# Cooperative Robotic Guidance for Tumor Localization in Breast Surgery

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**Aims:** Delineating tumor boundaries during breast-conserving surgery (BCS) can be challenging because breast tumors are often non-palpable. If the surgeon accidentally transects the tumor, the patient will experience positive margins and require repeat surgery to remove residual cancer. Approximately 5-57% of patients who undergo BCS will experience positive margins [1]. To address this problem, we developed a cooperative robotic guidance system that imposes a "force field" around the tumor boundary to prevent breach.

**Materials and Methods:** The *NaviKnife* system, developed at Queen's University, provides visual navigation in BCS using ultrasound guidance and EM tracking [2]. Preoperative ultrasound and AI are used to segment the tumor and reconstruct the volume in 3D for visual guidance. EM sensors, embedded in a needle within the tumor and attached to the surgical tool, enable real-time visualization of the tool's position relative to the tumor model in a navigation interface. For robotic guidance, we have extended *NaviKnife* by integrating a haptic device (Touch, 3D Systems, USA) to provide tactile feedback near the tumor boundary (Fig. 1). We conducted a pilot study with six users on simulated breast models to assess the utility of this system. Each participant completed several mock resections. Following the resections, participants filled out a survey to capture their impressions of the navigation experience. We also evaluated resection performance, percentage of total volume removed and resection time.

**Results:** When haptic guidance was used, every participant left either the same or a reduced amount of residual tumor tissue. Overall, users reported the task felt less frustrating, required less mental effort, and were more confident in performance when haptic feedback (HF) was enabled. Interestingly, with HF, users removed a greater combined volume of tissue and took longer to complete the resection. We believe with further training; increased resection time and volume removal could be minimized.

**Conclusions:** Our findings show that while HF may help reduce positive margins and lower mental workload, it may also lead to longer resection times and wider margins. Insights from this feasibility study will guide future improvements in system design, training strategies, and operational settings for haptic guidance in BCS.

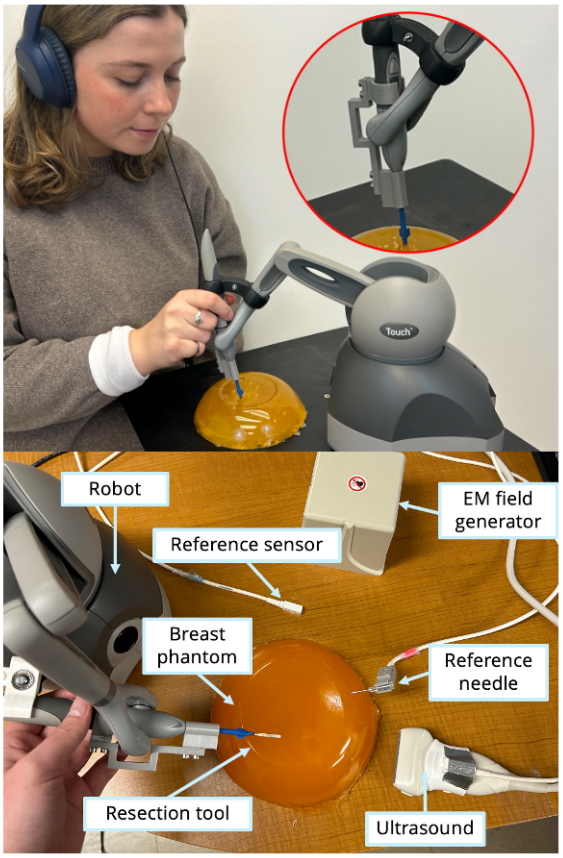


**Figure 1:** Top – user performing a simulated resection. Bottom – Overview of benchtop testing system.

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