Multi-spectral confocal imaging system for optical biopsy in surgery

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Introduction

We have developed a real-time multi-spectral confocal microendoscope imaging system (MCME) that provides surgical teams instant optical biopsies for early cancer detection via a laparoscope or daughter endoscope. Optical biopsy delivers instant in-vivo cellular images, comparable to those provided by histology, through a minimally invasive procedure. For the surgeon, this means that more tissue can be explored and abnormalities can potentially be dealt with during the same procedure with less harm to the patient. Currently, surgeons must extract tissue and wait for frozen section processing and pathology analysis to determine if the tissue is abnormal.

Diagnosis of cancer is often done by pathologists using thin sections of stained and processed biopsy tissue. Confocal microscopy, a more recent innovation, is also being used with greater frequency because it can directly image bulk sections of tissue with high clarity by only collecting light from in focus planes; light from out of focus planes is rejected. Since the confocal microscope alleviates the need for cutting tissue into thin sections, it has significant potential as an in-vivo imaging device that could supplant biopsies. However, a standard confocal microscope is a large device that is not especially suited for accessing the epithelial surface of most organs where biopsies are acquired. Realizing the potential of confocal imaging to ultimately supplant biopsies via in-vivo imaging, we worked on the initial technologies to enable in-vivo confocal imaging via coherent fiber optic bundles. Since the initial work, our research group has continued developing technologies to allow live in-vivo human cellular imaging via confocal microendoscopy during surgery. In this poster we present our current state-of-the-art developments for in-vivo cellular imaging and initial clinical results as directly applied to the detection of human ovarian cancer.

Mobile Surgical Device

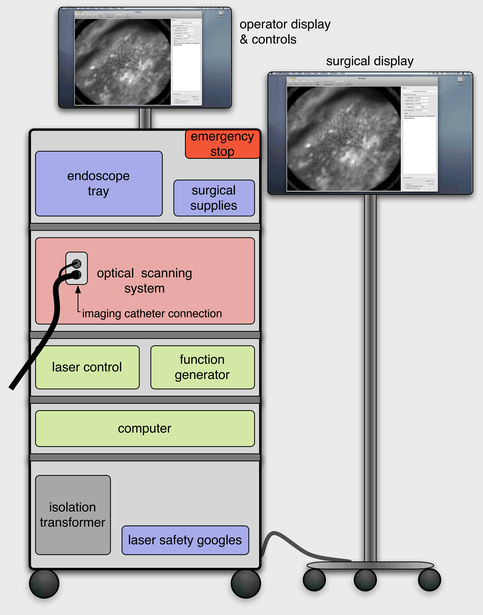

Figure 1: Surgical confocal microendoscope system
All the system components are housed on a mobile endoscopy cart. The mobile system has been designed to streamline all operations during surgery. Once the system is plugged in and the safety interlocks engaged, the system boots and all hardware is initialized. After the automatic initialization, the operator is presented with the software control system auto-initialized for live imaging.

Live Optical Biopsies in Surgery

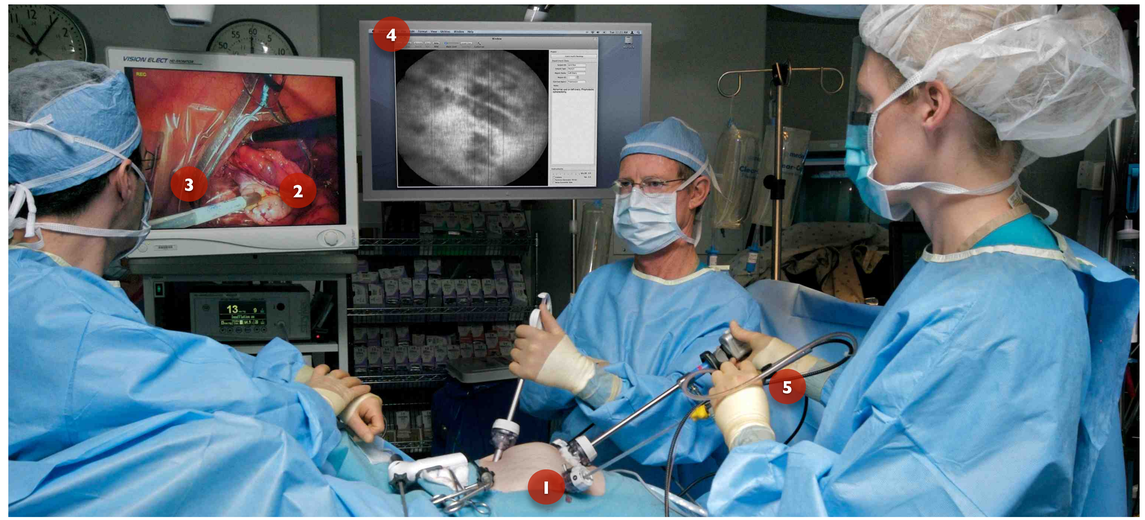

Figure 2: Live cellular imaging of ovaries in surgery
Dr. Kenneth Hatch directs a laparoscopic surgery in which a female patient's right ovary with an abnormality is "optically biopsied" during a clinical trial of our system. The assisting surgeon images the ovary with our 5mm confocal laparoscope entering the foremost trocar (1) and contacting the ovary (2) from the lower left (3). The integrated dye delivery system dispenses a tiny volume of fluorescent dye in the field of view resulting in a video of the epithelial cells (4) in real-time. Adjustment of the depth selector knob (5) allows the surgeon to image below the tissue surface.

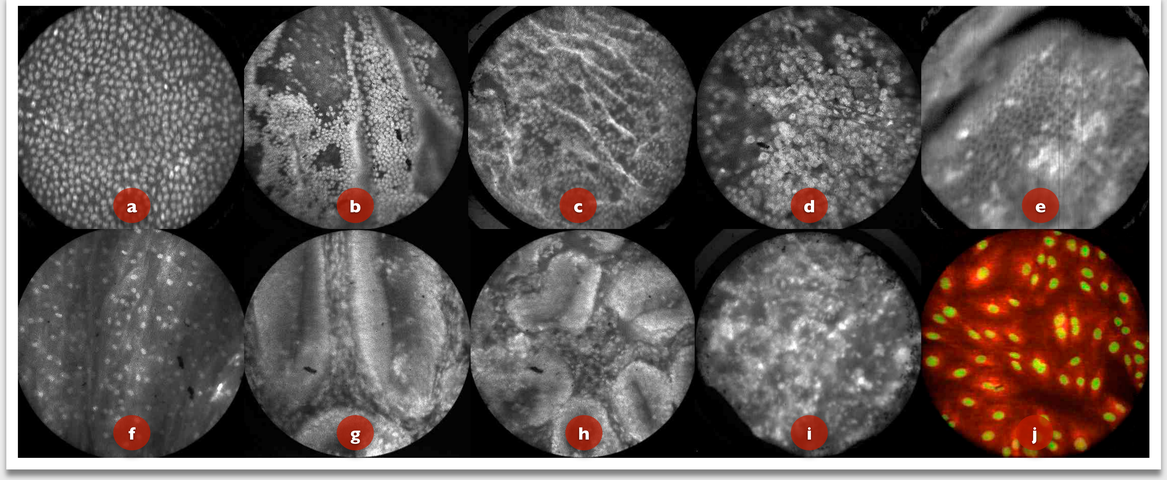

Figure 3: Cellular images using the confocal microendoscope
Example epithelial images demonstrating our system's ability to discriminate between normal and abnormal tissues. (a) Normal, (b) denuded epithelium, (c) sclerotic, and (d) tumor of human ovaries stained with acradine orange. (e) Human ovaries stained with fluorescein. (f) Normal, (g-h) Barrett's esophagus, and (i) tumor of human esophagus stained with acradine orange. (j) Multi-spectral image of muscle cell culture.

Imaging Catheters

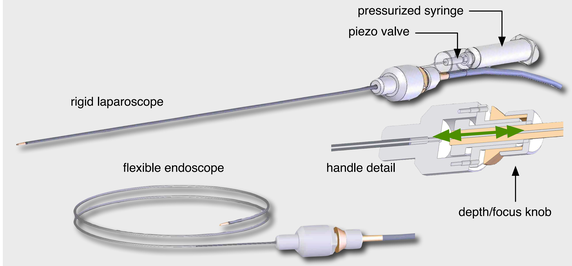

Figure 4: Confocal imaging catheters
A laparoscopic version is shown on top with an integrated dye delivery system that uses a piezo valve and pressurized syringe. The lower left figure shows the flexible endoscope version of the device. Both devices have the same handle that uses a depth/focus knob to translate the coherent fiber bundle routed through the center of the device .

Confocal Scanning System

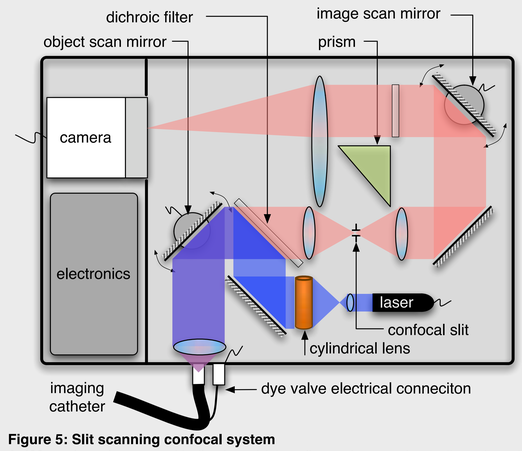

Figure 5: Slit scanning confocal system
A 488 nm laser is anamorphically shaped into a line and scanned onto the coherent fiber bundle in the imaging catheter. The excited signal re-enters the system, is descanned, and filtered through a confocal slit. Then the light is rescanned onto a two dimensional detector. Multi-spectral imaging is accomplished by turning the image scan mirror to its extreme position redirecting the light through a dispersing prism.

Acknowledgments

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