Development of the Stiffenable Exoskeleton Device for a Colonoscopy

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Colonoscopy provides a minimally invasive tool for examining and treating the colon without surgery, but current colonoscope designs still cause a degree of pain and mechanical trauma to the colon wall. The most common colonoscopes are long tubes inserted through the rectum with fiber optic lights, cameras, and biopsy tools on the distal end. The stiffness required to support these tools makes it difficult for the scopes to navigate the twisted path of the colon without causing mechanical trauma inside the colon wall or distorting its shape. The shaft of the colonoscope often causes looping (alpha, reverse alpha, or n), and it is very difficult to advance the distal tip of the colonoscope with looping. In order to avoid looping and minimize mechanical trauma, the author expanded on a design by Zehel et al., who proposed surrounding a flexible colonoscope with an external exoskeleton structure with controllable stiffness. The stiffenable exoskeleton device is comprised of rigid, articulating tubular units, which are stiffened or relaxed by four control cables. The stiffened or relaxed exoskeleton device guides navigation and provides stability for the colonoscope when it protrudes beyond the exoskeleton device for examination and procedures. This research determined the design requirements of such an exoskeleton device and tested requirements of such an exoskeleton device and tested its behavior in a colonoscopy training model. Moreover, the stiffenable exoskeleton device can be operated in purely a mechanical way, which is safe as a class II medical device, and no additional modification of the colonoscope is needed to use the stiffenable exoskeleton device. Colonoscopy training model is used to test the stiffenable exoskeleton device. First, the endoscopist inserted the colonoscope into the colonoscopy training model up to the end of the stiffenable exoskeleton device along the shaft of the colonoscope to the distal tip of the colonoscope, and then locked the stiffenable exoskeleton device and advanced the shaft of the colonoscope to examine the colon. When the distal tip reached the cecum, he or she unlocked the stiffenable exoskeleton device, retracted the shaft of the colonoscope and the stiffenable exoskeleton device, and checked for polyps or other colon disease. Also, the endoscopist can insert the stiffenable exoskeleton device and a colonoscope alternatively by stiffening and releasing the exoskeleton device. In that way, endoscopist can advance the colonoscope and the exoskeleton structure inch-by-inch without causing mechanical trauma in the rectum and the sigmoid colon. The endoscopist tested the stiffenable exoskeleton device using the colonoscopy training model and fulfilled its objectives. Several other diagnostic procedures involving the stomach, esophagus and the nose could also benefit due to the improvements provided by the stiffenable exoskeleton technology.

Design of a Testing Mechanism for Stent Failure Rates and Displacement Under Extreme Bending Conditions

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Stents are commonly associated with the mechanical support of the coronary arteries to improve blood flow and retain residual plaque following various angioplasty procedures. However, they are becoming more frequently used in other vessels in the human body, such as the carotid and femoral arteries. The femoral arteries transverse through the hip region, and are the sites of potential plaque build-up. Thus the design of a stent for the specific biomechanical stresses and conditions of this location is of growing interest. The effectiveness of stent designs are quantified by their ability to survive in the human body without failing mechanically, dislocating, or invoking a major inflammatory response. Common methods of failure are mechanical, including fractures and dislocations. Several different instruments are commercially available for the testing of stents under various stresses and application frequency. However, these machines generally test with small bending angles or they apply nonphysiological axial, radial and torsional loads; thus they are not idealized for motions to mimic accurate biomechanical motion. Specifically, for the design of a stent localized in the hip region, a test for significant bending cases is necessary. The placement of stress on a mock artery should be applied solely to the ends of a mock artery to remove any radial or axial stresses not caused directly from the bending motion. Furthermore, visualization of the stent inside the mock artery is desired for tracking displacement of the stent and cycle count until failure. The ability to quantify the mechanical failure and dislocation of stent designs under extreme bending conditions is a prerequisite to the optimization of physical stent designs and of stent spacing, orientation and placement. We compare a proprietary stent-like design (Innovasc Inc., Honolulu, HI) placed at fixed intervals versus a commercially available SMART stent (Cordis Corporation, Warren, NJ). Both designs are intended to retain the arterial plaque while minimizing the stress applied to the artery wall to prevent restenosis. The new stent prototype designs are uniquely configured to enable points of stress reduction along the length of interest. Early preliminary experiments with the Innovasc design show promising results in the reduction of restenosis in porcine models. Stent designs are tested in mock arteries of latex and silicone. The mock arteries are selected for internal diameters and thicknesses to match artery properties. Two symmetric cylinders holsters are allowed to rotate freely and are affixed to the ends of the mock arteries. A simple linkage system drives the two cylinders together and apart, allowing for the mock arteries to bend at a fixed angle of 120 degrees at frequencies (~10–20 Hz) without external stresses for one million cycles. Images are captured using a X-Stream Vision High-Speed CMOS camera (Integrated Design Tools, Tallahassee, FL) via a trigger system. Failure points and dislocations are noted and measured using the NIH ImageJ imaging software.