Radiation Therapy and 4-Dimensional (4D) Planning

The treatment of lung cancer with radiotherapy is rapidly changing as new technologies make the treatment safer and more effective. One of the more recent developments has been the development of tools that allow for designing radiation fields that account for a tumor’s specific motion, or it’s change in position over time, the fourth dimension.

In conventional radiotherapy treatment planning, patients are positioned in the CT simulator room in the position that they will be treated in. The patients then actually undergo a CT scan. The images are transferred to a treatment planning computer. Specialized treatment planning software is used that processes the CT images for analysis. A 3D image of the patients target region is created on the computer. In patients with lung cancer, this region typically includes the lungs, spinal cord, heart, esophagus, ribs and other tissues. The primary tumor and regional lymph nodes can often be identified on the CT scan and the 3D rendering. The radiation oncologist and team will identify the targets that need to be treated and proceed to design fields that encompass the targets while minimizing exposure to the normal tissues. This approach, however, doesn’t account for the motion of the tumor do to respiratory motion (from breathing).

The treatment planning CT scan represents a “snapshot” in time. In essence, it lets the radiation oncologist and team identify the tumor’s location at that time and in that particular portion of the respiratory cycle. In order to account for the tumor motion, most practicing radiation oncologists will add a “safety margin” around the target to account for this motion that is occurring while the patient is breathing. In effect, a larger region is exposed to radiation to make sure that wherever the tumor might actually be it will still receive radiotherapy. The size of the “safety margin” is typically about 1-2cm in every direction.

Recently, there has been increased awareness that the generic application of a “safety margin” for every lung tumor may not be the most accurate or safe way of treating a patient. It is possible that for some patients, their lung tumor moves by an amount greater than the applied safety margin. For other patients, their lung tumor moves very little and the generic safety margin is relatively large, so a large amount of normal lung is exposed to radiation treatment. Finally, with a single CT scan it is difficult to know for sure that an extreme position of the tumor was not imaged. For example, a patient may have been in deep inspiration or expiration during the CT scan, and the position of the tumor on the scan does not accurately reflect the position of the tumor while the patient is being treated.

4D treatment planning overcomes many of these problems. In this process, the patients undergo a series of CT scans during a respiratory cycle. The CT images are obtained rapidly, and so each image set shows the tumor in a slightly different position as it moves through a respiratory cycle. Each CT image set is correlated with its position in the respiratory cycle. By evaluating all the images sets, the radiation oncologist can design a treatment field that encompasses the entire extent of motion. More importantly, this is a patient specific motion encompassing approach. For some patients, this will result in larger but more accurate treatment fields than the conventional single CT scan approach. For other patients, this will
result in smaller fields that have less normal tissue exposure.

In order to do 4D treatment planning, a specialized multi slice CT scanner is needed and specialized treatment planning software. This technology is currently available at many centers.