University of Wisconsin La Crosse
DOS 531 – Clinical Oncology for Medical Dosimetrists
CSI Project
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1)

Placing a board or other buildup material under a patient's torso can serve several purposes when simulating in the prone position. The primary intent of this type of setup is to affect the relative positioning of the head and legs (Jen Price, Oral communication, June 26, 2015). With the torso raised, the head has more leeway to fall forwards, which may result in a more comfortable neck position for the patient depending on their body habitus. It may also straighten and lengthen the cervical neck, allowing more of it to fit inside the lateral fields, which will help to spare the throat, which would otherwise receive dose from the posterior beam. On larger patients, it may even have the benefit of flattening a skin fold at the back of the neck.

Raising the torso relative to the legs will allow the legs to pivot forwards slightly, which patients may find to be a more comfortable position. This can also rotate the pelvis, flattening the curvature of the lumbar spine, which can make the distance from source to target more consistent along the length of the spine.

2)

The upper spine and head ports of a CSI plan must be matched according to the angle of divergence of each field. On a prone CSI treatment, the upper spine field is delivered from the patient's posterior side, and the beam diverges more and more in the superior direction as the path continues anteriorly. When viewed from a sagittal perspective, the superior margin of the upper spine field will appear tipped, with the posterior portion of the edge more caudal than the anterior portion. The head ports are delivered laterally, so the beam's eye view of the head ports is close to being the same view as the sagittal view. From this perspective, it is simple to see that a turn of the collimator can be used to match the divergence of the upper spine field.

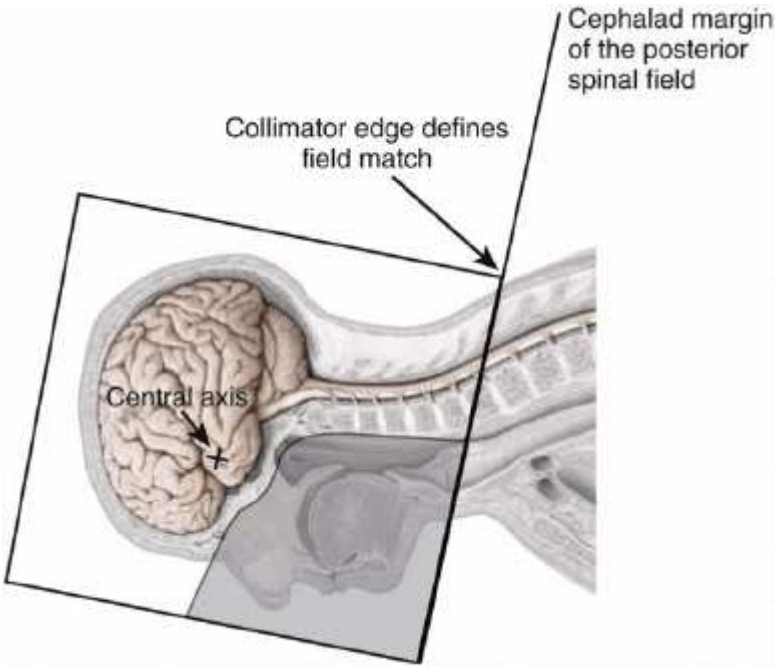

Figure 1. Collimator turn on head field to match divergence of upper spine field.[1]

When treating in the prone position, Loyola uses a source to surface distance (SSD) of 100 cm for most cases. The formula for determining the angle of the turn of the collimator is:

$$Collimator\ \theta = \tan^{-1}\left(\frac{spine\ field\ superior\ jaw\ distance}{source\ to\ surface\ distance}\right)$$

Loyola's standard technique is to open the superior jaw on the upper spine field to 18 cm, in order to leave a few centimeters of play for match line feathering. In such a case , the angle of the collimator turn would be:

$$Collimator\ \theta = \tan^{-1}\left(\frac{18\ cm}{100\ cm}\right)$$

$$Collimator\ \theta = 10.2°$$

The value for a full 20 cm jaw opening would be 11.3°. It is not practical to plan each feathered match with a different collimator turn angle, so the angle is usually rounded to either 10.5° or 11.0°.

The head fields also diverge, so it is important to consider that the caudal margin of the head field must have its divergence match the cephalad margin of the upper spine field. If the isocenter of the head field were placed directly on the margin between the fields, this could be accomplished with a half beam block, but Loyola's technique is places the head isocenter near the middle of the head. To account for this, the angle of divergence of the head field is computed in much the same way as the angle of divergence of the upper spine field, but the resulting angle is used as a couch rotation angle. When the couch is rotated appropriately, the line between the linac source and the field junction location is perpendicular to the long axis of the body.

$$Couch\ \theta = \tan^{-1}\left(\frac{head\ field\ inferior\ jaw\ distance}{source\ to\ axis\ distance}\right)$$

The size of the head field jaw opening is dependent on the length of the patient's neck and the size of the head. The upper spine field is designed to place the junction just above the shoulders, at the first opportunity where the lateral head fields can reach the patient's neck without cutting through the shoulders. Using a 15 cm inferior jaw as an example, the angle of the couch kick would be:

$$Couch\ \theta = \tan^{-1}\left(\frac{15\ cm}{100\ cm}\right)$$

$$Couch\ \theta = 8.5°$$

The couch will be turned by 8.5° off of its baseline position for each lateral field such that a line following the plane of the field junction points towards the linac source. This will require a couch position of 8.5° from one side and 351.5° from the other.

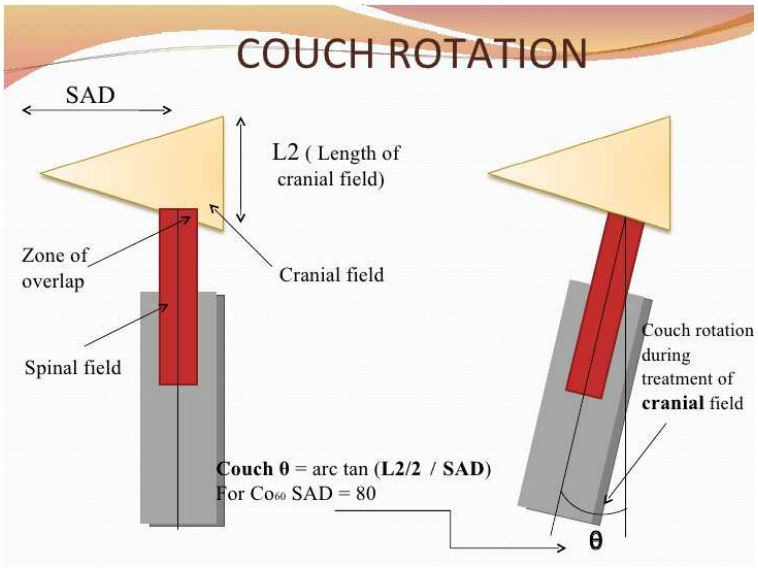

Figure 2. Explanation of couch angle derivation.[1]

3.

In order to match the divergence of the head fields to the back of the eyes, the same type of formula can be used with the distance from the isocenter to a point midway between the eyes as the numerator in the equation. The plane of the rotation that is required almost matches the plane of rotation of the gantry, so the gantry is the portion of the setup that is adjusted in this equation.

$$Gantry\ \theta \approx \tan^{-1}\left(\frac{iso\ to\ eyes\ distance}{source\ to\ axis\ distance}\right)$$

If the iso is positioned 7 cm behind the eyes, the necessary angle should be close to:

$$Gantry\ \theta \approx \tan^{-1}\left(\frac{7\ cm}{100\ cm}\right)$$

$$Gantry\ \theta \approx 4°$$

Using this approach, the gantry angle on each lateral beam would be rotated 4° anterior from its lateral position. For a prone patient, the resulting gantry angles would be 94° and 266°. In reality, the formula is an oversimplification because the plane of rotation has already been offset twice by the rotation of the couch and the rotation of the collimator. In regular clinical practice, the gantry rotation is set by contouring the eyes and then manually adjusting the gantry angle until the eyes line up along the field edge. Doing this manually is especially important, because any rotation of the head in the mask or asymmetry of the head may mean that one eye is already more anterior than the other, making any calculation that assumes symmetry irrelevant.

As seen below, using the oversimplified formula only provides an approximate angle, and not an accurate gantry angle that will result in block edges that cut flat across the eyes. In this example, the jaw edge is seen in yellow with insufficient rotation, and the MLC block that covers the anterior half of the eyes is seen in orange, with overrotation relative to the horizon but underrotation relative to the positions of the eyes. The eyes themselves are at different heights because the head is rotated inside the mask. In this case, manual tuning of the gantry angle was required.

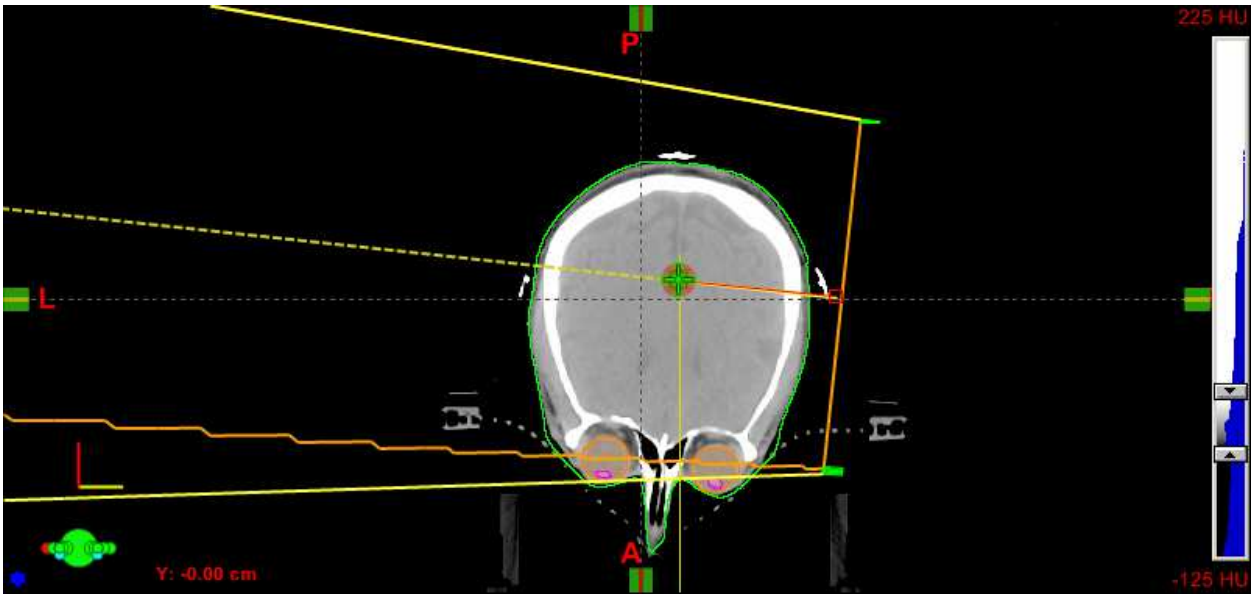

Figure 3. Example of failure to accurately compute the needed gantry angle with simple formula.

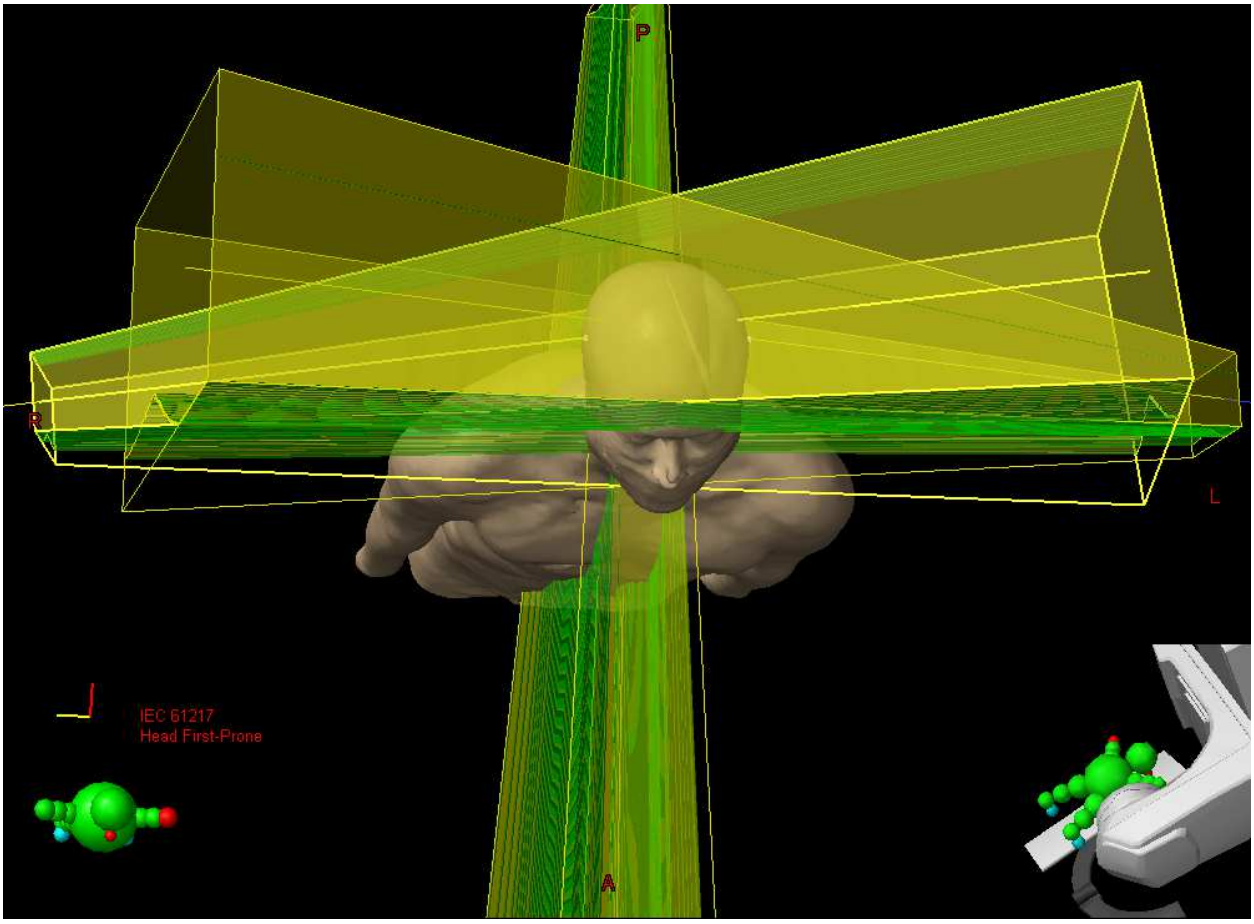

Figure 4. Rendering of upper spine field and lateral fields matched at cephalad surface of upper spine field and at anterior surface of head fields.

4.

An adult patient being simulated for prone CSI treatment at Loyola will need to have a two-part thermoplastic mask constructed. The patient should initially be set up in the supine position so that the facial portion of the mask can be made. The neck should be straight and the chin should be slightly elevated. Once the thermoplastic mask has hardened, the patient may get off the table and the table should be prepared for prone simulation. The facial portion of the mask should be placed into the prone head holder apparatus so that it can hold the patient's head in a comfortable position. Depending on the patient's body habitus, Styrofoam boards may be stacked under the torso but not legs as necessary to provide a comfortably straight neck position that keeps the chin tilted up slightly. The goal is to keep the chin above the diverging plane of the upper spine field, which will extend just past the tops of the shoulders. The more the shoulders can be pulled down, the less chin tilt is necessary. Excess chin tilt can cause a skin fold at the back of the neck, which should be avoided if possible.

An AlphaCradle bag should be placed over the boards (if present) or table and the patient should lie down prone with their face resting in the facial portion of the thermoplastic mask. The patient's shoulders should be pulled down in the caudal direction (use shoulder retractor straps if

necessary) and the AlphaCradle should be formed around them to hold them in the retracted position. The arms should be positioned parallel to the body and held in place by the AlphaCradle. The patient's spine should be as straight as possible in the left/right dimension with no rotation of the body. The legs should be straight, but a foam wedge may be placed under the ankles for patient comfort. If boards have been used to raise the torso, the legs may be allowed to fall forwards to the table. The AlphaCradle should extend at least to mid-thigh for comfort and for reproducible positioning of the pelvis.

While this is happening, the posterior portion of the thermoplastic mask should be built by stretching it over the back of the head and attaching it to the head holder assembly, forming a full front/back head immobilization mask assembly. In addition to the three point setup marks on the mask, at least two more marks should be placed on the patient's body along the path of the sagittal laser over the spine, typically at upper and lower spine locations. Some physicians like to see many more than two to ensure consistent lineup along the entire length of the spine (Edward Melian, Oral communication, June 28, 2015). These marks allow the straightness of the spine to be verified during treatment. Two additional leveling marks are placed on the patient's sides to allow therapists to

During the planning process, three isocenters will be used. The first isocenter, located approximately in the center of the head, is positioned to match the three point setup at the time of simulation. There are techniques that involve positioning the head isocenter at the border between the head and upper spine fields, or at the plane behind the eyes, but at Loyola, we always use the three point setup marks on the mask to define the head isocenter. This reduces the likelihood of setup errors by not immediately introducing a series of shifts before anything else is determined.

The second isocenter, which is used for the upper spine field, is selected by first setting up the beam dimensions, and then moving the isocenter until location criteria are met. Since each jaw on our linac is capable of opening up to 20 cm in its direction of travel, we have a maximum field size of 40 x 40 cm. In order to leave room for feathering, the jaws are initially set at 18 cm in both the superior and inferior directions, with the collimator turned such that the MLCs move left and right across the long axis of the spine. Using an SSD technique with 100 cm SSD, the isocenter is shifted inferiorly from the head isocenter (no left or right shifts) until the superior border of the field is almost touching the shoulders. The shoulders should be entirely below the plane of the superior field border. Once the upper spine isocenter location is determined via this method, the lower spine field isocenter can be determined.

Some centers will turn the couch 90 degrees at this point so that the lower spine field can be treated with a beam that has a gantry tilt such that its superior margin divergence perfectly matches the inferior divergence of the upper spine field, but this couch rotation is a potential source of error and patient motion. This technique also puts more exit dose into the structures of the pelvis, potentially including the gonads. At Loyola, the preferred technique for placing and sizing the lower spine field is to shift the couch in the inferior direction (no couch rotation) and create a symmetrical field whose superior border almost meets the upper spine field at the depth

of the cord, and that covers the end of the thecal sac around S2. Loyola's protocol for choosing the exact lower spine isocenter location is to leave a 4 mm gap at the middle depth of the cord when the beam is at 100 cm SSD. This ensures that the hot spot created by overlap of the fields is distal to the cord and not inside it. Once these three isocenters are determined, they never move, because room for feathering has already been built into their sizing. Movement of the isocenters would also be a dangerous source of potential error.

Field borders for the head field will be similar to a standard whole brain field, but will include more of the neck. At Loyola, the initial anterior, superior, and posterior jaw positions are set to include at least 1.5 cm of air around the head on each side. The inferior border will be set as needed in order to match with the upper spine field. The head fields are blocked to spare the eyes, nasal cavity, oral cavity, and throat to the extent possible. The blocking should not come closer than 1 cm to the brain, paying special attention to the cribriform plate and temporal lobe fossa on each side. This may require including part of each eye in the field. Below the level of the base of skull, the field is blocked at the anterior faces of the vertebrae, thereby sparing much of the soft tissue of the mouth and throat. The superior and inferior field borders of the spine fields are determined based on the coverage needed as discussed above, but laterally, the fields should extend 1.75 cm beyond the visible vertebral bodies on the beam's eye view. This ensures coverage of the spinal nerve roots as well as allowing some margin for setup error. The lateral borders of the lower spine field should follow the line of the SI joint when it extends into the pelvis.

The overlap of the fields at each junction creates hot and cold spots that need to be smeared out to equalize the dose. This is accomplished by feathering the junctions over the course of the treatment. The extra space that was incorporated into the upper spine field will be used to move the superior and inferior borders outwards by 1 cm per feathering step. The number of feathering steps is at the discretion of the physician, but 3 (original position plus two more) is typical at Loyola.

Therapists should make no attempt to move the isocenters or to move the patient for each feathering. Feathering is accomplished purely by changing the jaw positions of the fields, so patient setup for each plan variant is identical. This is an important factor in minimizing the possibility of errors. The setup procedure for the therapists on any plan variant is set up the patient to the three point setup marks on the mask, and then check both the leveling marks on the sides of the body and the straightening marks along the spine. The head fields should be treated first, and then the couch should be moved to the upper spine isocenter location. This is accomplished by moving the table by exactly the specified vertical (Y dimension) shift and then adjusting table height to 100 cm SSD. The therapists are then allowed to makes small changes left and right, but no changes in the Y dimension are allowed. After the upper spine field is treated, the table is again moved by the specified Y amount and table height is adjusted to achieve 100 cm SSD. The skin gap between the upper and lower spine fields can be examined as a second check, but no attempt should be made to move in the Y dimension based on the skin gap. Therapist have some leeway to make left and right shifts if necessary.

To feather the match line between the upper spine and head fields, the superior jaw on the upper spine field will be opened by 1 cm and both of the head fields will have their inferior jaw closed by 1 cm. To create a second feathering, the jaws are simply moved another cm each. Moving the location of the match line will change the angle of the match plane. With 100 cm SSD and 18.0, 19.0, and 20.0 cm jaw positions, the angle of the match planes will be 10.2°, 10.8°, and 11.3°. This difference is small and the width of the potential overlap region is small, so the difference is ignored.

The process to feather the junction between the upper spine and lower spine field is almost identical. As the inferior jaw of the upper spine field is opened 1 cm, the superior jaw of the lower spine field is closed by 1 cm. The small differences in angles ensures that even though the spinal cord gap is not re-measured, the fields will not overlap inside the cord.

Some centers deliver all three feathered variants at 1/3 strength every day of treatment without the patient moving. One advantage of this technique is that the feathering is known to be done with correct spacing because the patient does not move between fields. Another advantage is that an interruption or change in treatment becomes simpler to deal with when one does not have to factor in a different number of treatments at each position. The main disadvantage of this technique is that it extends the length of treatment because three times as many fields have to be delivered every day. Loyola's preferred regime is to move the match lines every 5 treatments.

References

1) Singh V. Diagnosis, treatment & management of medulloblastoma. Slideshare Website. http://www.slideshare.net/vandana_rt/diagnosis-treatment-management-of-medulloblastoma. Published September 30, 2011. Accessed June 27, 2015.