Set-up Uncertainty in Accelerated Partial-Breast Irradiation Using 3D-Conformal External Beam Radiotherapy: A Companion Study to a Prospective Phase I Ongoing Trial.

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BACKGROUND

The use of accelerated partial breast irradiation (APBI) for the treatment of early stage breast cancer is becoming more widely used. Even though long-term follow-up data is limited, it seems likely that it will become a standard treatment option for selected cases. The options for the delivery of APBI include balloon intra-cavitary (Mammosite), interstitial implants and focused external beam therapy. The use of external beams has the probable advantage of eliminating dose heterogeneity and improved normal tissue tolerance. However, in contrast to brachytherapy techniques, the target volume may move relative to the treatment delivery system. Thus, understanding set-up uncertainty is critical for the success of external beam APBI.

PURPOSE

To measure set-up accuracy in 3D-conformal external beam radiotherapy (3D-CRT) for APBI. Given the smaller clinical target volumes (CTV) used in APBI, the initial set-up errors and the inter-fraction variation of the patient’s surface was used to estimate the set-up uncertainty associated with APBI, which in turn would determine the size of the planning target volumes (PTV).

METHODS

- Forty-one patients have been enrolled to an ongoing, IRB approved trial of APBI by 3D-CRT using a linear accelerator. All patients gave written consent.
- To be eligible for the study, patients had ≤ 2 cm of invasive ductal carcinoma
- negative sentinel nodes
- at least 2 mm negative margins
- no lymphovascular invasion
- no extensive intraductal component.

The gross target volume (GTV) consisted of the lumpectomy cavity, usually defined by 6 surgical clips. The position of the initial mammographic lesion was checked for correspondence with the marked cavity. The PTV consisted of the GTV plus a 15-20 mm margin. The range takes into account the differing sizes of surgical excisions.

- The prescribed dose was 32 Gy in 8 fractions b.i.d., separated by 6 h. Patients were treated in the supine position with 3 or 4 beams.
- The treatment isocenter was positioned relative to a midline reference point as for whole breast irradiation. The position of the isocenter in the a-p view was marked by an additional tattoo. For each fraction, all patients had a a-p and lateral portal imaging to verify the position of the isocenter relative to identifiable bone landmarks.
- 39 patients were analyzed for the magnitude of isocenter re-positioning in any of the three dimensions (a-p; sup-inf; med-lat).
- In a companion study (7 patients, 43 fractions) for additional set-up uncertainty, after the isocenter position had been optimized on portal images, stereo-vision images were obtained from a 3D/4D camera (VisionRT, London, England) which record a surface topological map. The inter-fractional variation in a region covering the proximity to the tumor bed was analyzed.

RESULTS

- For each patient - all 8 fractions of therapy evaluated for isocenter position.
- The median shift required for repositioning the isocenter (in mm) was: 0 (12 pts), 2 (16 pts) and > 3 (11 pts).
- The first fraction was associated with the largest repositioning movement, where the median shift was 3 mm (range 0-10).
- Repositioning in the sup-inf dimension was usually small. The greatest shift was in the med-lat dimension.
- No significant effect of breast volume was observed on the mean isocenter shifts.
- Distance differences between the reference surface and daily conventional setup surfaces were sometimes greater than 10mm.
- Alignment by port films (4.3±3.7mm) did not improve surface concordance to reference compared to laser alignment (3.7 ±3.8mm).
- Virtual VisionRT alignment using translations and couch rotation improved surface concordance (1.7±3.8mm). Remaining disagreement is due to deformations and missing pitch and roll adjustment.

CONCLUSIONS

- Set-up uncertainty is critical to the effectiveness of APBI by external beam. A 3 mm of error in any direction results in a ~15% loss of coverage of the PTV, for an 8 cm diameter sphere.
- The use of portal imaging / films using bone landmarks of the chest wall, partly reduces set-up error, but still allows significant residual error in the placement of the isocenter in the PTV.
- Alignment by surface topology can further reduce misalignment of the patient. Principal limitation is the breast deformation. The main question remaining is the appropriateness of skin surface as a surrogate for tumor position.
- Given that the entire treatment is complete in 8 (or 10) fractions, APBI by 3D-CRT needs set-up uncertainty minimized for every fraction of therapy.