Technical Solutions for the Implementation of a PBI VMAT technique at BC Cancer Vancouver

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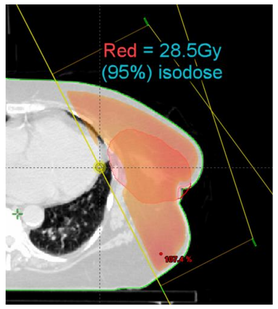
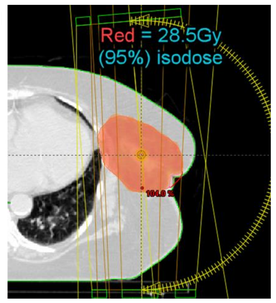
Introduction



A Partial Breast Irradiation (PBI) VMAT technique has been implemented at BC Cancer Vancouver following publication of the APBI-IMRT-Florence[1] trial. Prescriptions are 26Gy/5 or 30Gy/5 daily using a 2 partial arc VMAT technique. The IMPORT LOW phase III trial has shown that partial breast irradiation can reduce long term breast toxicity versus whole breast irradiation[2]. The PBI VMAT technique is offered when a partial breast "short" tangent technique would still irradiate a large volume of healthy breast tissue (e.g. Large breasted women), or when organ at risk planning objectives cannot be met (e.g. Left Inner quadrant tumor sitting directly over the heart).

The main barrier to implementation of the technique is image guidance: accurately localizing a 3D treatment volume in mobile breast tissue.

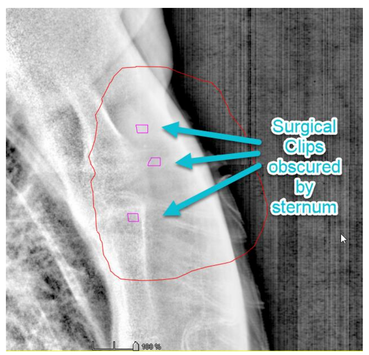


Technical Challenges and Solutions

Challenge: target visualization. Approximately 93% of post-lumpectomy intact breast patients receiving radiation therapy at BC Cancer Vancouver have surgical clips placed at the time of surgery to delineate the surgical bed. However, as a large regional cancer centre, surgeries take place at ~10 different regional hospitals or surgery centres, so the size and number of surgical clips varies. Some surgical clips are too small be reliably visualized on planar kilovoltage (kV) x-ray imaging or may be obscured by denser bony anatomy (ribs/sternum/spine). ~7% of patients do not have surgical clips, usually if their surgery took place outside of the Greater Vancouver region.

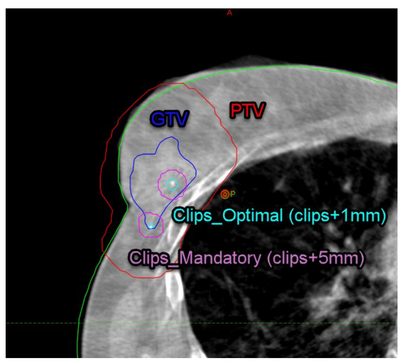
Solution 1: ConeBeam CT (CBCT) imaging is the only way to reliably visualize surgical clips, or seroma in the absence of clips. The CBCT images allow easy visualization of small surgical clips and allows for assessment of soft tissue and organs at risk (OARs) as needed. Contouring the surgical clips and adding a 5mm margin provides a very quick and simple way to localize the target volume and verify target position is within 5mm of plan, which is well within the 7-10mm PTV margin.

Solution 2: work with breast surgeons at regional hospitals to come up with standard guidelines for surgical clip placement. Surgeons at the largest breast surgery centre in Vancouver agreed to standardly place 5 surgical clips at edges of surgical bed as much as possible.



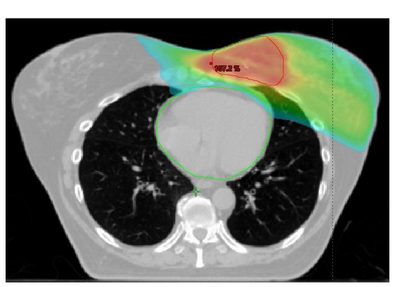
Left: planar kV image with surgical clips obscured by dense bone

Right: CBCT image with clips clearly visible



Challenge: Deep Inspiration Breath Hold (DIBH) is used for most left sided and some right sided tumors for heart and lung sparing. In our clinical experience, we found that most patients can comfortably hold their breath for 20 seconds and up to 40 seconds at a time. A full trajectory CBCT (fCBCT) acquisition time is 60 seconds, which requires 2-3 breath holds.

Solution: partial trajectory (200°) CBCT (pCBCT) acquisition at isocentre. pCBCT acquisition time is ~33 seconds, allowing CBCT acquisition in 1 breath hold for most patients. This reduces number of breath holds and image acquisition time.



CBCT Mode	Trajectory	Acquisition Time	Number of breath holds
Partial arc CBCT	200°	~33 seconds	1-2
Full arc CBCT	360°	~60 seconds	2-3

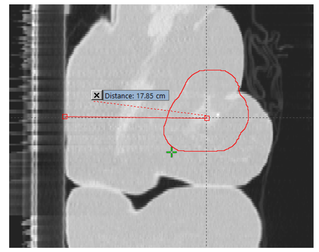
Left: DIBH technique inflates lung, used to lift breast and chestwall away from heart

Challenge: clearance for pCBCT Imaging. As the breast is located anteriorly and laterally on the body, the linear accelerator (Linac) treatment couch is usually offset both laterally and vertically at treatment isocentre. This causes increased collision risk between the gantry/kV detector and couch/patient for acquiring partial arc (200º rotation) CBCTs at isocentre on Varian Truebeam C-Arm linear accelerators.

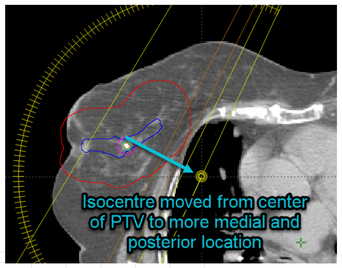
Solution 1: position patients flat instead of on an angled breastboard. Removing the in-house fabricated 12.5º breastboard raises the couch vertically approximately 8-11cm at isocentre and moves the patient's elbows ~12-15cm further away from the gantry head, increasing clearance for the linac gantry head and kV imager to rotate safely around the treatment couch and patient.

Left: patient positioned on angled breast board. Treatment couch 32cm below isocentre.

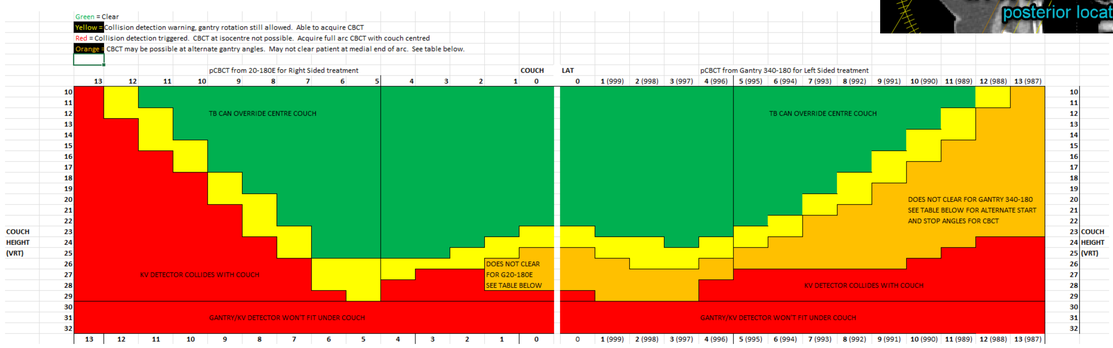
Right: patient positioned flat on treatment couch. Treatment couch 18cm below isocentre.



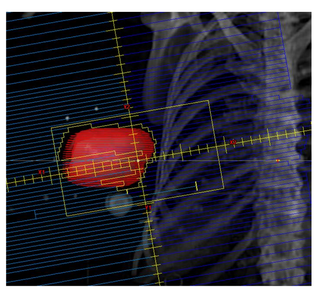
Solution 2: an in-house developed CBCT clearance matrix to guide isocentre placement. While our clinic's half-beam block tangent technique requires the isocentre be placed at the posterior edge of the tangent field, the VMAT technique has more freedom with regards to isocentre placement. Isocentre is placed to allow gantry and kV detector to clear the couch and patient while keeping the external breast contour within the 26cm field of view (FOV) of a pCBCT. If this is not possible (e.g. Wide patients/outer quadrant tumors) a full arc CBCT (FOV=46cm) with couch centered is used.



pCBCT clearance matrix



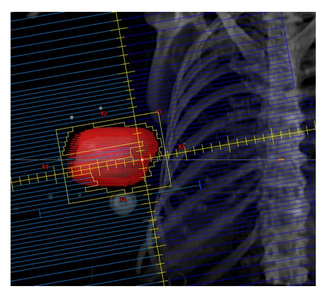
Challenge: isocentre placement outside of PTV can result in multi-leaf collimator (MLC) leaf gap leakage with the secondary collimator open



Solution: jaw tracking. Dynamically resizing the secondary collimator to the edge of the open MLC reduces MLC leaf gap leakage. Jaw tracking has been shown to reduce integral dose by lowering the low dose bath in VMAT[3]. This is particularly important for off-axis isocentres which lead to non-modulating leaf pairs inside the field when jaw tracking is not used.

Left: VMAT plan without jaw tracking. Yellow rectangle = secondary jaw, Blue = multi-leaf collimator (MLC)

Right: VMAT plan with jaw tracking.



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3. Thongsawad et al (2018). Dosimetric Effect of Jaw Tracking in Volumetric-Modulated Arc Therapy. *Journal of Medical Physics*, *43*(1), 52–57. https://doi.org/10.4103/jmp.JMP_75_17