

VIDEOCAPSULE INVESTIGATION OF SMALL BOWEL

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Introduction

The advent of wireless video-capsule endoscopy (1-7) has released the endoscopist from the requirement to exert force on a long floppy cable type endoscope to examine relatively short segments of small intestine. The key to the development of the wireless capsule endoscopy was miniaturization of electronic components and especially the development of very small video cameras and wireless transmitters. Miniaturization of electrical components has allowed the manufacture of a capsule sized endoscope without wires which can take video images of the gastrointestinal tract and transmit this information to a recorder, which is worn by the patient on a belt. Perhaps the most difficult problem with the development of wireless capsule endoscopy was thinking that it was possible and risking the time and money on making it to see how well it might work.

Future innovations

Wireless capsule technology is an incompletely developed technology and might change endoscopy forever and has the capacity to replace a good deal of conventional endoscopy. Will capsule endoscopy replace much of conventional gastroscopy and colonoscopy? The answer is probably yes but the time frame is unclear. Will capsule endoscopy be able to deliver therapy? This is also possible.

There are two major challenges to the expansion of capsule technology into a position where it can challenge conventional diagnostic gastroscopy and colonoscopy. The first challenge is power management. At present the M2A capsule contains two small 3 volt hearing aid batteries which allow about eight hours of continuous imaging. The use of CMOS technology for the video has the advantage of requiring extremely low power levels. Slowing the video frame rate to two frames per second increased the life span of the capsule. More batteries or more efficient batteries would help but might increase the size and weight of the capsule. The development of external power transmission methods using electrical field induction, radio-frequency, microwave or ultrasound technology would free the capsule from the requirement for batteries. This would substantially lighten the capsule, allow space and power for other functions such as biopsy or drug delivery but above all would allow the capsule to be powered for infinite periods which would make the problem of capsule colonoscopy much easier to solve.

The development of the capsule endoscopy was made possible by miniaturization of digital chip camera technology especially CMOS chip technology. The continued reduction in size, increases in pixel numbers and improvements in imaging with the two rival technologies – CCD and CMOS is likely to change the nature of endoscopy. The current differences outlined in Table 3 are becoming blurred and hybrids are emerging.

The main pressure to reduce the component size will be to release space that could be used for other capsule functions for example biopsy, coagulation or therapy. New engineering methods for constructing tiny moving parts and miniature actuators or even motors have been described. There are some engineering challenges to be solved. Transmission of sufficient power to medical devices in the body to allow extra functions is a major issue. Cleverly designed power management solutions to battery run devices may allow some new functions fairly soon. Controlling the orientation and movements of the capsule seems feasible. The development of external transmission systems which can beam power to devices in the human body needs more work but bioengineers working in the cardiology area have shown that it is possible to induce currents in remote internal devices with externally applied systems.

Although semi-conductor lasers exist which are small enough to swallow, the nature of lasers which have typical inefficiencies of 100-1000 percent make the idea of a remote laser in a capsule stopping bleeding or cutting out a tumour seem something of a pipe dream at present because of power requirements. The construction of an electrosurgical generator small enough to swallow and powered by small batteries is thinkable but currently difficult because of the limitations imposed by the internal resistance of batteries. Small motors are currently available to move components such as biopsy devices but need radio-controlled activators. One limitation is the low mass of the capsule endoscope. A force exerted on tissue for example by biopsy forceps may push the capsule away from the tissue.

Future diagnostic developments are likely to include capsule colonoscopy, attachment to the gut wall, ultrasound imaging, biopsy and cytology, propulsion methods and therapy including tissue coagulation.

Challenge to using capsule endoscopy for colonoscopy

There are challenges to using wireless capsule endoscopy for colonoscopy. Currently the capsule acquires images for 8 hours and has usually reached the right side of the colon before the battery expires. The capsule would have to run for 24 – 48 hours in order to perform a complete examination of the colon. The power problem could be addressed in several ways. Solutions to this difficulty might include: more batteries, batteries with a delay mode which are switched on when the capsule is in the ileum, external power transmission or methods to move the capsule faster in the colon. Effective timed colon cleaning will be necessary. Deletion of identical frames would make it easier to examine the images since the capsule in the colon can remain stationary for prolonged periods. Wireless capsule colonoscopy has already generated images from all areas of the colon and has imaged pathology especially in the right side of the colon, but also in the rectum.

Wireless laparoscopy is feasible but needs to develop and offer advantages over conventional laparoscopy. Wireless imaging of cardiac or vascular structures is possible but would require substantial development and control strategies. The manufacture of an autonomous video capsule the size of a red blood cell as described in Isaac Asimov's "The Fantastic Voyage" is some way in the future. Reduction in size by an order of magnitude is currently feasible with available components.

Attachment of capsule endoscope to the GI tract

The capsule might be stitched or clipped to the wall of the stomach so that prolonged examination of bleeding ulcers or varices became possible. An on/off radio-controlled command might be helpful to conserve power. Long term endoscopy with wireless endoscopes attached to the wall of the gut could improve management of bleeding and other disorders.

Tissue interactive diagnostic methods

At present the capsule does not take biopsies, aspirate fluid or brush lesions for cytology. These common endoscopic maneuvers may be possible during capsule endoscopy. They require real-time viewing and will also require radio-controlled triggering and remote control capsule manipulation if they are to be used with precision. Biopsy using a spring loaded Crosby capsule like device with an evacuated chamber would be feasible with existing capsule technology and patients seem able to retrieve capsules from stool using a net and a magnet almost all the time in preliminary patient studies. Brush cytology is another possibility and has been used in vivo.

Electro-stimulation for propelling capsule endoscope

One way to manipulate a wireless capsule endoscope autonomously in the human gastrointestinal tract is to use electrostimulation to propel the device for example with a pair of bipolar electrodes at either end of the capsule. Electrodes attached to an M2A capsule have been used to propel this device in the human small intestine. A dumb-bell shaped capsule allows the imaging capsule to view the traction capsule. A radio-controlled electro-stimulation capsule has been developed. Radio-commands can be sent from a transmitter and aerial to the receiving traction capsule causing it to propel the video capsule forwards or backwards in the human gastrointestinal tract.

Water-jet propulsion has also been used to propel this very light weight (3.7 gram) capsule in the gastrointestinal tract.

Capsule coagulation

A prototype coagulation capsule has been built and tested which uses an exothermic chemical reaction to generate heat. It seems probable that other therapeutic applications will be added in the future.

Olympus in a recent news release (November 30, 2004) has announced the following developments in capsule endoscopy. These include: Wireless powers supply system, Capsule guidance system, Drug delivery system, Body fluid sampling technology, Self-propelled capsule, Ultrasound capsule.

Conclusions

Video-enteroscopy has opened up a new world of diagnoses and possibilities to the gastroenterologist. It is a privilege to see images of small intestinal abnormalities at video-endoscopy such as an ulcerated Meckel's diverticulum or active bleeding from a tumour in the middle of the small intestine, which were not possible till recently. The development of wireless capsule endoscopy has changed video endoscopy of the small intestine into a much less invasive and more complete examination. The increasing use of these resources and the comfort and ease with which some of these examinations can be performed make it likely that wireless capsule video imaging will have a substantial impact on the management of small intestinal disease and other parts of the body.

Einstein who probably knew more than most about the potential impact of physics on the future of mankind was goaded during an interview in 1929 on board the Belgoland into saying "I never think about the future; it comes soon enough".

REFERENCE LIST

1. Iddan G, Meron G, Glukhovsky A, Swain P. Wireless capsule endoscopy. *Nature* 2000; 405(6785):417.
2. Appleyard M, Glukhovsky A, Swain P. Wireless-capsule diagnostic endoscopy for recurrent small-bowel bleeding. *New England Journal of Medicine* 2001; 344(3):232-233.
3. Appleyard M, Fireman Z, Glukhovsky A, Jacob H, Shreiver R, Kadiramanathan S et al. A randomized trial comparing wireless capsule endoscopy with push enteroscopy for the detection of small-bowel lesions. *Gastroenterology* 2000; 119(6):1431-1438.
4. Lewis BS, Swain P. Capsule endoscopy in the evaluation of patients with suspected small intestinal bleeding: Results of a pilot study [comment]. *Gastrointestinal Endoscopy* 2002; 56(3):349-353..
5. Mylonaki M, Fritscher-Ravens A, Swain P. Wireless capsule endoscopy: a comparison with push enteroscopy in patients with gastroscopy and colonoscopy negative gastrointestinal bleeding. *Gut* 2003; 52(8):1122-1126.
6. Pennazio M, Santucci R, Rondonotti, Abbiati C, Bessari G, Rossini FP, De Franchis R. Outcome of patients with obscure gastrointestinal bleeding after capsule endoscopy: Report of 100 consecutive cases. *Gastroenterology* 2004; 216; 643-653.
7. Costamagna G, Shah SK, Riccioni ME, Foschia F, Mutignani M, Perri V et al. A prospective trial comparing small bowel radiographs and video capsule endoscopy for suspected small bowel disease.[comment]. *Gastroenterology* 2002; 123(4):999-1005.