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Taking endoscopy to a higher dimension: Computer Aided 3-D NOTES

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Taking endoscopy to a higher dimension: Computer Aided 3-D NOTES

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With a novel approach, abdominal surgery can be performed through the natural orifices with a following incision in stomach or colon. ”Natural Orifice Translumenal Endoscopic Surgery” (NOTES) is assumed to offer significant benefits to patients such as less pain, faster recovery, and better cosmesis than current laparoscopic techniques. The potential advantages can be only achieved through secure and standardized operation methods. Several barriers identified for the clinical practicability in flexible intra-abdominal endoscopy can be solved with computer-assisted surgical systems. For some of them additional 3-D information is useful, for some it is mandatory. At our institute a 3-D endoscope called Multisensor-Time-Of-Flight (MUSTOF) endoscope is in development. In this paper some MUSTOF based solutions for NOTES will be pointed out: The so obtained 3-D information can be registered with preoperative CT or MR data. These enhanced volumes can be used to find the transgastric or transcolonic entry point or to provide better orientation. It also will enable intra-operative collision prevention and an optimized field of off-axis view. With such an progressive endoscopic system, translumenal surgery will be able to be performed in a safe and feasible manner.

1. Introduction

In medical applications 3-D information can be acquired by endoscopic ultrasound [1], magnetically anchored instruments [2] or active optical approaches like a modulated light source. The last one is used with our MUSTOF system [3] and measures distance by its dependency on time of flight (TOF) which causes a detectable phase shift, so it is called TOF technology [4]. With a precondition of real-time ability and an accuracy of 1mm, existing problems with NOTES can be solved. Especially registered with preoperative CT or MR volumes there will be great improvements possible.

2. NOTES

In 2003 and 2004, the first documented human NOTES procedures were performed in India. In March 2007, first hybrid transvaginal cholecystectomies were reported in the USA and France [5]. NOTES offers a great area of active research in experimental endoscopy and has the potential to significantly advance the field of minimally invasive surgery [6]. So in July 2005 leading surgeons and gastroenterologists met together in New York City to coordinate further research activities in NOTES. They founded the Natural Orifice Surgery Consortium for Assessment and Research (NOSCAR). In a White Paper they addressed fundamental challenges to the safe introduction of NOTES and discussed potential barriers [7]. Three points seem to be solvable with additional 3-D data.

2.1. Peritoneal access

Translumenal surgery offers challenging possibilities for trauma reduction. Current investigations are mainly focused upon optimization of the access routes and its safe closure [8]. Not also the route, but above all the optimal location of the secure introduction of the instrument into the abdominal cavity is hard to find. To visualize the vessels on the reverse side of the hollow organ and so to reduce the risk of lacerations would be a great improvement.

2.2. Maintaining spatial orientation

In contrast to gastroenterologists, who are accustomed to working in line with their camera and light source, laparoscopic surgeons normally use multiple instruments and access ports. According to the white paper many NOTES procedures will be performed with the endoscope in a retroflexed position where the image is upside down and an off-axis manipulation is required. Potential solutions to perform advanced procedures with two or more instru-

ments and assistants include incorporating visualization systems and electronic image stabilization/ inversion. If the principles learned in advanced laparoscopic operations are applicable to NOTES, then orientation, as well as triangulation, will be fundamental requirements for any NOTES surgical system [7].

2.3. Development of a multitasking platform

Because some procedures will require a team to manipulate instruments, devices with multiple ports are likely to be important. The role of robotics in this area seems promising, though a great deal of development work remains to be done. Development should focus on manual tools that ultimately can be modified for robotic control [7]. Several approaches with computer-assisted surgical systems [9] require additional 3-D information to prevent injury or navigation errors.

3. 3-D endoscopy contributions

3.1. Orientation

To provide more information on position and orientation of the robotic device or the endoscope intraoperative 3-D data could be registered with preoperative CT or MR data. With the aid of the calculated transformation parameters, position and orientation can be represented, corrected and visualized.

3.2. Augmented Reality

Registration with preoperative volumes opens up lots of additional possibilities. The most promising one is to show hidden organs or vessels by augmented reality. They have to be segmented in the preoperative volumes and to be transformed by iteratively computed transformation parameters. Then these organs and vessels can be displayed by Augmented Reality (AR). This additional information is needed to avoid injuries, e.g. while finding the entry point to the peritoneal cavity which requires a wall incision in stomach or colon without knowledge of structures behind the visible wall.

3.3. Enhanced field of view

Endoscopic axis in-line view and loss of spatial orientation is especially for surgeons quite uncomfortable. To compensate this disadvantage, 3-D surface knowledge can be used to extend and virtually rotate the field of view (fig. 1).

Using a 3-D mosaicking technique, field of view can be extended by reconstruction of the operation area.

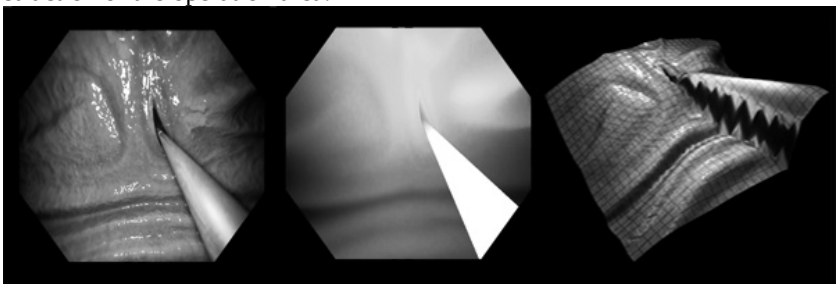

Fig. 1. l.: conventional color image, c.: depth values, r.: off-axis view

3.4. Collision Prevention

The increasing demand of robotic devices to control multiple instruments through only one flexible endoscope needs additional control mechanisms to avoid unintentional injuries. To enable efficient collision prevention, real-time distance information is needed. Avoidance of impending tissue injury or collision with other instruments can be realized as well as auto-positioning depending on respiration or other patient movements. For the spectrum of endoscopic surgery there is an urgent demand for a stable platform for secure movement and stabilization of the tissue during the operation in the peritoneal cavity.

4. Conclusion

Having additional 3-D data will not be an unalterable precondition for performing NOTES. But it will help especially a safer introduction of robotic devices and surgeons who are not used to flexible endoscopy with in-line-view and loss of orientation. Since gastroenterologists and surgeons are still not absolutely familiar with this new NOTES approach, they both will accept new technologies more likely than with established procedures.

References

[1] A. Fritscher-Ravens, C. A. Mosse, K. Ikeda, and P. Swain, “Endoscopic transgastric lymphadenectomy using EUS for selection and guidance,” Gastrointest Endosc, vol. 63, no. 2, pp. 302–306, Feb 2006.

[2] D. J. Scott, S. J. Tang, R. Fernandez, R. Bergs, M. T. Goova, et al., “Completely transvaginal NOTES cholecystectomy using magnetically anchored instruments,” Surg Endosc, vol. 21, no. 12, pp. 2308–2316, Dec 2007.

[3] J. Penne, K. Höller, S. Krüger, and H. Feussner, “NOTES 3D: Endoscopes learn to see 3D; basic algorithms for a novel endoscope,” in A. H, Arajo, H, Vitri, J. (Eds.): Proceedings of VISAPP 2007, 2007, pp. 134–139.

[4] R. Lange, 3D Time-of-flight distance measurement with custom solidstate image sensors in CMOS/CCD-technology, Ph.D. thesis, Department of Electrical Engineering and Computer Science at University of Siegen, 2000.

[5] J. Hochberger, K. Matthes, P. Köhler, et al., “NOTES a perspective for gastrointestinal medicine,” Endosk. heute, vol. 21, no. 1, pp. 2–5, Mar 2008.

[6] S. von Delius, S. Gillen, E. Doundoulakis, et al., “Evaluation of different transgastric access techniques for NOTES,” Endoscopy, vol. 39, no. 10, pp. 854– 859, Oct 2007.

[7] D. Rattner and A. Kalloo, “ASGE/SAGES working group on natural orifice translumenal endoscopic surgery october 2005,” Surg Endosc, vol. 20, no. 2, pp. 329–333, Feb. 2006.

[8] D.Wilhelm, A. Meining, S. von Delius, M. Burian, S. Can, A. Fiolka, et al., “Second generation sigmoid access for NOTES using the ISSA-system,” Endoskopie heute, vol. 21, no. 1, pp. 70, Mar 2008.

[9] F. Härtl, K. Höller, S. Beller, and H. Feußner, “Current status of the use of medical robots in Germany, Austria and Switzerland,” in 3rd Russian- Bavarian Conference on Biomedical Engineering, J. Hornegger, E. W. Mayr, S. Schookin, H. Feußner, N. Navab, Y. V. Gulyaev, K. Höller, and V. Ganzha, Eds., Erlangen, 2007