Beam energies treatment for lung and larynx

Larynx Error Plan

Errors:

- Beam energies for larynx treatment are not correct – both fields have 10MV instead of 6MV
- Field sizes are not right
    - The Right Lateral (RLat) field is too big resulting in shielding errors
    - The Left Lateral (LLat) field is too small and is just skimming the anterior portion of the patient’s shell
- The number of fractions on the plan is one (1) instead of 20 daily fractions.
- The global maximum dose is 110. 98% (given as 6103. 7 cGy) and is largely outside the Planning Target Volume (PTV), meaning the plan is too hot
- The 108% region is a hot spot as it exceeds the International Commission on Radiation Units and Measurements (ICRU 50 & 62) maximum value of 107%
- The LLat field wedge is too thin 1 ^{o} , so not helping with uniform dose distribution of the plan, hence the right skewed isodoses and the 108% hot spot
- The plan’s maximum spinal cord dose of 5112 cGy, exceeds the maximum dose constraint value for the organ of 5000 cGy.
- Multi-Leaf Collimators (MLC) use on the plan
    - There is not much conformality to the PTV anteriorly from the RLat field

  - There is insufficient shielding of the neck anteriorly
  - Some MLC are not pulled up properly as they are on the field edge which is better shielded by the Primary collimators

- The RLat field is over-wedged (60 ^{o}), resulting in the 108% hotspot region
- The RLat field is not placed optimally re-collimator angle in order to better avoid the spinal cord
- The Dose Volume Histogram (DVH) data/graph/chart is insufficient as it is only for the spinal cord excluding for example the PTV information
- The isocentre could be placed more centrally for the plan

Criteria use to evaluate the suitability of the treatment plan

This is a conventional parallel-opposed field arrangement, which is suitable for head and neck treatment of the larynx (Barrett and Dobbs, Practical Radiotherapy Planning, page 171). Since this is an error plan, the fields do not match in size though they are parallel opposing. The radical dose prescription is 55 Gy in 20 daily fractions of 2. 75 Gy over 4 weeks (Barrett and Dobbs, 4 th Ed., page 175). This would apply as a prescription for a T1-2 N0 glottic larynx tumour with a volume of 26-49 cm ^{3} (RSCH, St Luke’s Radiotherapy Clinical Protocol, Head and Neck Larynx).

Use is made of isodose charts, PTV coverage as indicated by the D_{95} (95% isodose line), maximum PTV dose (D_{max}), maximum spinal cord dose, dose volume histograms (for PTV and spinal cord), and departmental protocols to evaluate the suitability of the treatment plan. The Quantec/Emami et. al. (2013) document of Tolerance of Normal Tissue to Therapeutic Radiation provided the dose constraints for the organs at risk e. g. the spinal cord. NICE guidelines only stipulate an offer of choice of trans-oral microsurgery or radiotherapy to people with newly diagnosed T1b-2 squamous cell carcinoma of the glottic larynx.

The plan is optimised by use of beam modifying devices like wedges and MLC (Barrett and Dobbs, page 171), and checking the effect using the planning software.

Solutions to eliminate identified errors:

1. The beam energy needs to change from 10MV to 6MV in the field properties of the planning software. This will ensure adequate coverage of the PTV as a significant part of the larynx is very close to the skin. A less energy beam offers less penetration and lower build up depth (for skin sparing effect) for dose deposition.
2. The RLat field size can decrease slightly anteriorly, while the LLat field size can increase slightly to ensure adequate anterior coverage. The fields could also be more symmetrical.
3. The LLat wedge's orientation needs to change so that the Thick end is Anterior as per the setup information (Toe in).
4. The number of fractions is should change to 20 from the current one fraction. This would give the appropriate dose prescription for the plan of 55Gy/20#/4weeks/2. 75Gy per fraction
5. The current plan is too hot, so the beam weightings need adjusting downwards until the plan conforms to the ICRU limits of maximum 100% + 7% (= 107%), and the lower limit of 100% – 5% (= 95%) of the

proscription dose (ICRU). This process can also improve by correcting the wrongly orientated LLat wedge and using a better wedge angle on it, as well as adjusting down the angle of the over-wedged RLat wedge.

6. Correcting the 108% hotspot region is through adjusting the wedge angles, re-orienting the LLat wedge and adjusting the field weightings.
7. The thin 1 ^{o} LLat wedge angle needs changing up to 30 ^{o} for the wedge to have an effect on the isodose distribution, on top of reversing its orientation. This would help in creating a uniform dose distribution for the plan and a reduction/elimination in/of hotspots.
8. According to the Quantec/Emami et al. (2013) guidelines, the spinal cord is to receive a maximum core dose of 50Gy, but the current plan is exceeding this limit. Adjusting the collimator angle for the fields to be parallel to the spinal cord will help avoid treating this critical organ This is also aided by reducing the field weightings, adjusting the wedge angles and orientation of one of them, adjusting the field sizes posteriorly.
9. The MLC leaves need to close where they are open outside the treatment field edges. There is a leaf to shield the anterior corner of the neck but is pulled back, so needs to be part of the configuration. There are five (5) pairs of almost central leaves, that are on the field edges inferiorly and superiorly, they need pulling back by 0. 5 cm from the field edge so they do not interfere with primary collimation (Royal Surrey County Hospital (RSCH), St Luke’s Radiotherapy Clinical Protocols). Adjusting the RLat field size anteriorly will aid in correcting the shielding of the neck and improve conformality to the PTV.

10. The RLat field wedge needs reducing to at most 30 ^{o} to aid uniform dose distribution and reduction of hotspots.
11. Changing the collimator angle of the RLat field so that it is parallel to the spinal cord, will avoid treating through this critical organ. This will result in reducing the spinal cord's maximum dose for the plan to within the organ's maximum dose constraint value of less than 50Gy, thus aiding in optimising the plan.
12. The DVH information of the plan should include the PTV data and line plot to enable plan evaluation of its suitability.
13. Making the isocentre more central may improve the uniform dose distribution of the plan.

Suitability of Plan and Alternative beam arrangement

According to De Virgilio, A., et. al. (2012), there is currently no set therapeutic gold standard for the treatment of laryngeal squamous cell carcinoma. This contributes to a lack of consistency and inhomogeneity in treatment planning. The plan under consideration is a 2D conventional plan, which in itself is suitable with the exception of the errors, but is not optimal. The identified errors are correctable and the plan optimisable. In remaining with the conventional plan, a third anterior low-neck field with a light weighting (3DCRT) is an option to improve dose distribution and eliminate hotspots. However, this would require the addition of electron beams to match the photon fields, according to Herrassi, M. Y., Bentayeb, F, and Malisan M. R. (page 98-105). Another option is to use Intensity Modulated RadioTherapy (IMRT) with 3 or 5 beams, or Volumetric Modulated Arc Therapy (VMAT) with one arc, (Matthiesen C, Singh H, Mascia et. al. (2012)).

IMRT offers more conformality in regards to carotid arteries as stated by Gomez, D., Cahlon, O., et. al. (2010). Portaluri, M., et. al (2006), suggest that 3D Field-in-Field techniques are a valid alternative as they offer the best global performance when considering PTV coverage and parotid sparing.

Conclusion

The task was instrumental in reinforcing the importance of understanding the process of treatment planning, and how to check the suitability of the plan before its approval. There is not much information to work with in suggesting alternative beam arrangements. Useful information could have been correct TNM classification, appropriate oncological classification taking into account the anatomic-embryologic and functional complexity of the larynx. There were glaring errors in the plan, and as an exercise, they were useful in sharpening treatment planning knowledge. IMRT is the preferred treatment technique that is efficacious especially for parotid gland and carotid artery sparing.

Lung Plan

Errors:

- Beam energies should all be 6MV, some are 10MV on the plan
- There are too many fields for the plan
- The LLat beam is going through the contralateral lung
- The field placement of the right posterior oblique (RPO) is not optimal as its MLCs are shielding part of the PTV contributing to the inadequate 95% dose coverage of the PTV.

- The global max value of 109% exceeds the ICRU guidelines, meaning the plan is very hot in places.
- There is an 80% hot spot on the chest, which is very hot for the area close to the skin
- There are many wedges on this plan resulting in hot and cold spots and a high dose gradient in the PTV.
- The Right Lateral and Anterior fields are over-wedged, resulting in the 80% and 109% hot spots.
- The RPO and LLat field wedge angles are not conventional (50 ^{o} and 33 ^{o} respectively, when considering the standard wedge angle specifications of 15 ^{o} , 30 ^{o} , 45 ^{o} and 60 ^{o} .
- The Lateral fields (Right Lateral and Left Lateral), are too big in relation to the size of the PTV, resulting in unnecessary irradiation of healthy tissue.
- The current plan exceeds the spinal cord core dose (maximum 50Gy), as interpreted from the DVH data.
- There is less than 95% PTV coverage laterally , resulting in a max dose to the PTV of 5304 cGy, which is very much less than the expected 6080 cGy (95% of 6400 cGy).

Criteria use to evaluate the suitability of the treatment plan

Barrett and Dobbs (page 252), acknowledge that there are a number of challenges to covering the PTV fully and remaining within the ICRU constraints, while maintaining acceptable toxicity levels at the same time. A three (3) field conformal plan is normally used for stage I or II non-small cell lung cancer (NSCLC). A compromise on choosing the best plan is mostly dependent upon the location and size of the PTV, and its closeness to critical structures, like the spinal cord and oesophagus.

The plan should try to minimise dose to the contralateral lung as much as possible by using anterior oblique, posterior oblique and lateral beams. Beam modifying devices such as wedges compensate for obliquity at the chest, with MLC shielding conforms each beam to the shape of the PTV (Dobbs and Barrett).

Use is made of the Quantec/Emami et. al. (2013), document on Tolerance of Normal Tissue to Therapeutic Radiation in checking dose constraints to organs at risk e. g. brachial plexus, oesophagus and spinal cord. Plan evaluation also uses isodose charts, dose volume histograms and departmental protocols to establish the suitability of the plan. NICE guidelines for Radiotherapy with curative intent for Non-small cell Lung Cancer stipulate that the patient should have good performance status (WHO 0 or 1). It says, CHART should be offered first, but if unavailable then conventional radiotherapy of 64-66 Gy in 32-33 fractions over 6 ½ weeks or 55 Gy in 20 fractions over 4 weeks is the next option. This plan is for 64 Gy in 32 fractions over 6 ½ weeks, so meets with this criterion.

Dobbs and Barrett (page 253), mention that careful evaluation of the plan using DVHs is especially important when considering keeping the V20 below 32 per cent (the volume of lung receiving more than 20Gy of the dose).

Solutions to eliminate identified errors:

1. Barrett and Dobbs (page 255), point out that beam energies above 10 MV should be avoided due to greater range of secondary electrons in lung tissue, which result in a wider penumbra and thus more radiation to normal tissue. Beam energy of 6MV is adequate, while use of 10MV is for separation at the centre is greater than 28 cm. (Dobbs and Barrett, page 252). As no mention of the separation, it is appropriate to use 6MV on all the beams for this plan instead on mixed energies.
2. This is a conventional plan, and the common number of beams 3 instead of the current 5. The many fields have not helped in conforming the plan to the PTV and improving the dose distribution, but have contributed in unnecessary irradiation of normal tissues. So, removal of the anterior and left lateral beams, would bring the plan back to a conformal 3 field plan. The right posterior oblique field would need setting at around 215 ^{o} -225 ^{o} in order to cover the PTV better and its MLC not to shield the PTV as at the present. (RSCH and London Cancer centre protocols).
3. The left lateral field is treating through the contralateral lung, which is operationally against ICRP (2007), ICRU and IR(ME)R 2000 guidelines of keeping dose as low as reasonably achievable (ALARA) to patients, employees and the general public. The corrective measure is to remove the left lateral field from the plan.
4. The gantry angle for the right posterior field is not optimal and moving it to around 215 ^{o} -225 ^{o} range would improve coverage of the PTV and avoid the spinal cord, even though the MLC is shielding the cord (ideal) in the current setup but also part of the PTV that is not ideal and compromising the 95% coverage of the PTV.

5. The global maximum value of 109% exceeds the ICRU target of maximum 107% within the PTV. Removing the anterior and left lateral fields, and adjusting the over-wedged posterior and right lateral field wedge angles to either 15 ^{o} or 30 ^{o} depending on the uniformity of the dose distribution within the PTV, will rectify this issue. The remaining field weights will need adjusting as well to fully optimise the plan.
6. Moving the RPO beam angle to between 215 ^{o} and 225 ^{o}, as well as reducing the wedge angle to 30 ^{o} and removing the anterior beam from the plan will correct the 80% hotspot region.
7. Removing the anterior field will effectively eliminate the 80% hot spot region on the chest. Removing the left lateral field and wedging the right anterior oblique field will help in reducing or eliminating the 109% hot spot region in the PTV. These measures will also result in more uniformity in dose distribution when combined with adjusting the weights of the remaining fields.
8. The current plan has many wedged fields (some over-wedged), which is rectified by removing the anterior and left lateral field from the plan, adjusting the right lateral wedge angle to either 15 ^{o} or 30 ^{o}, and that of the posterior field from 50 ^{o} to either 15 ^{o} or 30 ^{o} and inserting a 15 ^{o} or 30 ^{o} wedge on the anterior oblique field. This should improve the uniformity of the dose distribution within the PTV.
9. The non-conventional wedge angles of the posterior and left lateral fields (50 ^{o} and 33 ^{o} respectively), have not improved the dose distribution in any noticeable way, as there is still a high dose gradient

in the PTV. Reverting to the standard angles and using either 15 ^{o} or 30 ^{o} at most, would improve the dose distribution of the plan.

10. The two lateral fields are too big; therefore adjusting them posteriorly would improve the PTV coverage of the plan and less irradiation of normal tissue. The left lateral field however needs taking off the plan altogether.
11. The current plan shows excessive dose to the spinal cord and according to the Quantec/Emami et. al. (2013) document, the maximum core dose to the spinal cord should not exceed 50Gy.

    Moving the right posterior field angle to 215 ^{o} -225 ^{o} range and removing the anterior beam will correct this anomaly
12. The less than 95% coverage of the PTV is achieved by:
    - positioning the posterior field optimally (between 215 ^{o} and 225 ^{o}), so that the MLC will not shield the PTV' but still manage to shield the spinal cord;
    - adjusting the field sizes of the oblique fields; applying 15 ^{o} or 30 ^{o} wedge to the right anterior oblique field and adding MLCs to it so that it conforms the PTV better thus improving the dose distribution to the plan;
    - and applying MLCs to the right lateral field to conform the PTV better.

Suitability of Plan and Alternative beam arrangement

This plan is not suitable for patient treatment in many respects, as highlighted by the errors identified. Improving it is by reverting to the conventional three field/beam plan, with two right oblique fields and the right lateral field as the third one (Barrett and Dobbs, page 252). Other treatment techniques, e. g. IMRT (with emphasis on carotid sparing), helical tomotherapy, VMAT have been found to offer better results on dosimetric comparisons. However, a multi-modality approach could be the best approach when considering new data coming from immunology, molecular biology and genetics on top of the usual surgery, chemotherapy and radiotherapy treatment options (Franco, P., et. al. (2016)).

Conclusion

This exercise highlighted the importance of quality assurance and having several layers of checking the suitability of treatment plans that are eventually used on the patients.