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Abstract

TITLE: ASSISTIVE-AUTONOMY IN COLONOSCOPY: PROPULSION OF A MAGNETIC FLEXIBLE
ENDOSCOPE

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ABSTRACT BODY:

Background: Advancement of the insertion tube during colonoscopy induces tissue stress leading to potential discomfort and perforation. The use of magnetic fields for endoscope actuation has been promising—as the endoscope can be pulled from its front. Our team has developed a novel magnetic flexible endoscope (MFE) that uses magnetic field sensing, robotic control, and real-time image processing to enable autonomous maneuvering. The impact of assistive autonomy in colonoscopy is currently unknown.

Methods:
Platform: The MFE contains a permanent magnet (PM), camera, illumination module, and channels for instruments, insufflation, irrigation, and suction. A robotic arm maneuvers a second PM to manipulate the MFE. System software facilitates intelligent-magnetic actuation. Using image-feedback for lumen detection, complemented by magnetic control, the MFE can be steered through a lumen with little human input—under assistive autonomy.

Experiment: The MFE was evaluated in a human colon phantom traveling rectum to cecum under three control methods: (1) user teleoperation without computer-aided control, (2) user teleoperation using computer-aided magnetic control, and (3) semi-autonomous navigation where an operator intervened only at times to augment lumen visualization (i.e. touched the screen to command direction of motion). For this proof of concept study, an expert endoscopist (>2000 colonoscopies) and two novices (no colonoscopy experience) completed each control method five times. Outcomes of interest included successful cecal intubation, trial time, robot pose data/processing, and NASA Task-Load-Index (TLX).

Results: Cecal intubation with computer-aided and semi-autonomous control was 100% successful (n=30); while teleoperation trials without computer assistance was 53% successful (n=15). Trial times were quicker for computer-aided and semi-autonomous control when compared to teleoperation control (343.1 ± 176.4 and 356.6 ± 137.0 v. 638.9 ± 263.0; p=0.023). There was no difference between endoscopist experience and cecal intubation time for teleoperation and computer-aided methods. The novices were quicker compared to the expert when using semi-autonomous control (p<0.01). The

system was robust, necessitating manual reset infrequently (semi-autonomous: n=4; time taken to reset: 457 s; computer-aided: n=1; time taken to reset: 120 s). All users had lower TLX frustration, effort, physical demand, and improved performance with computer-aided and semi-autonomous control when compared to teleoperation.

Conclusion: The MFE successfully traversed the colon and intubated the cecum under both semi-autonomous and computer-aided control. Computer-aided and semi-autonomous control methods were superior to teleoperation with improved performance, quicker cecal intubation times, and reduced mental demand—especially for novice users. Trials with higher levels of autonomy and increased sample size are ongoing.