Three-field virtual simulation of the breast using a non-vertical match plane

Ruth Beddows and Glyn Shentall

Royal Preston Hospital, Radiotherapy Department, Preston, UK

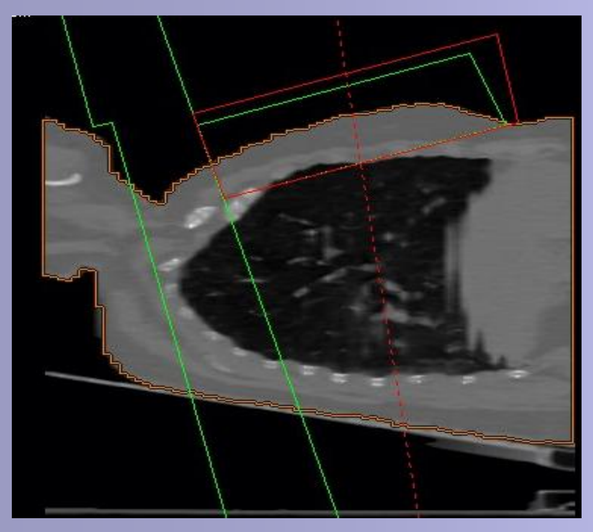

Fig.1. Sagittal view showing the non-vertical match plane on the virtual simulation software (Advantage Sim) achieved with the spreadsheet calculations.

	A	B	C	D	E	F	H	I	K	L	M
4											
5	AdvantageSim Coordinates			R	A	S	Advantage SIM angles				
6	Coordinates of medial border			12.50	-78.00	-150.00			Lt Medial	Lt Lateral	
7	Coordinates of lateral border			6.00	23.50	-150.00	GANTRY		286	117	degrees
8	Coordinates of Origin			12.00	85.00	-100.00	COLLIMATOR		176	184	degrees
9	Maximum tissue thickness			7.60	mm		FLOOR		-79	-80	degrees
10	Maximum Lung Depth			2.10	mm		SCF GANTRY			68	degrees
11	Coll angle matching chest wall			261	degrees		Field Width			0.8	cm
12	Half Field Length			100	mm		Field Length			20	cm
13							Angle of post border			176	
14											
15									R	A	S
16	Increase number for Inferior Shift				mm		Iso Coordinates		11.78	-27.41	-150.00
17											
18				Shift to isocentre from tattoos:			0.0 cm Left of Tattoo				
19							11.2 cm Post of Tattoo				
20							5.0 cm Inf of Tattoo				
21											

Fig.2 Microsoft Excel Spreadsheet used for calculating match plane angles.

$$\theta_G = \pm\cos^{-1}(\cos\beta\cos\alpha\cos\varepsilon - \sin\alpha\sin\varepsilon) \Rightarrow \theta_G' \pm\cos^{-1}(\cos\beta'\cos\alpha'\cos\varepsilon - \sin\alpha'\sin\varepsilon)$$

$$\theta_C = -\sin^{-1}\left(\frac{\sin\varepsilon\cos\theta_G + \sin\alpha}{\cos\varepsilon\sin\theta_G}\right) \Rightarrow \theta_C' = -\sin^{-1}\left(\frac{\sin\varepsilon\cos\theta_G' + \sin\alpha'}{\cos\varepsilon\sin\theta_G'}\right)$$

$$\theta_T = \sin^{-1}\left(\frac{\sin\alpha\cos\theta_G + \sin\varepsilon}{\cos\alpha\sin\theta_G}\right) \Rightarrow \theta_T' = \sin^{-1}\left(\frac{\sin\alpha'\cos\theta_G' + \sin\varepsilon}{\cos\alpha'\sin\theta_G'}\right)$$

Where θ_G, θ_C and θ_T are the angles of the gantry, collimator and table respectively, α is the angle of the axis of the treatment volume with respect to the horizontal obtained from a lateral radiograph and β is the angle between the central axis of the treatment beam and the vertical measured in the treatment plane. ε is the divergence of the beam. The dashed symbols represent the modified versions of the above, used for the Vsim technique, where:

$$\alpha' = Tan^{-1}\left(\frac{Tan\alpha}{\cos\beta}\right)$$

$$\beta' = Tan^{-1}\left(\frac{Tan\beta}{\cos\alpha'}\right)$$

Fig.3. Showing modifications to the Gantry, collimator and floor settings to achieve a match plane using Virtual simulation.

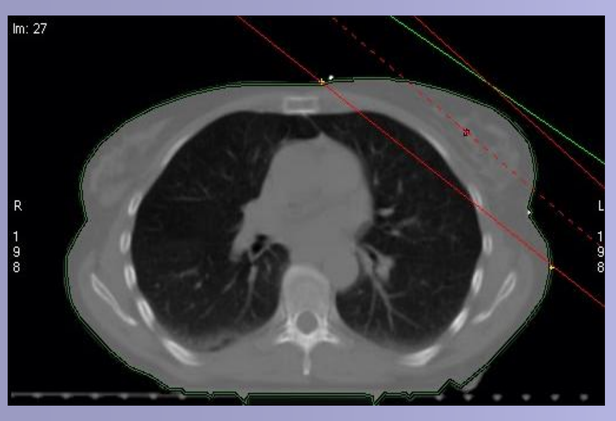

Fig.4. Showing a transverse CT slice with the medial and lateral markers defining the posterior border. Using the spreadsheet the beam angles set up so that there is an exact match between the markers and the diverging beam edge.

Introduction: A common technique for three field breast irradiation requires the creation of a matchplane between the tangent fields and the anterior s'clav field. Published work on planning this matchplane (by Casebow) is based on simulator techniques, and the adjustments used to calculate gantry, collimator and floor angles, requires modification if the technique is to be successfully reproduced during CT virtual simulation (VSIM) Fig.1.

Method: The key difference between simulator and VSIM planning is that the former is usually planned coplanar and the latter planned non-coplanar. Corrections to the Casebow method have been introduced into an Excel spreadsheet (Fig.2) to account for this and other historical anomalies, such as planning with the sternum horizontal or assessing sternum angle.

The first correction is to the baseline gantry angle. In the previous method it is measured in the simulator, with the patient on a breast board, but the patient is treated flat. The breast board angle is the angle of the sternum to the horizontal, in our case where the patient is scanned in the treatment position, the angle of the gantry is not measured in the match plane and has to be corrected for (Fig.3).

The second correction is to the angle of the match plane to the vertical. In the previous method it is the breast board angle (sternum was horizontal before the patient laid flat). In our case we are measuring the angle from the baseline BEV and therefore a correction needs to be made to make it relative to the horizontal (Fig.3).

Incorporated into the spreadsheet is a function to move the isocentre inferiorly and superiorly to achieve optimal coverage of breast tissue without compromising the match plane or alignment of the posterior borders (Fig.4). The spreadsheet calculates this using coordinate transformation of the isocentre shown in Fig.5. The isocentre is rotated in the z-axis by the angle of the posterior border and then rotated in the x axis by the angle of the modified collimator angle. This brings the field into the orientation shown in Fig.5. and the required shift can be applied to the z-coordinate. In practice it is more convenient to enter a shift in CT slice numbers or longitudinal distance along the patient and so the spreadsheet shifts the z-coordinate z' by z' = Dcosθ (where D is the longitudinal distance for the required shift). The isocentre coordinates are then rotated back into the treatment plane and used in the final set-up, showing a superior or inferior shift whilst retaining a match plane and post border coverage.

Finally, an additional method has been included into the spreadsheet using the virtual simulation software and coordinate transformations to calculate the geometric SSD to the reference point of the angled s'clav field (Fig.6). The SSD at the geometric centre is calculated using coordinate transformation. The coordinates of the isocentre and the geometric centre of the SCF field, shown in Fig.7, are determined using the Advantage Sim software. The isocentre is at 100cm SSD. By rotating the coordinates of the geometric centre 90° in the y-axis (to account for the table rotation) and a rotation in the x-axis by the gantry angle of the SCF field, the Y-coordinates (anterior-posterior) are in the same plane and are subtracted to give the difference in SSD between the two positions.

Results: The match plane angles were initially evaluated with a test plan in solid water. Simulation was carried out on an Elekta linear accelerator with radiographic film sandwiched within the solid water. A good match plane was visible after the film was developed and no overlap or under lap was present with additional irradiation of a matched field. The spreadsheet has been tested on over 20 patients. The virtual simulation software shows a good match plane and posterior border match using the settings from the spreadsheet. On treatment setup a definite match plane can be seen with the light field and DRRs (Fig.8) show good agreement with the virtual simulation software.

Conclusion: Virtual simulation provides many benefits over a conventional simulator for breast planning. This method provides an accurate and efficient method for creating a matchplane in a VSIM technique which has been implemented successfully at Preston.

Contact Ruth.beddows@lthtr.nhs.uk and Glyn.Shentall@lthtr.nhs.uk

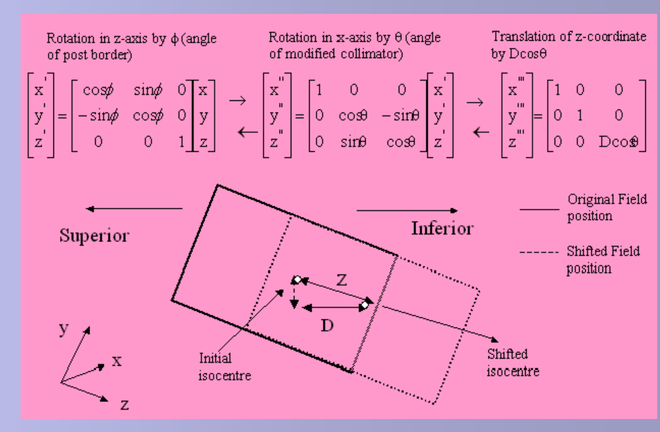

Fig.5. Showing mathematical coordinate transformation of the isocentre in order to shift the z-coordinate inferiorly or superiorly.

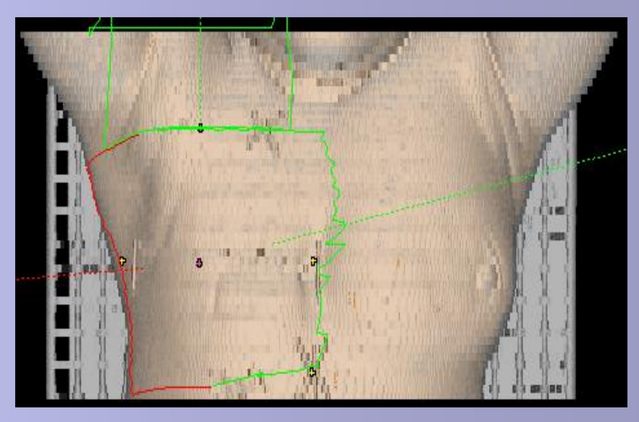

Fig.6. Image showing skin view on the Advantage Sim software for the matching 3-field technique.

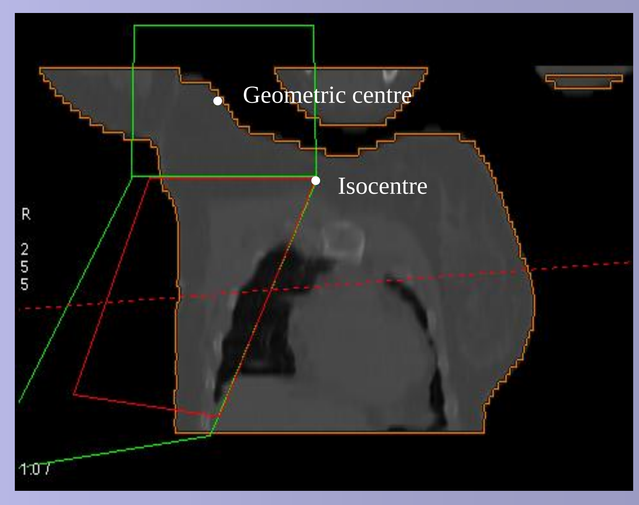

Fig.7. Showing the positions of the geometric field centre and the isocentre for the matching SCF Field.

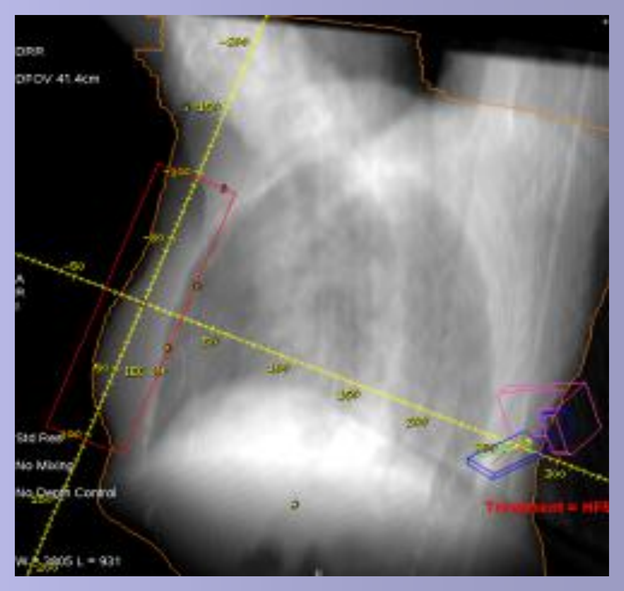

Fig.8. DRR showing BEV of the breast tissue coverage using the match plane angles. If the coverage is lacking inferiorly a shift can be applied to the isocentre moving the field inferiorly and keeping the match plane.