in a younger population. It is very radiosensitive and responds well to both chemotherapy and radiation therapy. The cure rate for early stage HL can be as high as 95%. In order to properly diagnose the patient, he/she will undergo a PET/CT scan to determine exact stage and location of the tumour. The patient is then given a series of chemotherapy over a period of 2-6 months. In localised disease, radiation therapy is prescribed to the pre-chemotherapy involved nodes as defined in the PET/CT scan. In advanced disease, the patient will undergo a more intensive chemotherapy. For those patients, radiation therapy is then prescribed to the post-chemotherapy PET positive nodes. Before PET/CT scanning was available, it was very common to irradiate a patient's entire chest to a full dose because we could not accurately determine where we should direct our radiation fields for each individual patient. This dose to the entire mediastinum in patients often resulted in long term complications, such as muscle atrophy in the neck and shoulders and an increase in breast cancer risk for women. Because PET/CT scanning can now localize the tumour much better, we can restrict our radiation fields the area affected alone, allowing for a much smaller treated volume and much less healthy tissue being unnecessarily irradiated.

PET/CT scanning also allows us to determine whether or not a patient has metastatic disease (cancer spread from the primary site to other organs in the body). This is very beneficial to the patient as it eliminates a potentially very difficult and time-consuming curatively intended radiation treatment course when the hope for cure is non-existent. At the time of diagnosis of a metastatic disease, the course of a patient's treatment changes dramatically from one of cure to one offering relief from pain and extension of life. This is also a practical issue in all radiation therapy departments as it shortens the number of treatments for one patient from up to 39 for example, for a curatively intended prostate regimen, to 5 or 10 treatments for painful bony metastasis to the hip or spinal column. This will allow patients awaiting treatments to come into our hospital more quickly.

A dedicated PET/CT scanner in a radiotherapy department is of a huge benefit to the patient and their treatment team. A dedicated PET/CT scanner is set up like a linear accelerator to reproduce the position a patient will be treated in. Features include a flat scanning bed, reproducible immobilization considerations and devices, lasers to guide technologists and radiation therapists and compatible software. Reproducing the treatment position helps in contouring the tumour and positioning the treatment fields so that the area being treated is as accurate as possible. This is important with mediastinal disease, for example, where if the patient is scanned with their arms down, the tumour then contoured, then the patient is treated with their arms above their head this can significantly change the location of the tumour. A reproducible position also helps dosimetrists and radiologists fuse other imaging modalities such as MR to the PET/CT scan to help guide them in tumour delineation. It is also very important to have well trained PET radiologists who are experienced in the detection of malignant tissue to aid the radiation oncologist in contouring malignancies.

PET/CT scanning is quickly becoming the foremost tool used for cancer diagnosis and it is still early in its developmental stage. New tracers used in PET scanning are continually being improved upon, opening the door to even more benefits of PET/CT scanning in the fight against cancer. One example being tracers of hypoxia in tissues. Hypoxic tumour tissue is less likely to respond to radiation therapy than non-hypoxic tumour tissue and therefore needs higher radiation doses. Hypoxia tracers may allow us to prescribe different radiation doses to different parts of the tumour, thereby increasing the chance of cure without increasing the dose to normal surrounding tissues.

As PET/CT scanning improves our ability to both stage and diagnose cancers, dosimetrists need to also acquire the skills to allow them to implement all the new diagnostic information from those technologies into the treatment planning for each individual patient, if these new techniques are to provide the utmost benefit to the patients. The dosimetrists expertise is continually evolving and requires a broader knowledge of modern imaging than ever before.

References

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