Minimally invasive surgery with hydraulic assistance

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Hydraulic instruments support surgeons when working with endoscopes. The gripping force at their tip is greater. Medicines are able to operate more precisely. Credit: Fraunhofer IPA

Endoscopic surgery requires great manual dexterity on the part of the operating surgeon. Future endoscopic instruments equipped with a hydraulic control system will provide added support during minimally invasive procedures. Their outstanding sensitivity simplifies the biopsy procedure.

Minimally invasive techniques, also known as "keyhole surgery," enable surgeons to operate on patients without requiring major incisions. This method causes much less trauma for the patient, and is commonly used when performing lung, esophageal and joint biopsies, and most especially when operating inside the abdominal cavity. An endoscope is inserted through one or two small incisions in the abdominal wall, allowing the internal organs to be visualized for surgery.

Surgical techniques have advanced by leaps and bounds in recent years. The same cannot be said for surgical instruments. In certain types of endoscope, the tip can be oriented at different angles. "This basic control mechanism, which demands great dexterity and even physical strength on the part of the surgeon, has barely changed since the earliest days of endoscopy," says Timo Cuntz, a member of the Project Group for Automation in Medicine and Biotechnology PAMB in Mannheim, a part of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA. The force required to deflect the tip is transmitted by a wire mechanism known as a Bowden cable (similar to a bicycle brake cable). Modern endoscopes are additionally equipped with tiny pincers, clamps or scissors for removing tissue samples, for example. These miniature instruments are controlled mechanically, too. The cable mechanism transmits the surgeon's hand movements at one end to the tiny instruments at the other extremity of the endoscope.

Using hydraulic fluid instead of wires

Cuntz adds: "The movement of the wires inside the Bowden cable generates friction and hence a loss of force. Only a small proportion of the force applied actually reaches the tip of the instrument, making it difficult for the surgeon to manipulate the tissue precisely." The surgeon's work would be made much easier if it were possible to reduce the friction and increase the power density. Hydraulic instruments are one of the alternatives being considered as a substitute for mechanical

transmission based on Bowden cable. "Instruments with hydraulic force transmission have demonstrated promising results in our tests. They allow the surgeon to carry out much finer movements," says the engineer. A plastic tube filled with a sterile, biocompatible fluid based on medicinal white oil is used in place of the wire cable. To control the attached instruments and orient the tip of the endoscope, the surgeon manipulates a hydraulic cylinder or robotic muscle that exerts the required pressure to compress the fluid and push it through the hydraulic tube onto a second, spring-mounted cylinder. The advantage of this system is its lower frictional loss and higher gripping force – up to 50 newtons have been achieved in the laboratory. The system, which the researcher likes to compare with the hydraulic brakes on a mountain bike, also offers the option of connecting a pump to generate the pressure needed to dissect or remove precise areas of tissue.

The particular strength of hydraulically actuated instruments is the efficiency with which power is transmitted to the distal tip, especially in the case of meandering rather than straight insertion paths – for instance through the digestive tract. This also allows the use of more flexible feed lines, with very small diameters and a low bending radius. Cuntz and his fellow researchers at PAMB are currently building an endoscopic instrument with an outer diameter of no more than three millimeters. Such hydraulically actuated instruments are ideally suited for use in connection with a technique known as natural orifice transluminal endoscopic surgery (NOTES), in which the surgeon operates through natural body orifices in order to access internal organs; going through the stomach, for instance, when performing an appendectomy.

The reliability of the novel power transmission concept has been demonstrated in endurance tests, using both rigid endoscope tips and simple gripping tools. Laboratory prototypes with flexible tips have also been tested. Timo Cuntz and other members of the Mannheim project group will be present at the combined Compamed (Hall 08a, Booth K38)

and Medica (Hall 10, Booth G05) trade shows in Düsseldorf from November 12 to 15. Exhibits include several hydraulic technology demonstrators, including an endoscopic instrument equipped with a gripper that can be oriented in any direction. The necessary force transmission is provided by six integrated hydraulic cylinders.

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