X-Ray Induced Acoustic Computed Tomography (XACT) for Real-Time Monitoring of External Beam Radiotherapy

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Background, Motivation, and Objective:

As a newly invented technology, X-ray induced acoustic computed tomography (XACT) provides an effective solution for the challenging problem of in vivo dosimetry and real-time online monitoring of X-ray beam position during external beam radiation therapy. In this work, via the experiments on soft tissue phantoms and animal models, we examine the feasibility of XACT in quantitatively mapping the X-ray dose deposition in a targeted tissue, and for real-time monitoring of the dose delivery position in a biological sample.

Statement of Contribution/Methods:

In vitro experiments performed with a prototype XACT system, which involves the rotation of a single immersion ultrasound transducer around the targeted sample, was firstly used to explore the dose sensitivity of XACT. The results were verified by comparing to the measurements from the gold-standard radiochromic film. Then, a clinically ready XACT system integrated with B-mode ultrasound (US) for dual-modality imaging was built onto a Verasonics ultrasound platform. The feasibility of this system in real-time monitoring of the dose delivery position was studied. The potential of this technology to guide the radiotherapy of cancer originated in liver, prostate, and brain was evaluated using clinically relevant animal models in ex vivo and in vivo setups.

Results/Discussion:

The dose resolution as small as 2.9% of delivered X-ray dose can be achieved by XACT. The quantified dose measured by XACT was highly correlated to the film measurements, which demonstrated that XACT has a clinically acceptable sensitivity for mapping the dose deposition. The relative displacement of the X-ray beam over the target tissue can be visualized by the integrated XACT and US dual-modality imaging in a real-time fashion, with spatial resolution better than 0.37 mm. The experiments on animal models including rabbit livers and pig brains showed promising results, paving the road toward clinical translation of the technology. In the future, this dual-modality imaging technology may allow not only online monitoring of the X-ray dose deposition but also alignment of the X-ray beam to a moving treatment target.

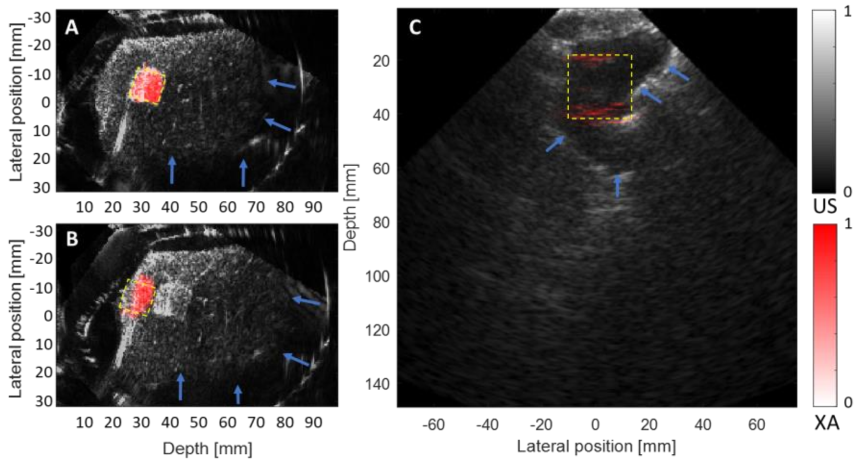

Figure 1. The pseudo-color XACT images (showing the location of X-ray dose deposition) superimposed on the gray-scale US images (showing the sample structure including the position of the tumor in a rabbit liver). (A) X-ray beam on the target of the artificial tumor in the liver. (B) X-ray beam off the target of the artificial tumor in the liver. (C) In vivo dual-modality imaging showing both the rabbit liver and the X-ray beam deposition. The yellow squares are the beam delivered positions. The blue arrows show the boundaries of the liver.