Purpose: Projection x-ray imaging and telerobotic diagnostic ultrasound can complement each other as image guided radiation therapy (IGRT) tools. The purpose of this study was to develop and evaluate an IGRT system and workflow that integrates these two modalities for patient positioning and real-time tracking.
Methods: In the designed workflow, pre-treatment positioning is performed by stereoscopic x-ray imaging of target surrogates, such as implanted fiducial markers. When the target is in position, a reference soft-tissue ultrasound image of the target is acquired using a novel telerobotic ultrasound system. During treatment beam delivery, the ultrasound system continuously acquires spatially localized soft tissue images concurrently with the acquisition of megavoltage (MV) x-ray cine images from the treatment beam. Target position is monitored in real-time using both modalities. Ultrasound monitoring signals result from comparison of the reference image template to the current ultrasound image using cross correlation based techniques. X-ray monitoring signals rely on tracking fiducial markers visible in the MV images. To evaluate the approach experimentally, an intensity modulated radiation therapy (IMRT) plan for a tissue-mimicking multi-modality phantom with implanted gold markers was simulated. The phantom was placed on a motion stage, and target shifts before and during treatment were simulated.
Results: Target displacements were monitored in real-time by the ultrasound system and detected below 3 mm. The displacements were subsequently confirmed with kV x-ray localization, and the target was repositioned. During IMRT delivery, view of fiducial markers was blocked by multi-leaf collimator leaves in some MV cine images. Ultrasound complemented MV image tracking by successfully monitoring the target during periods of marker blockage.
Conclusions: Strengths of x-ray and ultrasound modalities may be combined to achieve an IGRT system capable of (1) absolute pre-treatment patient positioning, and (2) robust real-time displacement monitoring during beam delivery without additional dose to the patient.