Radiotherapy Planning
(Contouring Lung Cancer for Radiotherapy dose prescription)

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Let us keep this simple and stick to some basic rules
Patient positioning

- Must be reproducible
- Must be stable and comfortable
- Options are:
  - arms above the head, T-bar, Vac-loc, wing board, etc
Planning image

• IV contrast should be used, if possible
• Thin slices enable high-resolution DRRs

• The best concordance between measured and actual diameters and volumes has been obtained with the following settings:
  • W = 1600 and L = -600 for parenchyma
  • W = 400 and L = 20 for mediastinum [16].
• improves consistency in contouring

» Giraud P. Radiother Oncol 2000; S39.
Planning image

- Fluoroscopy for motion – not the best
- Slow CT is better

- 4D CT with phase binning and composite image reconstruction – gold standard

- To be correlated with PET-CT images

» Senan S et al. Radiother Oncol 2004; 71: 139-146
Decision on lymph nodes

- Lymph nodes with a short axis diameter of ≥1 cm are generally considered pathological

- Included in the GTV unless
  - metastases have been excluded by other means such as mediastinoscopy or PET scanning

• Table
Elective nodal irradiation

- No evidence to suggest that elective nodal irradiation is indicated in any patient group receiving curative / radical doses of radiotherapy for NSCLC

- Publications where disease recurrence patterns were established following involved field radiotherapy in stage III NSCLC:
  - no induction chemotherapy was administered in one study
  - a majority of patients in a second study received no chemotherapy

- In all these studies, the incidence of isolated failures in initially uninvolved nodes was <7%.
• Induction chemotherapy has not been shown to improve local control over that achieved using radiotherapy alone,

• the entire pre-chemotherapy GTV is to be treated to the full dose
  – use co-registered pre-treatment and planning CT scans
  – a more accurate reconstruction of pre-chemotherapy target volumes
• Three-dimensional software tools
  – for generating 3D margins around contoured GTVs or CTVs
  – they decrease inaccuracies and reduce inter-clinician variations in contouring

Functional imaging – PET

• More accurate staging
• More accurate tumour outlining
  • Distinguishing tumour from collapse
  • Selective irradiation of involved mediastinal LNs
• Targeted dose escalation
  • RTOG phase-II trials ongoing
**FDG-PET**

• FDG-PET scans are superior to CT scans alone for correctly staging mediastinal nodes

• Incorporating FDG-PET findings into CT-based planning scan
  – Results in changes to radiotherapy plans in a significant proportion of patients [18,37,72]
  – May increase or decrease target volumes
  – Can reduce inter-observer variability in delineating target volumes [37].
  – Inflammation or infection also influences FDG-PET uptake
Functional imaging – PET

- Reduces tumour delineation variability among radiation oncologists
  - Van Der Wel et al. IJROBP 2005; 61:649-55.

- Makes radiation fields generally smaller, may lead to less side-effects
  - Belderbos et al. IJROBP 2006; 66: 126-34.

- Selective mediastinal node irradiation did not lead to higher isolated nodal recurrences
Margins – CTV

• Standard recommendation:
  – Margin for microscopic extension is 5–6 mm for RT planning in NSCLC

Margins – PTV

• To establish the random and systematic errors in treatment planning and delivery at your institution

• To establish tumour motion and organ motion

• 3D margins for the PTV can be calculated based upon the requirement for a certain coverage probability

  – e.g. a large part of the CTV (99%) should receive 95% of the prescribed dose

Organs at risk (OAR) – Spinal cord

• Traditional: 44 Gy in 2Gy/ fraction
• Some trial protocols: 48Gy in 30 fractions

• QUANTEC paper
  – $D_{\text{max}}$ of 50Gy – 0.2% risk of myelopathy (for partial or full cross-section)
  – $D_{\text{max}}$ of 13Gy (single fraction) – 1% risk of myelopathy (for partial or full cross-section)
  – $D_{\text{max}}$ of 20Gy (hypofractionation) – 1% risk of myelopathy (for partial or full cross-section)
Organs at risk (OAR) – Lungs

• Established facts: the following predict the risk of high-grade radiation pneumonitis:
  • V20; i.e. the volume of both lungs minus the PTV receiving 20 Gy
  • mean lung dose

• Whole lung V20 ≤ 30%
  • <20% risk of symptomatic pneumonitis

• Mean lung dose = 20Gy
  • 20% risk of symptomatic pneumonitis
    » QUANTEC paper
• Pneumonitis/fibrosis
  – < 10% of patients
  – Can be fatal
  – Can have a long term impact on quality of life
Follow-up (January 2010)
Organs at risk (OAR) – Oesophagus

• High-grade esophagitis
  – an important dose limiting toxicity for chemo-radiotherapy
  – it correlates with treatment scheme used and volume of irradiated organ

• The incidence of grades 3–4 acute esophagitis is low (5%) with conventional fractionation, even when elective nodal irradiation is performed

Toxicity of concurrent CTRT

• **Oesophagitis**
  – Up to 30% of patients
  – Can lead to dehydration and hospitalisation
  – Transient
  – Manageable
  – Very rarely leads to long term complications

• **Pneumonitis/fibrosis**
  – < 10% of patients
  – Can be fatal
  – Can have a long term impact on quality of life
Organs at risk (OAR) – Others

• There is presently limited data correlating 3D planning parameters with late cardiac and pericardial toxicity

• As the 5-year disease-free survival in stage III NSCLC remains under 20%, these risks may not be an issue for most patients

  » Senan S et al. Radiother Oncol 2004; 71: 139-146
"THIS COULD GET TRICKY -- BEFORE I CAN OPERATE, I'LL HAVE TO FILE AN ENVIRONMENTAL IMPACT STATEMENT."
OARs

- Lungs: auto-contouring tools, then visual check
- Spinal canal
- Brachial Plexus: Pancoast tumours, SABR/SBRT
- Heart / Pericardium: some trial protocols, SABR/SBRT
- Central airways (prox bronchial tree): for SABR/SBRT
Contouring OARs
Brachial Plexus

• Only major trunks to be contoured

• Using Subclavian and axillary vessels as surrogate

• Start inferiorly at the bifurcation of the Brachiocephalic vein/artery

• Follow the vessels upwards

• Stop when the vessels cross the Second rib
Brachial Plexus

Some coronal images
Heart & Pericardium

- Heart is to be contoured with the pericardial sac

- Superior limit of the contouring is the inferior extent of the aortic arch

- Inferior extent is the lowest part of the left ventricle’s inferior wall, that is distinguishable from the liver

- Includes the heart, main pulmonary vessels, ascending aorta, SVC.
Heart & Pericardium

Some coronal images
Proximal Bronchial Tree

• Start at least 10 cm superior to the extent of the PTV or 5 cm superior to carina

• PBT + 2 cm all around is the “no-fly zone”

• PTV (but not the ITV) can encroach on the “no-fly zone”
Proximal Bronchial Tree

Some coronal images of the PBT (green) and the “no-fly zone” (yellow)
Prescriptions can be ...

- **Dose based**
  - The PTV should receive 60Gy
  - The spinal cord should not receive >44-48Gy

- **DVH based**
  - 95% of the PTV should receive 60Gy
  - No more than 35% of the lung(-PTV) should receive 20Gy or more

- **Biological**
  - The tumour control probability should be >95%
  - The risk of grade 2+ lung toxicity should be <8%
  - *Less known about exactly how to do this/what numbers to use*
Plan Evaluation

• Check plan against dose constraints
  – Have objectives / constraints been met
• Isodoses
  – Scroll through specific isodose levels
    • 95% of PTV(s)
    • Identify hot spots
  – ? dose dumped into an unexpected place
• Look at Dose Volume Histogram
• Check for the unexpected!
  – Things that you had not thought of!
Dose volume histograms

- 3D plan information can be summarised into a 2D graph:
  - but remember some spatial information is lost
  - a DVH only tells you information about the structures you have accurately contoured

- Volume and dose statistics can be read off from a DVH
  - $D_V$ (absorbed dose in fraction $V$ of the volume)
  - $V_D$ (volume receiving at least an absorbed dose $D$)
Pitfalls

• Things to look out for:
  – Structures undefined / unclear nomenclature
  – Over complication
  – Hot spot outside PTV
  – Baggy PTV coverage
  – Build up region
  – Bolus
Now, some contouring...........

Thank you