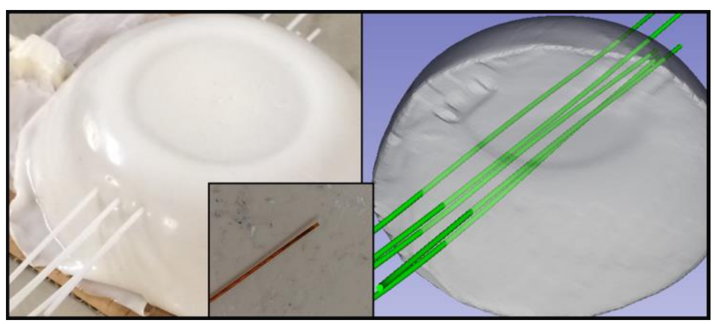
Electromagnetically-generated catheter paths for breast brachytherapy

T Vaughan[1], H Brastianos[2], A Lasso[1], T Ungi[1], CB Falkson[2], G Fichtinger[1]
[1]*School of Computing, Queen's University, Kingston, Ontario*
[2]*Division of Radiation Oncology, Queen's University and Kingston General Hospital, Kingston, Ontario*
Consortium Affiliation: CANCER

INTRODUCTION: Breast conserving therapy is recommended for women with early stage breast cancer. The treatment consists of surgical removal of the tumor followed by radiation therapy. One strategy to deliver radiation therapy is multi-catheter interstitial breast brachytherapy, which involves inserting catheters through the breast then guiding radioactive sources to the tumour bed. Brachytherapy is advantageous because of its short treatment period of one week and confined area of treatment, as opposed to whole-breast irradiation which can last from three to seven weeks and exposes surrounding organs to radiation. Brachytherapy relies on accurate information about the placement of catheters to ensure appropriate radiation doses are delivered. The process of localizing catheters is usually done using CT, fluoroscopy, or ultrasound imaging, but these are difficult to interpret or they expose the patient to radiation. In this paper, we study a method for localizing catheters based on electromagnetic (EM) tracking, and evaluate it in a phantom study.

METHODS: A radiation oncology resident performed thirteen catheter insertions on two plastic phantoms (Figure) under ultrasound guidance. A small EM sensor (Figure) was fed through each of the catheters and pulled out slowly at an average rate of 5 cm per second. The PLUS toolkit [1] (www.plustoolkit.org) relayed sensor information to a navigation computer where a record of position information was kept. Least-squares polynomial curves were fit to the position information using the MarkupsToModel utility in SlicerIGT (www.slicerigt.org), a free add-on to the open-source 3D Slicer platform [2] (www.slicer.org). EM-generated catheter paths were created in this manner three times for each catheter, yielding three full sets of EM-generated paths. We evaluated these EM-generated paths against CT-generated paths, which were created by performing threshold segmentation on CT and then centerline extraction with the Vascular Modeling Toolkit (www.vmtk.org). A rigid registration was performed to align the paths and then we measured the shortest distances (error) between the EM- and CT-generated paths at uniformly-sampled points along the length of the phantom. We were evaluating the method for error lower than the 0.68 mm slice resolution of the CT scanner.

RESULTS: The mean error of EM-generated paths (Figure) was 0.38 mm, with a standard deviation of 0.13 mm. After determining that the data were normally distributed (Shapiro-Wilk test, $p < 0.001$), we performed a one-tailed one-sample t-test and determined that the error was statistically significantly lower than the slice resolution of the CT scanner ($p < 0.001$). The CT-generated path accuracy was limited by the CT resolution so we conclude that, in this study, EM-generated paths were at least as accurate as the CT-generated paths.



Left: Phantom. Center: EM sensor (trakSTAR model 55, NDI, Waterloo, ON). Right: EM-generated paths.

CONCLUSIONS: The EM-generated catheter paths in this study were accurate, and comparable to those generated using CT. We plan to evaluate EM-generated catheter paths further for use in clinical studies.

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