Laparoscopic Image Guidance via Conoscopic Holography

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Spatially registered 3D preoperative medical images can improve surgical accuracy and reduce reliance on memory and hand-eye coordination by the surgeon. They enable visualization of internal structures within the anatomy of a patient on the operating table. In the case of biopsy, for example, this would allow the surgeon to guide the needle tip to a tumor though opaque tissue. It has been well established that for soft tissues, image registration can be performed by aligning the preoperative image with a cloud of points that describe the surface of an organ [1]. Collecting this point cloud can be challenging, generally requiring open surgery to permit line-of-sight access for laser triangulation (e.g., the system of Pathfinder Therapeutics, Inc.). We present a conoscopic holography-based system for collecting a point cloud less invasively-through a laparoscopic port. The system consists of a commercial conoscope (Optimet, Inc., Probe Head Mk3), designed for precision machine-shop linear measurements, that is tracked (the surgical tool is also tracked) with an optical tracking system (Claron Micron Tracker H3-60). The conoscope laser beam can, in principle, be aimed through a laparoscopic port. The 1 degree of freedom linear distance measurements it returns are converted into a point cloud using optical tracker information. Proof-of-concept for obtaining point clouds via conoscopic holography and registering them to known shapes is provided in [2]. However, the procedure for collecting these point clouds requires the surgeon to manually ′paint' the surface of the organ with the laser beam, aiming it at many points on the surface by manipulating the conoscope base unit, thus pivoting the tube in the laparoscopic port. It would be desirable to relieve the surgeon of this task by creating a system for automatically aiming the laser beam from a stationary conoscope. We hypothesize that this can be done with a suitably designed actuated mirror assembly at the tip of the laparoscopic tube. To assess whether a conoscope can make an accurate distance measurement when reflected by a mirror, we conducted a set of experiments. We placed a front-silvered mirror at a fixed 45 degree angle relative to the conoscope, 12 cm in front of it. Total beam length was 185-315 mm measured in 10 mm increments. The results were similar to direct measurements of the same distance without a mirror. We recorded a standard deviation of error of less than 0.01 mm in each 10 mm increment. A second experiment was then carried out to assess the effect of mirror angle. The laser was swept across a flat surface 105 mm from the mirror by rotating the mirror. The standard deviation of the data points from a true line was less than 0.1 mm along a 175 mm line segment. These experiments indicate the feasibility of using a mirror to aim a conoscopic holographic laser, paving the way for an automatic laparoscopic laser, paving the way for an automatic laparoscopic point cloud collection device to be developed in future work.

Development of Photoinitiated Nitric Oxide Releasing Polymer Films for Controlled Drug Delivery

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Nitric Oxide (NO) is small, free radical gas that has been shown to have a wide variety of physiological functions, including the ability to hinder tumor angiogenesis at high, but non lethal, concentrations. Previous work suggests that if NO could be effectively delivered in vivo to tumors of patients currently undergoing chemotherapy treatments at the appropriate levels, less damaging chemotherapy treatments could be used against cancer. This could increase the overall survivability of cancer patients, especially in those prone to the harmful effects of chemotherapy: children, elderly, and those of weak immune systems. If NO is especially successful at preventing and eliminating tumor growth, angiogenesis, and carcinogenesis the need for stressful chemotherapy treatments could be eliminated altogether. This project is focused on developing novel photosensitive NO donors that can be incorporated into polymeric systems and used in a fiber optic drug delivery system. Development of these NO-releasing polymers will allow continued investigation of NO's role in tumor death by precisely controlling the surface flux of NO that cells are exposed to. Generating specific surface fluxes of NO from polymer films has been demonstrated by using polymer films that contain photoinitiated NO donors, prepared by synthesizing S-nitrosothiol (RSNO) derivitized polymer fillers that are blended into hydrophobic polymers and cast into a film. These films generate and sustain a surface flux of NO based on the wavelength and intensity of light used. Polymers releasing NO are more promising as an NO donor than simply injecting NO into samples because they allow for spatial and temporal control of NO delivery. The specific concentration of NO needed to produce desirable effects on tumor cells (i.e. apoptosis) is not known. Data will be presented that show the synthesis and NO-release properties of novel RSNOs based on the nitrosation of benzyl mercaptan thiols. Specifically, UV-Vis spectrum of benzyl mercaptan in toluene and S-nitrosobenzyl mercaptan after the addition of t-butyl nitrite will be presented. We are currently investigating the effects of varying NO-surface fluxes generated from photolytic NO donating polymer films on aortic smooth muscle cell cultures obtained from mice. Once we have established that we can quantitatively determine the effects of different levels of NO on the proliferation of smooth muscle cell cultures, work will begin to apply this methodology and these novel NO-releasing polymeric systems to begin investigating what durations and surface fluxes of NO are necessary to have tumorcidal effects on specific cancer cells.

