Automated megavoltage imager positioning model

Abstract Purpose: Electronic portal imaging is widely employed to confirm positioning of a patient receiving radiation therapy. In most cases an orthogonal pair of images is sufficient to provide millimetre accuracy to most treatment sites in three dimensions when coupled with an online correction protocol. Accurate positioning of the imaging panel is crucial in sparing radiosensitive electronics surrounding the amorphous silicon (ASI) detector plate, and avoiding collisions between the equipment with the treatment couch. This paper presents a model that can be used to accurately calculate ideal imager panel positions for Varian® imaging panels without the need for time-consuming and potentially inaccurate judgment.

Methods: The position of the imaging panel is expressed using a coordinate system in three dimensions: longitudinal, lateral, and vertical. Calculation of ideal coordinates requires the input of radiation field dimensions, collimator rotation, and treatment couch parameters. A program using Microsoft® Excel (Microsoft, Seattle, WA, USA) was created to obtain the proper EPID position during the imaging process. Results: The model was designed using Microsoft® Excel and provides suggested offsets once field and patient set-up parameters have been entered. Instantaneous assessment of any offset is provided and prompts are provided if the panel is irradiated beyond the ASI plate or if collision is likely. After testing for accuracy in predicting the imager position, the algorithm has been used clinically in over 700 patients with no reports of errors. Accurate positioning of the panel has been found to reduce time spent on the positioning of the panel to ensure it is accurately positioned. Conclusion: Through the use of the model, a single imager position can be calculated for multiple fields and positioned pressing a single button in the treatment room. Irradiation of electronics and collisions are no longer subject to human judgment, the model thereby delivering on its goals.

Keywords: automated positioning, collision avoidance, decision making model, electronic portal imaging, imager.
the light field, a representation of the radiation field(s) dimensions that the panel will be exposed to. Translations of imager panel position in the longitudinal (I-long) and lateral (I-lat) can be used to ensure field exposures remain within these recessed areas. This process is potentially inaccurate, is likely to vary from day-to-day based on users’ perception of position and takes time to locate – thereby reducing efficiency in the treatment room.

Taking orthogonal images will require gantry (and hence imager) rotation about the patient and couch. Careful positioning of the imager vertical (I-vert) is required to avoid any possible collisions between imager and couch. Offsets in the I-vert can be made through visual assessment of the clearance between the imager with the couch/patient with gantry rotation although this may result in collision with the couch top or patient. Overcompensation for clearance will result in larger field sizes at the imaging panel due to greater divergence. It may also reduce the quality of the image produced.\(^3\) The visualisation process for field placement in I-vert may be subjective, time consuming, and produce inaccuracies in imager panel positioning.

Auto-positioning of the imager may be modelled if the following two aims are achieved:

1. Determine the I-vert to avoid collision of the imager panel with the couch upon gantry rotation.
2. Determine the I-long and I-lat offsets to allow the field to fall within the ASi detector array.

This paper presents a model that can be used to accurately calculate ideal imager panel position for Varian\(^\text{"}\) imaging panels without the need for time-consuming and potentially inaccurate judgement.

Methods

The Varian\(^\text{"}\) ASi1000 imaging panel is precisely positioned using a proprietary coordinate system that locates the panel in relation to the isocentre of the linear accelerator. When imager coordinates are entered into the patient plan data for any field, the imager can be automatically moved to this predefined position. A Microsoft\(^\text{®}\) Excel model fulfilling criteria of collision avoidance and positioning relative to the radiation field has been produced for use in-house.

A handheld remote is used to set the imaging panel position, allowing for manual or automatic positioning of the imager in three dimensions. The 'auto-go' function positions the imager to any pre-defined position for the treatment or set up field. Auto-positioning may eliminate operator errors, overcompensation, and inaccuracies in estimating the required imager position. The method for developing the model is now detailed.

Collisions

The lowest and most outer point of the couch must be defined (Point LO) to determine the furthest point of the couch from isocentre (Figure 2). The furthest point of the couch will be the closest point to the imager panel. The imager circumferences about the isocentre at a set distance, it will not collide with the couch if point LO is less than the I-vert. The distance from isocentre to point LO can be determined using Pythagoras' theorem (Equation 1).

\[
c^2 = a^2 + b^2
\]

Where:

- \(c\) = Distance from isocentre to point LO
- \(b\) = Net lateral couch
- \(a\) = Lowest point of couch from isocentre

Determining the lowest point of the couch

The lowest point of the couch is the distance from isocentre to the lowest point of the moveable table top (Equation 2). This includes couch vertical, thickness, and the depth of supporting rails. The couch vertical is the distance from the isocentre to the upper surface of the couch top and is calculated through the treatment planning system. The couch thickness (2 cm) and the depth of supporting rails under the couch top (9 cm) are constant (Figure 2).

\[
\text{Lowest point of couch} = \text{couch vertical} + \text{couch thickness} + \text{depth of rails/rails} = \text{couch vertical} + 11 \text{ cm}
\]

Determining net lateral couch

The net couch lateral edges are calculated (Equations 3a and 3b). Patient positioning on the couch top, and offset of equipment on the couch top both affect the couch lateral position (Appendix A).

\[
\text{Left outer edge} = \frac{\text{Width}}{2} + \text{Left offset} \quad \text{Or} \quad \frac{\text{Width}}{2} - \text{Right offset}
\]

\[
\text{Right outer edge} = \frac{\text{Width}}{2} + \text{Right offset} \quad \text{Or} \quad \frac{\text{Width}}{2} - \text{Left offset}
\]

The measured couch top width is 53 cm. The left-right offset from Equations 3a and 3b are the respective net couch lateral co-ordinates expressed as a distance from centre. The left and right outer edges of the

Figure 2: Side view of couch and rails displaying point LO: The lowest and most outer edge of couch (including support rails).
Determining imager vertical (I-vert)

The I-vert is the measure of distance (cm) from the isocentre to the imager. The model calculates and suggests an I-vert by adding a margin to point LO (Equation 4). A decision was made to place a high priority on clearance around the patient and the bed, therefore a clearance of 10 cm was placed as a fixed parameter in the decision making model. This margin also allows for any minor daily set-up variances in couch vertical and lateral.

\[
I \text{-vert} = \text{Point LO} + 10 \text{ cm}
\]  

Field divergence to the imager can be minimised with a smaller I-vert. The model adapts to this by querying the user whether gantry rotation is required and providing a “yes” or “no” output. If “yes” is selected, the suggested I-vert is given from the larger of the two point LOs so that clearance is allowed from the most outer point of the couch. Conversely, if “no” is selected, the suggested I-vert is given from the smaller of the two point LO.

Field position on imager

The four borders of the imaging panel are defined as upper, lower, left, and right. The borders are oriented as if viewed from the couch with gantry at 0 degrees (i.e. upper border is nearest to the gantry). Each collimator jaw is designated a border on the imager and this will vary with every 90 degree increment of collimator rotation (Appendix B).

The imaging plate has physical dimensions (length x width) of 30 cm x 40 cm. When centred, there is 15 cm of detector array to each of the upper and lower edges. There is also 20 cm of detector array from the centre to each of the left and right edges. The actual field sizes at the imager are a function of divergence (I-vert) and collimator size (Figure 3). Each collimator will contribute to different edges of the imager (Equation 5). Individual calculations are required for each jaw \(X_1/X_2/Y_1/Y_2\).

\[
\text{Coll size at} \quad I \quad \text{vert} = \text{Coll size} \times \frac{100 + I \text{ vert}}{100}
\]

Where:

- \(\text{Coll} = \text{collimator}\)
- \(I \text{ vert} = \text{imager vertical}\)

Results

The model developed is a Microsoft® Excel based algorithm with a user interface for data entry (Figure 5a). I-vert, I-long, and I-lat coordinates are calculated for each plan as variables of “patient orientation”, “couch vertical”, “isocentre”, and individual field “collimator” settings and “jaw sizes” are transcribed from the treatment plan data. The model displays where the net field borders are located on the imager panel (i.e. the maximum size of combined fields on a single imager position).

Assessment is also made on whether the entered fields can be captured (i.e. within the imager panel) or whether the panel is to be retracted after verification images. Where a field size is too large for the panel or clearance is not guaranteed, the model will prompt the user that modifications to the imager position are required, specifying which field is breaching the panel dimensions. There is also an option to bring the panel closer.
Figure 5a: Screenshot of the imager model with no warnings, the single position in I-long, I-lat, and I-vert (bottom left) co-ordinates are valid for all fields entered, allowing for gantry rotation.

Figure 5b: Screenshot of the imager model with all warnings active, changes are required in specific field sizes and I-vert to ensure all warnings are disabled. Clearance for gantry is recommended if multiple fields are being captured.
to the patient to minimise divergence if a single field is being captured, activating a ‘retract imager for other fields’ prompt (Figure 5b).

Significant testing was performed prior to the clinical release of the model. The first stage ensured that calculated couch positions from the model matched the actual couch positions. Once couch position calculations were verified, testing of the I-vert position accuracy was performed in conditions of multiple gantry rotation positions.

Testing was performed for I-long and I-lat offsets to ensure each offset was in the correct direction and magnitude as calculated in the model. To date, the model has been successful in achieving its aims for over 700 patients without any reports of error. Simple departmental protocols were introduced to supplement the use of the imager: the imager panel is to be retracted to avoid exposure to fields over 19 cm. Isocentre check fields are hence limited to 19 cm as these fields fit within the 30 cm panel length (upper to lower edge) at most I-vert positions. There are no limits on field widths for isocentre check fields due to image width. As the model can detect whether fields are too large to fit, a ‘retract’ imager warning will appear for excessively wide treatment fields.

Discussion

Prior to the introduction of the imager model, confidently avoiding collision could only be achieved by the user entering the treatment room to perform the gantry rotation. This model allows for consistent and precise imager positioning through the use of the “auto-go” function. Offline review of images has demonstrated that the algorithm accurately calculates the correct imager position as the entire radiation field is captured, and not irradiating the electronics of the imager panel.

Setting the imager position to a single I-long and I-lat position for multiple unique field sizes improves set-up and treatment procedure times by eliminating the need for users to enter the treatment room to re-position the imager. Calculation of required offsets from planning improves in-room efficiencies, eliminating the need for user judgement or decision making. The option for gantry clearance in the model allows the user to set the I-vert at a position where full gantry rotation can be achieved without risk of collision. Additionally, the model can assist in positioning the imager for improved image qualities by suggesting distances closer to the radiation source compared to results from manually-controlled positioning.

Couch coordinates are vital for the model to perform I-vert calculations since the position of the patient laterally on the couch top will affect the couch co-ordinates on any given set-up. Ideally, the margin applied to the I-vert for collision avoidance should be 0 cm. This would be the case if set-up to an exact couch lateral was achieved for each patient; however, a margin of up to 3 cm in either direction has been applied to the model for safety. Similarly there are slight variances day-to-day in the couch vertical.

Further work is being undertaken to the model to calculate field edges for collimator angles other than 0, 90, 180 and 270 degrees. The version of the model presented calculates purely from given field dimensions; oblique angles will complicate these field dimensions for the upper/lower/left/right edges of the imager. Contributions to each imager edge will then be a function of a combination of accumulated field size from multiple fields as well as the angle of rotation. The introduction of the model has also inadvertently improved patient set-up guidelines with more stringent localisation/positioning of the patient laterally.

Conclusion

The model described has been developed in-house to calculate and allow users to enter imager position offsets for each individual patient. This has successfully been implemented and now imager position requires minimal human intervention. Correct positioning will ensure longevity of equipment by averting ionising damage to electronic circuitry, and reduced the risk of collision with the couch or patient.

References


Appendices

Appendix A – Determining net couch lateral offset

Two factors affect the couch lateral offset:

1) Sagittal location of isocentre in relation to couch lat = 0

   i.e. For supine/head first patient positioned with midline in line with centre of couch laterally:

   Isocentre position towards patient left will result in a couch lateral of 999.9 cm or less.

   Isocentre position towards patient right side will result in a couch lateral larger than 0.0 cm.

2) Original offset of patient on centre of couch laterally

   Isocentre is offset by the given offset amount (patient offset to the left of the couch would result in a subtraction to net isocentre position by the offset amount, similarly patient offset to the right of the couch would result in an addition to net isocentre position by the offset amount).

Appendix B – Determining upper/lower/left/right edges of field

This is dependent on the collimator rotation and the divergence based on I-vert, the following conditions are considered and the borders are then identified when collimator rotations of either: 0, 90, 180, or 270 are selected. Field borders

![Field borders](image)
Collimator conditions showing relative jaw position and field border on the imager

\[
\begin{array}{cccc}
    Y_2 & X_2 & 0^\circ & Y_2 \\
    X_1 & 90^\circ & Y_1 \\
    Y_1 & 180^\circ & X_1 \\
    Y_1 & 270^\circ & X_2 \\
\end{array}
\]

**Appendix C** – Determining I-long and I-lat offset

The field borders are determined using collimator angles to determine the orientation of field borders (Appendix B), and the combination of I-vert and jaw sizes. The difference between jaw sizes is determined using the following subtractions for each axis in accordance with the Varian® co-ordinate system (below):

- Lower – Upper
- Right – Left

Once the difference has been determined, it is divided by two to determine the centre of the field. The resulting offset if positive is a move in the positive scale towards the centre of the field, if negative the move to the same magnitude is made to a co-ordinate of:

\[1000 - \text{(Centre of field)}\]

eg. Collimator 0°, \(Y_2 = 10\) cm, \(Y_1 = 8\) cm, I-vert = 50 cm

**Step 1**)
- Upper = \(Y_2 = 10\) cm, Lower = \(Y_1 = 8\) cm
- Field at imager:
  - Upper = \(10\) cm \(\times\) 150 / 100 = 15 cm
  - Lower = \(8\) cm \(\times\) 150 / 100 = 12 cm

**Step 2**)
- Difference = 12 cm – 15 cm = -3 cm

**Step 3**)
- Division: -3 cm / 2 = -1.5 cm

**Step 4**)
- Resulting offset co-ordinate = 1000 -1.5 cm = 998.5 cm

**Appendix D** – Assessing field edge (after offset has been performed)

Assessment of the field edge requires the dimensions of the imaging plate, and the resultant field sizes (Appendix C). Where no offset has been entered, it is assumed the I-long and I-lat is equal to 0.

Dimensions of eligible field sizes after offsets have been performed are determined by each of the four resultant field sizes. As the offset centres the field, a simple subtraction may be made:

- Centre of field to upper edge = 30 cm / 2 = 15 cm
- Centre of field to lower edge = 30 cm / 2 = 15 cm
- Centre of field to left edge = 40 cm / 2 = 20 cm
- Centre of field to right edge = 40 cm / 2 = 20 cm

**Assessment of field edge**:
- Upper edge = 15 cm – Resultant upper edge
- Lower edge = 15 cm – Resultant lower edge
- Left edge = 20 cm – Resultant left edge
- Right edge = 20 cm – Resultant right edge

If a negative number results from the assessment of field edge, the field on the imaging panel is too large. Solutions include decreasing the overall jaw sizes for the relevant axis, or decreasing divergence by raising the I-vert (i.e. decrease in I-vert number) where allowable/possible.