Use of PET in Radiotherapy
Practical Issues in RTP

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BAROC is a Radiation Oncology centre in the regional city of Ballarat.

It was setup under the SMU scheme as a satellite centre to the Austin ROC.

Clinical staff are part of Austin Heath.

Physics & Engineering are part of Radiation Oncology Victoria.

Ballarat is located approx 110km from the Austin, which generally translates to 1 ½ hrs travel time each way.

Closest PET scanners are located in Melbourne.

Normally work with the Austin PET centre.

Participate in Austin Health Project "Use of PET in Radiotherapy"

Positron Emission Tomography

Technique used in Functional Imaging

Compare with Nuclear Medicine and recently Functional MR

Functional Imaging is the measurement of a characteristic that determines the function of a certain region of tissue. A map (Image) can then be created which shows which areas of tissue have that characteristic of interest. In Nuclear Medicine and PET this is done by attaching a radioactive isotope to a biologically active compound (Tracer) that will be taken up by the cells of the tissue of interest. Note the radioactive isotope may be biologically active in itself. With fMR the characteristic of the tissue may be determined from chemicals already present.

PET has gained wide spread use in Oncology due to the Tracer, fluro-deoxy-glucose (^{18}F-FDG) which is an analogue of glucose with ^{18}F being a positron emitter.

A significant number of types of cancer are "glucose hungry" and PET using ^{18}F-FDG can be used to produce an image of their distribution in vivo.

"^{18}F-FDG follows the initial phases of glucose metabolism but does not enter the Kreb's cycle after phosphorylation and therefore is effectively trapped in the cells to allow tissue glucose metabolism measurement." - http://www.austin.unimelb.edu.au/

PET is more than ^{18}F-FDG

With positron emitting isotopes which include ^{11}C, ^{13}N, ^{15}O PET has the potential to be used with any organic compound and hence any biological function.

However, currently over 90% of studies use ^{18}F-FDG.

A significant number of which are Staging of Lung Cancer.

In oncology there is significant interest in, 18F-FLUOROMISONIDAZOLE (FMISO).

FMISO is a hypoxic marker with the potential ability to predict tumour resistance to radiation or chemo therapy.

^{11}C-Choline as a tracer for Prostate cancer is also of current interest.

Benefits of PET.

A tumor may not be detectable in a CT scan, however it may be detected in a PET scan.

The number and spread of metastasis may be determined from a PET scan.

The treatment volume associated with a tumor may be modified based on a PET scan.

Increased if it shows the tumor has spread outside what is visible on the CT.

Reduced if it shows a portion of the volume does not have active cells.

Functional images can be combined with Anatomical images.

Being able to accurately locate the tissue of interest against anatomy can significantly increase the power of the combined modality over each individually.

PET & CT have attributes that compliment each other, for example

Both are spatially accurate

The CT image can be used to generate an attenuation map to correct the PET image.

Time to acquire CT image does not add significantly to overall time.

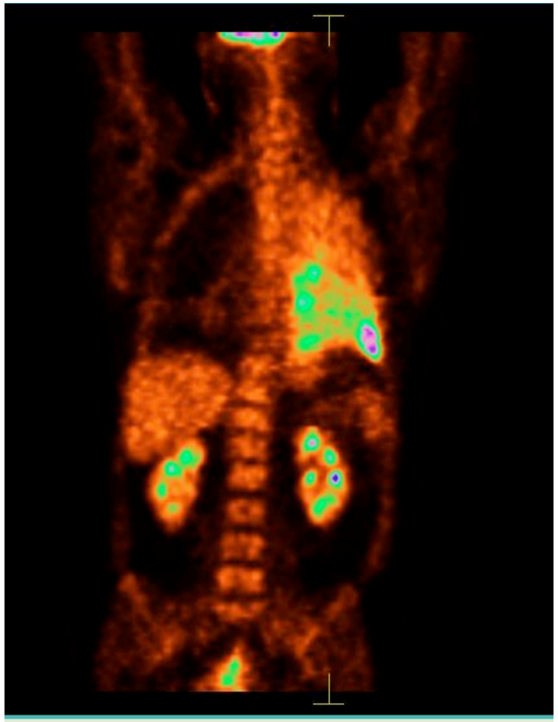
CT is now a relatively well established and inexpensive modality. Doesn’t add significantly to either the overall complexity or cost of a combined system – PET/CT

A combined system has both imaging gantries with a single patient bed that passes through both. It has the potential to minimise patient movements between the 2 scans. However there is still an issue of the time factor for scans eg CT takes <30seconds PET takes >30minutes.

CT

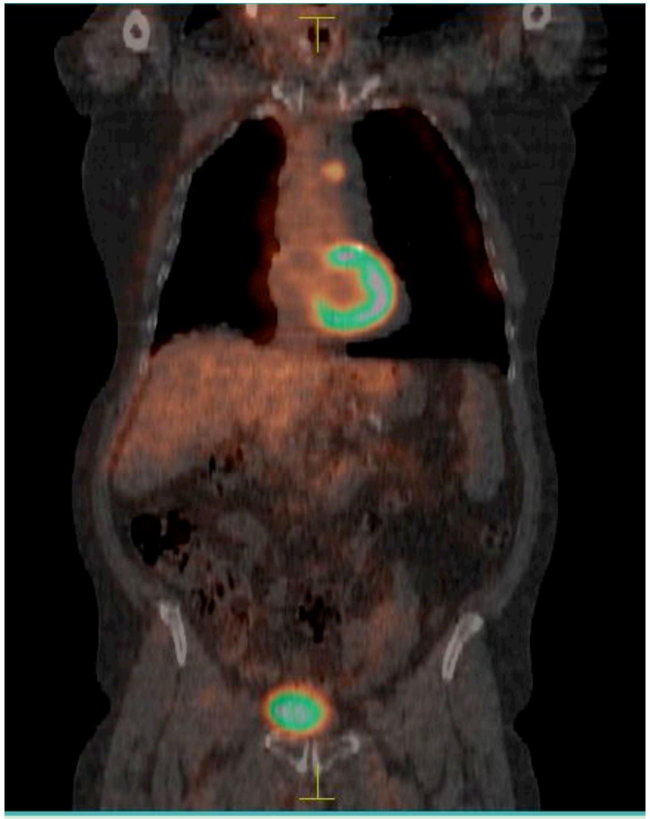
PET/CT

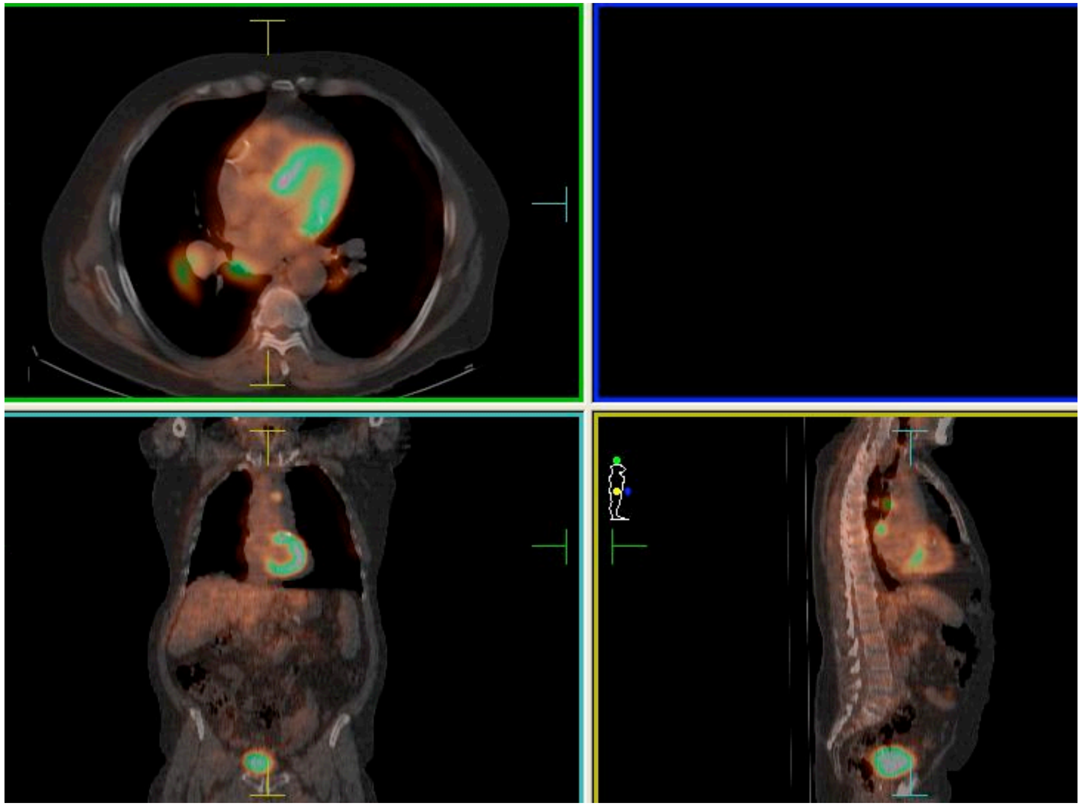
PET



Diaphragm is moving in/out of chest cavity during scan.

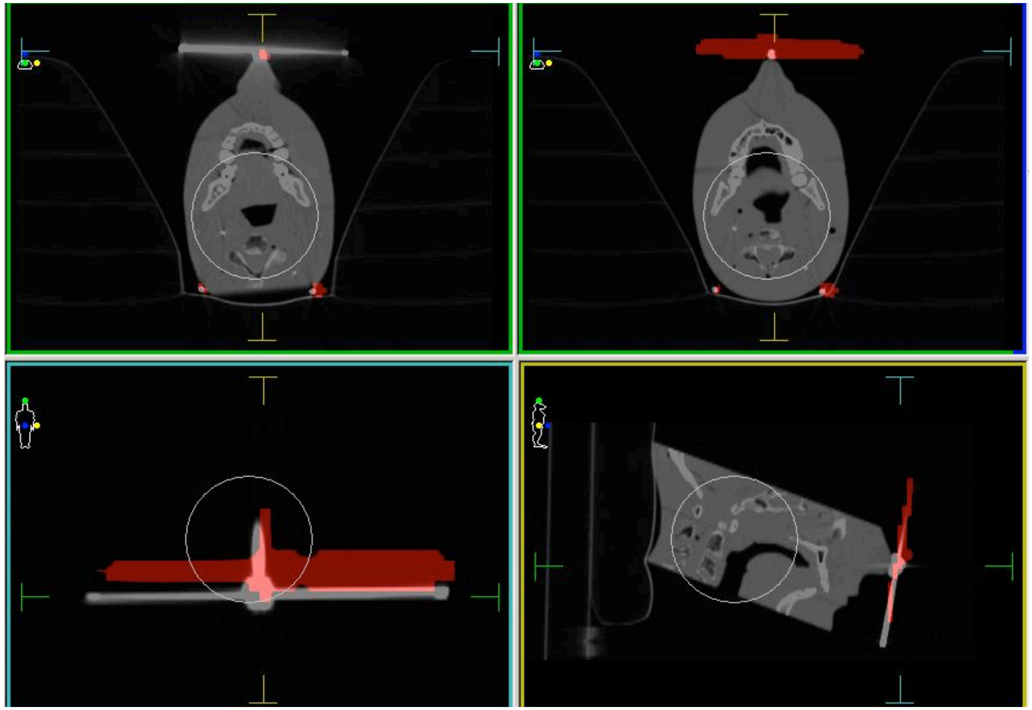
PET/CT didn't look quite right?

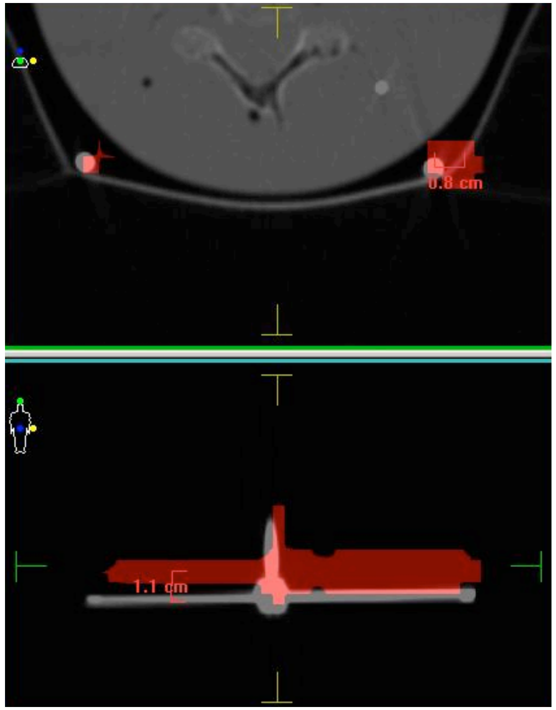




Phantom study with solid line sources demonstrates mis-match was approximately 1cm.

Problem has now be resolved.





PET in Radiotherapy

The direct use of PET images in the Radiotherapy planning process.

Images, in digital format, from PET scanner are imported into planning system.

Registered / Fused with Planning CT images.

Regions of Interest (ROIs) can then be marked using either image set.

The treatment plan can then be produced using these ROIs.

Currently PET is used to diagnose and determine if a patient is suitable for Radiotherapy,

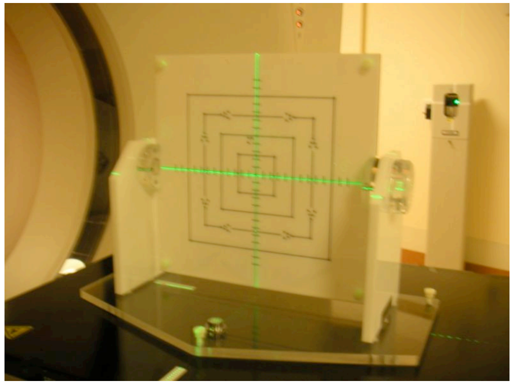
However, currently, is not used significantly in the actual treatment planning process.

What is meant by a Planning CT scan?

CT scan acquired such that

1. There is a method of position reference that allows the treatment region, which is visualised on the CT, to be targeted by the therapy system.
2. The patient position is reproducible on the treatment couch

Sagital

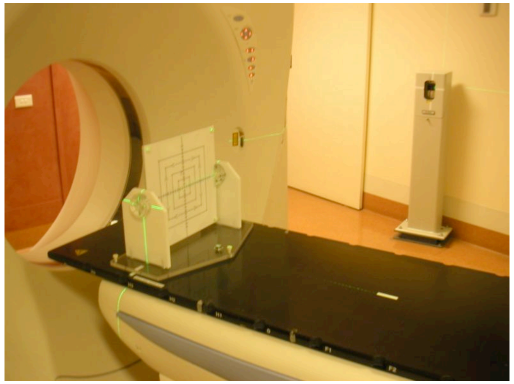


Beam check device in

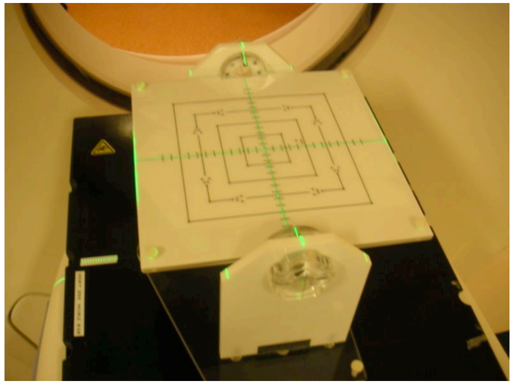
3 orientations to check:

Note – Flat Top for Couch

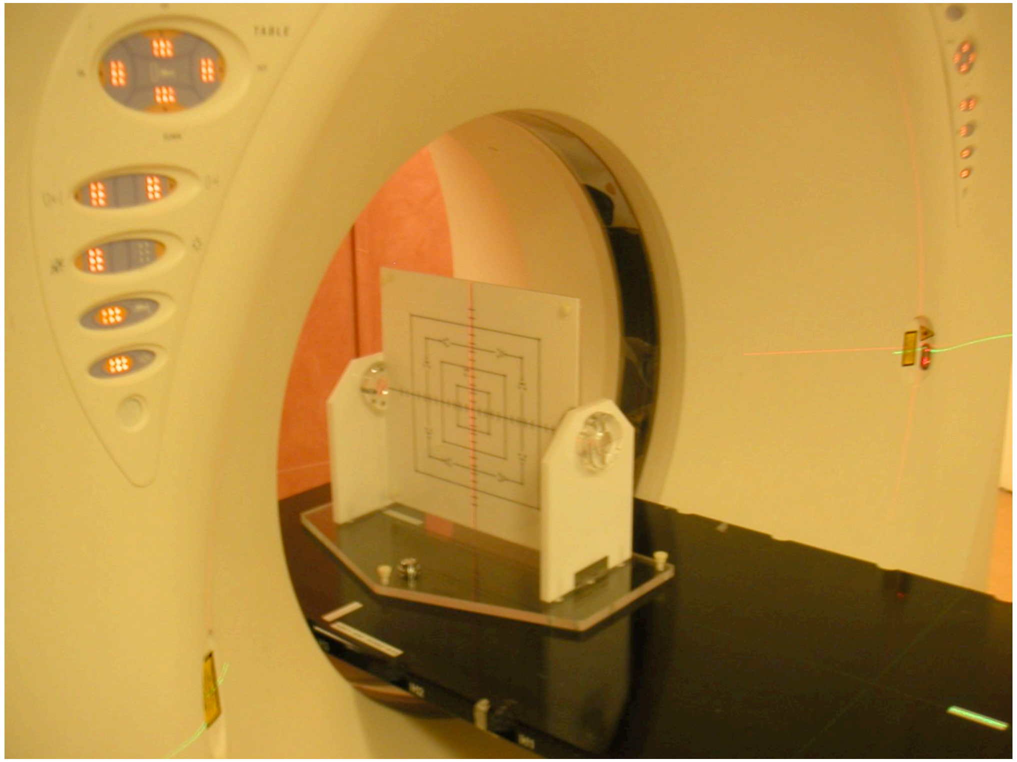
Transaxial



Coronal



Scan phantom – beam check device



The CT scanner usually has internal lasers indicating plane of scan. Generally these are not accurate for RTP.

CMS XiO

4 View Window

Showing:

Transaxial

DRR

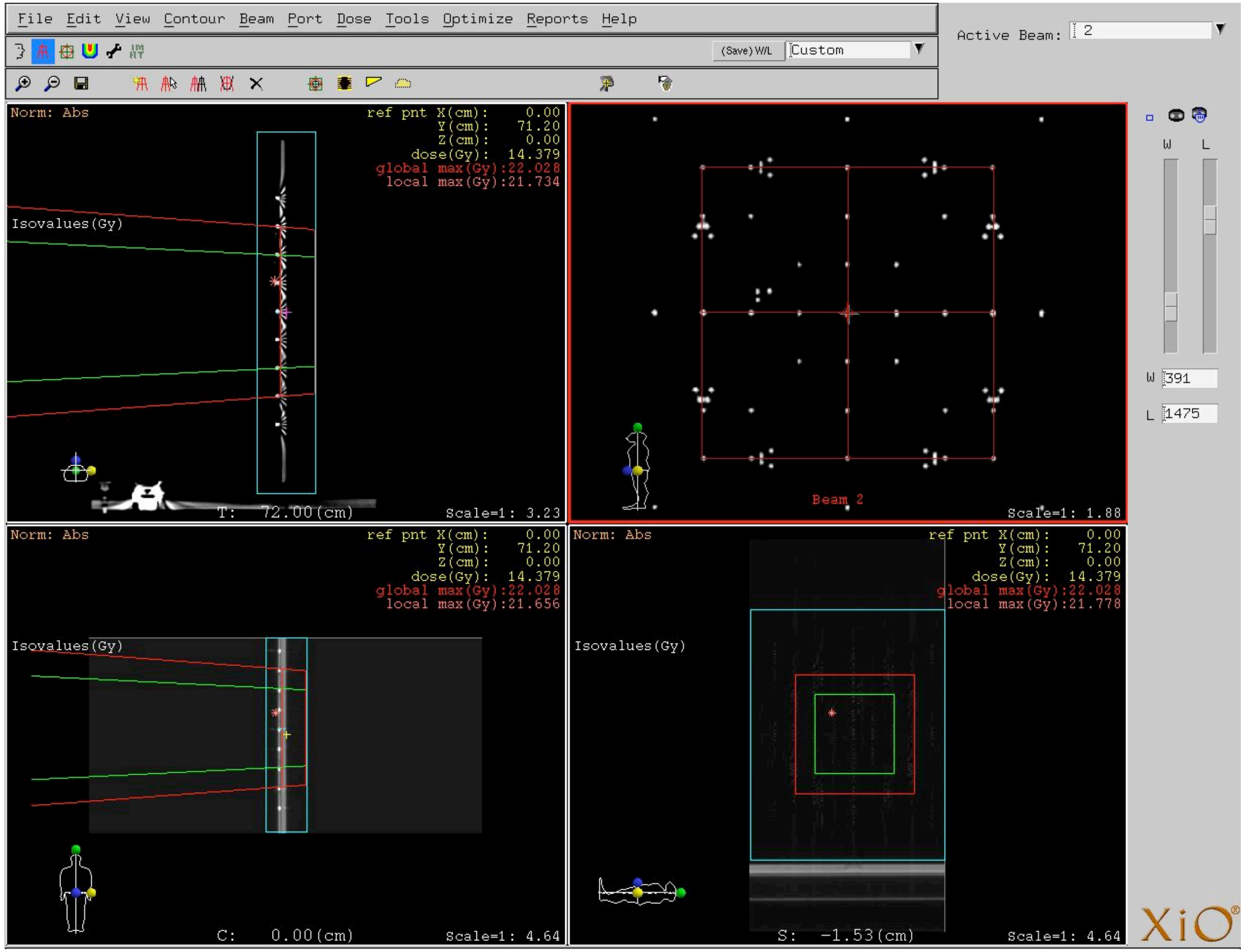
Coronal

Sagital

Green - 10 x 10

Red - 15 x 15

Beams @IsoCentre



Varian 2100C Linac - Treatment

Practical issues of:

Acquiring a PET scan for Radiotherapy.

Importing a PET scan into a Treatment Planning System

Fusing a PET scan with a Planning CT.

Acquiring a PET scan for Radiotherapy.

Use same Patient Positioning devices as for Planning CT

Note includes Flat Top for Couch

This ensures best match of patient position between the 2 scans

Use Fiducial markers that can be identified on both CT & PET

Currently we use canula which can be filled with ^{18}F solution, adjusted such that they are hot enough to be seen but not so hot that they saturate camera.

Markers can be attached to patient fix device eg head mask ensuring accurate placement for both scans.

Base board for fix devices can be a problem depending on diameter of gantry

Different base boards used at Ballarat and Austin.

Best result if Radiotherapist familiar with patient and fix devices involved in patient setup.

Resource problem for Ballarat. Note Head & Neck protocol requires 5 PET scans.

Example Patient Fix device – using Thermo-Plastic head mask

Importing a PET scan into a Treatment Planning System

Use DICOM protocol – modality CT for CT , PT for PET (some systems use NM for PET)

Note CT & PT include a parameter for re-scale (gain,offset) for each slice. Generally in CT this is not used (1,0), however it is used in PT. Several systems reading this data did not take account of this, producing a “stripe” artifact.

Dataset can be transferred by network or copied to CD or other medium.

Treatment planning system has to be capable of loading multiple image sets, generally they are capable of CT however not all accept PT.

Ballarat & Austin both have CMS systems.

CMS have both a Planning system XiO and a Simulation system FocalSim/FocalPro

XiO has limited capabilities for handling multiple datasets.

However, Focal has good capabilities.

Therefore prepare ROIs on Focal, then transfer to XiO for finalisation of the plan.

Fusing PET scan with Planning CT.

Use Fiducial markers. If they are placed accurately, scans should align.

Check by referring to common features.

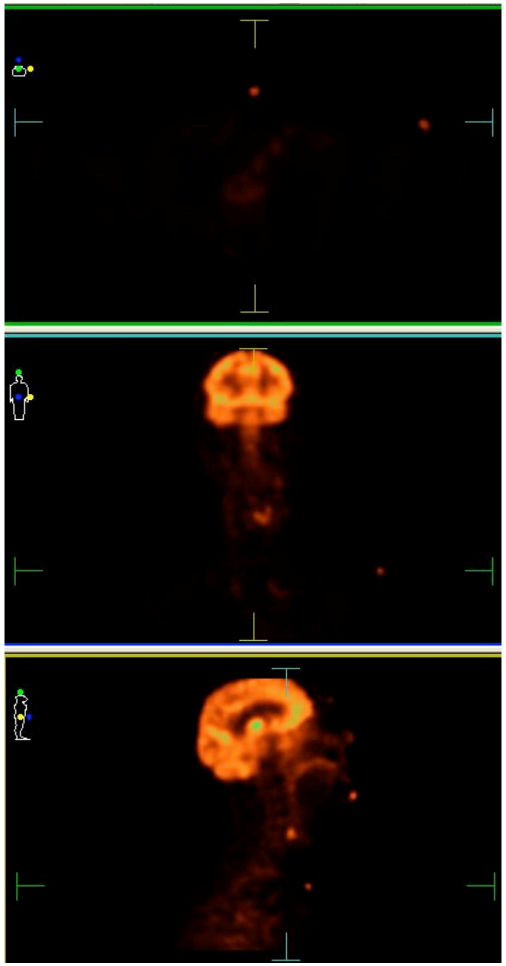
If both the PET & the CT allow definition of "zero" point of scan, and this point has been used on both scans, then the scans should align without having to apply a transformation. Generally, we don't have this working, however does work for PET/CT.

By having setup the patient in the fix device and verified the alignment between the scanners, not only do we ensure the best match for the patient, but we also reduce the transformation to translations only. Avoiding rotations which are generally more difficult to account for.

CT from PET/CT

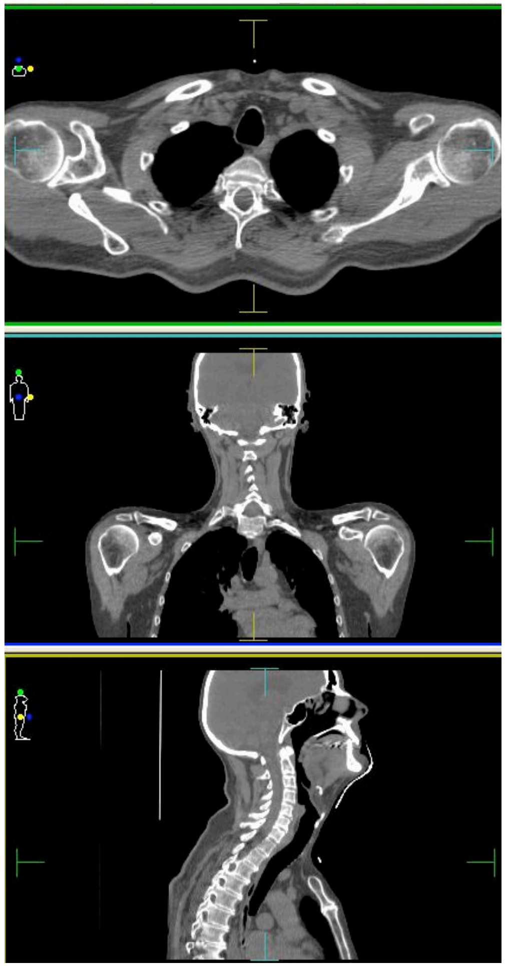
PET/CT

PET from PET/CT



CT from PET/CT

Planning CT



PET/CT

Fused Planning CT & PET from PET/CT

Fusing PET scan with Planning CT.

Without Fiducial markers.

Most systems have “auto-fusion” options, Focal included, doesn’t work well for PET to CT.

However, if we have a PET/CT

Use “auto-fusion” to register the CT from PET/CT to the Planning CT, generally works well.

Then apply transformations to PET from PET/CT. PET now aligns with Planning CT.

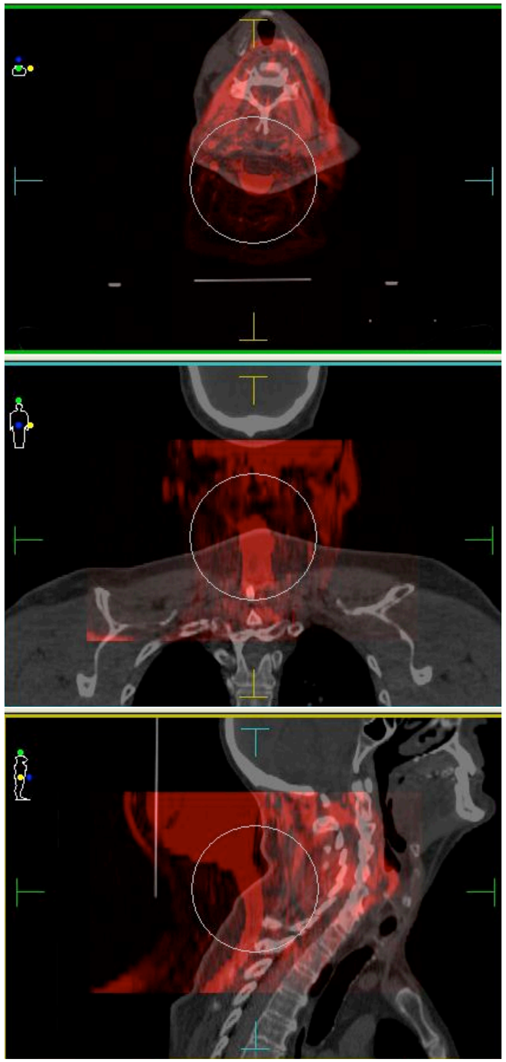
Some PET systems have an attenuation map that is equivalent to a low resolution CT and can be used in the same manner.

Align scans on common features. Variable results.

Compare:

Prospective – we have options for preparing patient

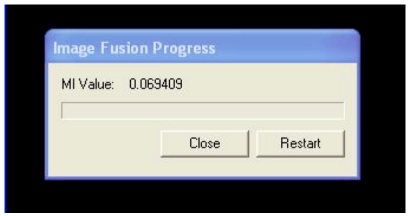
Retrospective – scans already done, we then do what we can.

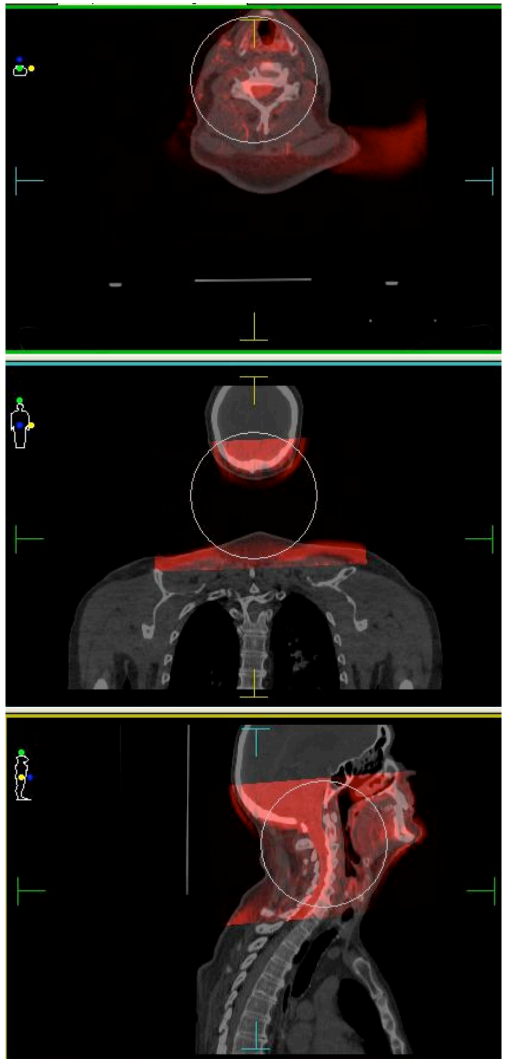


Automated Image Fusion

Based on mutual information algorithms.

Auto-correlation.





Contouring ROIs

Best if both Radiation Oncologist and PET Specialist are involved.

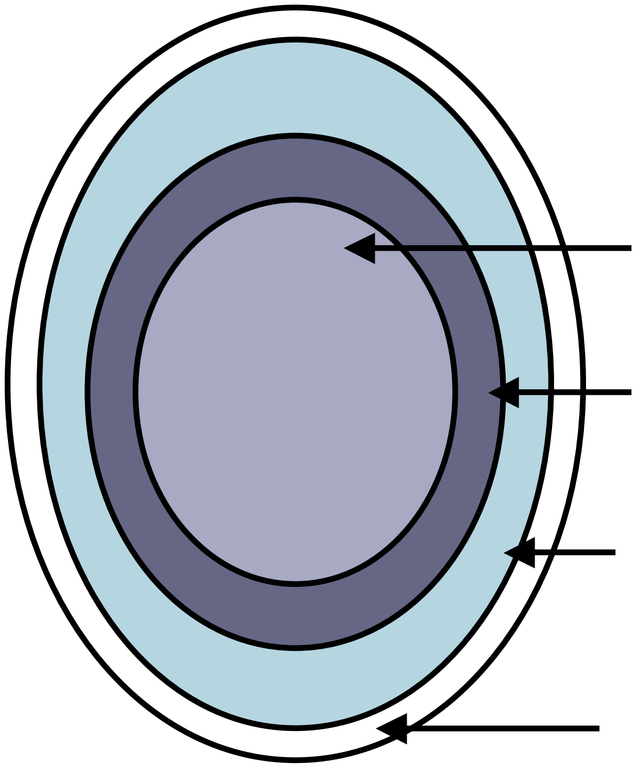
Tools should be familiar to both departments.

If possible, viewing/contouring workstations should be available in both departments.

Not only will the Planning CT to the PET be considered but possibly several other modalities.

Workstation should be capable of not just 2 but multiple image sets.

Volumes originally defined in ICRU – Report 50



GTV – Gross Tumor Volume

Volume in which we can detect the tumor clinically or with image (CT)

CTV – Clinical Target Volume

Volume that contains the microscopic extension surrounding the GTV (PET)

PTV – Patient Treatment Volume

Safety margin to allow for daily setup errors

Treated / Irradiated Volume

Treated volume now almost equivalent to PTV due to comformal techniques, however Irradiated volume still extends beyond PTV.

Tomtherapy have developed an integrated imaging and treatment system that is analogous to a CT.

A (Mega-Voltage) MV CT image can be acquired prior to each fraction of treatment.

Treatment uses the same beam modulated in an analogous manner to the projection images of a CT.

References:

18F-FLUOROMISONIDAZOLE (FMISO) AS A MOLECULAR MARKER OF HYPOXIA IN NON SMALL CELL LUNG CARCINOMA (NSCLC)

Authors *K. Pathmaraj, S. Foo, J. Sachinidis, A.M. Scott

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POSITRON EMISSION TOMOGRAPHY (PET) IN THE RADIOTHERAPEUTIC MANAGEMENT OF HEAD AND NECK CANCERS: EFFECT OF PET WHEN USED IN TREATMENT PLANNING.

Principal Investigators:

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M.B., B.S.; FRACP — Austin Health, Assoc. Professor, University of Melbourne

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