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The use of phantom simulation for brachytherapy training and education

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Introduction: Brachytherapy is a form of radiotherapy involving the precise positioning of radioactive sources near the tissue to be treated. It is often an invasive technique requiring a sterile surgical environment and a multi-disciplinary team of professionals working together to perform the complex procedure. Education and training, however, often does not take the required precision or complexity and team-oriented aspects of the technique into account. Typical training for a new site implementing a technique is limited and often includes a site visit for some members of the commissioning team to observe the procedure. For a brachytherapy team, many aspects of the technique are only performed during their first patient. Furthermore, there has been a demonstrated learning curve for brachytherapy techniques where published data has shown implant quality is improved with the experience of the treatment team. Simulation has been shown to be an effective training method and recent technological development has allowed simulation to become practical for many medical procedures. It allows the entire treatment team to perform end to end testing with local equipment in the relevant environment. It also provides the opportunity to quantitatively assess procedure outcomes in ways that may not even be possible for patients and demonstrate the capability of the team to deliver a safe and effective treatment before the first patient. We have developed anthropomorphic gelatin phantoms incorporating treatment volumes visible on appropriate medical imaging for brachytherapy simulation. These have been applied to LDR and HDR prostate treatments, HDR gynecological and LDR breast treatments. The most comprehensive simulations were for the commissioning of the LDR breast partial breast seed implant (PBSI) technique. Phantoms were used to deliver mock implants as a process improvement initiative, resulting in a number of changes in technique as well as equipment development and implant results were quantitatively assessed.

Methodology: Multi-material anthropomorphic phantoms were made from ballistic gels with imbedded target volumes. The phantom materials were chosen to demonstrate contrast on ultrasound and CT images for treatment planning and image guidance during the procedures. The speed of sound in the gels was verified to result in appropriate distance measurements on the ultrasound images. The gels were formed using molds generated from CT contours for patient specific simulations or from simple shapes and generic representative anatomy for training or commissioning phantoms.

11 breast phantoms were constructed for PBSI commissioning and simulation. These were used for a variety of purposes including full end to end testing. End to end testing followed the clinical procedure from acquisition of the planning images, development of the treatment plan, markup on the phantom and full delivery simulation with the entire treatment team. Post-implant CT images were acquired following the mock implant and registered to the planning image in order to assess delivery accuracy in reference to the treatment plan.

Results: Phantom simulation was effectively used for commissioning measurements and to validate end to end testing in variety of brachytherapy developments including HDR and LDR prostate, interstitial gynecological and LDR breast techniques. Process improvement recommendations during mock PBSI implants resulted in multiple procedure modifications. This included the introduction of a markup procedure to place surface marks on the patient using 1-1 scale treatment plan printouts to fabricate anatomical plastic cutouts. This method enhanced the ease, accuracy and speed of defining the insertion point of the fiducial needle on the implant plane. An initial systematic error of 5mm was identified when the plastic plug holding the stylet at the proper location in the needle was removed due to a retraction as it was removed. Once recognized, this error was compensated for by advancing the stylet until the seed train was felt again before delivering. Delivering in this manner no longer showed the systematic error in depth. Fiducial entry point positioning improved from 5mm to 2mm and fiducial angle error decreased by 6.4 degrees from the initial simulation to

the last. Seed placement errors occurred in anterior-posterior, depth and lateral displacements and improved consecutively as simulations were done. Observations in translucent phantoms indicated needle angulations and translations which appeared to be related to bevel position during insertion. When re-insertion was done accounting for this error, accuracy improved.

Conclusion: Phantom simulation is an effective tool for commissioning a new brachytherapy technique. It can be used for training and education of the entire treatment team in the clinical environment and serves as an end to end test of the technique when post-implant analysis of the implant accuracy is performed. PBSI simulations showed systematic seed delivery errors which were shown to be corrected with procedural changes in successive simulations. Phantom simulation improved practitioner comfort as well as improved the speed and accuracy of the implant procedure.

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