DOS 771
Planning Assignment – Lung
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5/3/2015

Prescription: 6000 cGy in 30 fractions of 200 cGy, delivered daily, 5 fractions per week.

Organ at Risk	**Desired objective**	**Achieved objective**
Spinal Cord	Max dose < 45 Gy	48.1 Gy (not met)
Esophagus	Mean dose < 34 Gy	19.6 Gy (met)
Right lung	V20Gy < 37%	26.3% (met)
Left lung	V20Gy < 37%	0% (met)
Heart	V40Gy < 50%	0% (met)

Plan 1

a) With 6 MV beams, the dose distribution is highest a few centimeters from the surface of the skin near the anterior/posterior (AP) and posterior/anterior (PA) beam entrance points, and the dose tapers down the deeper it goes. The isodose lines bow inwards towards the central axis as depth increases. In the portion of the beam passing mostly through open lung, this bowing is relatively smooth, but the portion of the beam clipping the mediastinum has ragged irregular isodose lines.

b) The PTV is not completely covered by the 95% isodose line. The PTV coverage by the 95% isodose line is 93.6%.

c) The point of maximum dose is near the AP beam in the right breast tissue. The hot spot is 7750 cGy (129% of Rx).

Plan 2

a) After switching to 23 MV beams, the isodose lines show a much more uniform distribution of dose. The hot spots near the beam entrances are much lower, and perturbation of the isodose lines in the mediastinum is reduced.

b) The global point of maximum dose is still near the AP beam entrance point, but it is a few centimeters deeper than with 6 MV beams. The reason that the maximum dose point is near a beam entrance point is due to the shape of the depth dose curves, which fall off faster than linearly because of radius-squared components involving spherical energy distribution. At a depth of D_{max}, the point being measured has full dose from one beam plus some contribution from the opposing beam. At the center of the patient, the attenuated strength of each beam adds up to less than this value.

Plan 3

a) When the beam weights are adjusted to 43.5% on the AP beam and 56.5% on the PA beam, the global maximum dose reaches its lowest value.
b) When the beam weights are adjusted, the PTV coverage remains almost unchanged. The differences are subtle. The V95 coverage drops less than 1% from 91.5 % to 90.9%. For all intents and purposes, the equally weighted and unequally weighted plans might as well be seen as equivalent with regard to PTV coverage.

Plan 4

Strategies for cord avoidance…

i. The third beam will not intersect the cord if the gantry angle is kept between 195 degrees and 240 degrees.
ii. If the blocking around the PTV is tightened to avoid the cord, the range of viable gantry positions for the third beam is between 170 degrees and 280 degrees.
iii. Changing only the jaw on the cord side (in this case X1), the range of possible angles that block out the cord is between 175 and 265 degrees.

I tested two gantry angles: 225 degrees and 270 degrees. The 225 degree right posterior oblique (RPO) position was chosen because it avoids the cord, it avoids skin entrance point overlap with the PA beam, and it minimizes the amount of contralateral lung in the field. With this arrangement, a flattened diamond of higher dose is created where all three beams overlap. In the points at the long ends of the diamond, where it is closest to the skin, hot spots are created in the posterior rib and in the mediastinum just deep to the sternum. Changing beam weights can reduce these hot spots but not eliminate them. Then again, the hot spots are only around 106% of Rx, which isn't bad. The two obtuse-angle corners of the diamond have relatively lower dose, making it difficult to get full coverage by the 95% isodose line. The plan could be normalized to a lower isodose level to achieve coverage, but this would heat up the hotspots too. If wedges are introduced to the 225 degree plan, a lower global maximum dose can be achieved while maintaining good coverage of the PTV. The best variant of this geometry used the following wedges:

- AP: 10 degree collimator turn with a 45 degree hard wedge pushing dose mostly to the right, but also very slightly in the inferior inferior direction.
- PA: 60 degree hard wedge pushing dose medially, away from entrance point of the RPO.
- RPO: 60 degree hard wedge pushing dose laterally, away from entrance point of the PA.

With this arrangement, and with AP, PA, and RPO weighting of 20.3%, 41.1%, and 38.6% respectively, the 95% prescription isodose line covers 99.6% of the PTV and the global maximum is 103.3% of prescription.

Trying another strategy, with the 3rd beam at 270 degrees and with the MLC leaves blocked to avoid the cord on the new beam, the isodose distributions take on a squarish box shape. I had expected the dose around the target to be biased towards the direction of the entrance point of the third beam, but it was largely symmetrical both left/right and anterior/posterior. This could be partially explained by the tumor's attachment to the mediastinum, because the denser mediastinum tissue would provide more scatter contribution than the low density lung tissue adjacent to the other side. This imbalance of scatter contribution from one side or the other seems to counterbalance the effects of attenuation and radius-squared falloff on the primary beam of the new field.

The best 270 degree plan variant used the following wedge:

- AP: 25 degree dynamic wedge to push dose in the inferior direction, compensating for chest wall slope.
- PA: 15 degree hard wedge to push dose medially, to make up for lack of scatter contribution from the trachea.
- Right lateral (RLAT): no wedge needed.

With this arrangement, and with AP, PA, and RLAT weightings of 36.7%, 41.7%, and 21.6% respectively, the 95% of prescription isodose line covers 99.9% of the PTV and the global maximum is 103.0% of prescription.

The 270 degree plan was superior to the 225 degree plan in many ways. The DVH shows lower dose for the heart, trachea, and esophagus. The spinal cord is hotter with the 270 degree plan, largely due to the higher weighting of the AP beam as compared to the 225 degree plan. Even though the 270 degree plan aims more directly at the contralateral lung, the dose distribution is mostly more favorable. The maximum dose in the contralateral lung is 1159 cGy versus 2231 with the 225 degree plan. The V10 is 2.9% versus 12.9%, but there is more low dose coverage with a V5 of 27.4% versus 15.6% on the 225 degree plan.

This assignment gave me valuable practical experience with lung planning. I learned more about how to manage wedges when more than two beams are involved, which can be a complex interplay.

On my next lung plan, I will start by rotating the AP and PA fields slightly to keep them off the spinal cord, so that I can keep the dose much lower without having to adjust later in the process. Although 23 MV beams appear to give reasonable coverage at depth without high entrance dose, I do not fully trust the planning system's algorithm to calculate dose accurately at boundaries between solid tissue and lung tissue, which makes almost any lung plan suspect. I could already see how scatter contribution differences from the mediastinum and lung on one side of the other of the tumor caused distributions I had not expected, and I could see how the air in the trachea created a region nearby where it was difficult to achieve full dose coverage. A lower energy beam can achieve electron equilibrium over a shorter distance, so while the algorithms shortcomings may not be fixed, the lower energy may reduce the magnitude of the error. A lower energy will create higher entrance doses, so I will have to spread the dose across several beams. Before this assignment, I was hesitant to use a direct lateral beam because I thought the exit dose into the contralateral lung would be too high, but I now see that the mediastinum acts somewhat like a shield, attenuating the exit dose before crossing over to the other side.