Overview

Background and Significance: High dose rate (HDR) brachytherapy is a standard radiation therapy for skin, vaginal, cervical, uterine and prostate cancers, which affect over 350,000 new patients in the United States annually.[1] HDR brachytherapy brings a very high activity (~10 Ci) Ir-192 radioactive source to a prescribed treatment volume for specified time intervals using contact, intracavitary and interstitial techniques. Before treatment, computed tomography (CT) images are acquired to verify HDR applicator positions against patient anatomy and plan the delivered dose with high precision in 3D. Unfortunately, it is currently not feasible to track HDR source position during treatment (e.g. using CT) due to excessive dose, shielding and workflow challenges, hence internal dosimetry cannot be verified directly. The uncertainty in delivered versus planned dose may cause overdose or underdose of the prescribed treatment volume and increases the dose delivered to healthy tissues, which impacts clinical tolerance and efficacy. This limitation also increases the likelihood of medical events with detrimental results, including patient death.[2]

Real-time 3D (i.e. 4D) tracking of HDR brachytherapy sources *in vivo* would permit direct verification of delivered dose and enable adaptive therapy strategies to reduce procedure risk, increase treatment precision, and ultimately improve clinical outcomes. Recent investigations have proposed source tracking using multiple point-detector triangulation,[3,4] planar autoradiography,[5,6] or pinhole camera imaging of the high energy gamma radiations emitted by Ir-192.[7,8] While these approaches have demonstrated 4D tracking capabilities, their clinical value for *in vivo* dosimetry is limited as they cannot provide information about source position relative to anatomy.

Innovation: This work proposes to investigate using a digital tomosynthesis (i.e. limited angle CT) imaging system to perform real-time tracking of HDR brachytherapy sources *in vivo*. We expect that this approach can achieve 4D source tracking with sub-millimeter spatial resolution and up to 30 frames per second (FPS) timing resolution. Moreover, this approach can be used to directly relate source position to patient anatomy during treatment. This capability would allow deviations from the planning volume or source trajectory to be identified and the treatment adapted. This work aims to establish feasibility of such a system by investigating the impact of system hardware parameters, acquisition geometry and image reconstruction on 4D source tracking capabilities, and by quantifying their potential clinical impact on real-time dose verification and adaptive therapy. Completion of this work will lead to a 4D imaging system design and construction with potential for clinical translation, all within Stony Brook University. This highly innovative project leverages the x-ray imaging expertise from Radiology and the radiation therapy expertise from Radiation Oncology, and the investigators will have strong preliminary results to seek external funding support (e.g. NIH, NCI) to pursue system construction and clinical translation, which will improve HDR brachytherapy clinical outcomes at Stony Brook Medicine.