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Medical Equipment Insights

3D Laparoscopic Monitors

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ABSTRACT: Minimally invasive surgery (MIS) is a relatively new surgery comprising various procedures performed with special miniaturized instruments and imaging reproduction systems. Technological advances have made MIS an efficient, safe, and applicable tool for pediatric surgeons with unquestionable advantages. The recent introduction of three-dimensional (3D) high definition systems has been advocated in order to overcome some of the problems related to standard MIS visual limitations. This short paper recapitulates the necessity to minimize MIS visualization limitations and reports the characteristics of new laparoscopic 3D systems.

KEYWORDS: three-dimensional surgery, minimally invasive surgery

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Minimally invasive surgery (MIS) permits the surgeon to explore the patient's internal spaces with very little trauma. The advantages of MIS have been widely demonstrated.[1,2] However, small spaces and anesthesiological management limit its use in children. From a surgical point of view, new technologies, including the development of small instrumentation, applied to MIS allow the surgeon to easily reach the deepest recesses of the human body and have a general vision of the affected region.[1–4]

These techniques, however, still have visual limitations. First of all, standard MIS imagery is two-dimensional (2D). As the surgeon can only speculate over the structures' depth by moving the scope (motion parallax) or probing the surrounding environment,[2,5] it means a critical and important sensory loss which can be overcome only by long at times unacceptable surgical experience, not required in conventional open surgery.[6] The second challenge concerns having to adjust the camera several times in order to widen the field of view. This adjustment requires coordination between surgeon and assistant. Finally, the movements of the instruments on screen do not reflect those of the surgeon's hands (hand eye coordination problem).[2,7]

These visual limitations are related to the fact that we live in a three-dimensional (3D) world. We routinely use a binocular view to understand the 3D world we are living in; our brain receives two separate images from each eye and is able to combine them to perceive depth (stereopsis). We constantly refer to an internal representation of the world, built by our visual cortex using visual depth cues. Among them, we have monoscopic cues (extracted from a single 2D view) or motion-based cues. Motion pictures allow the expression of movements and the placement of objects in 3D space; that is how we recreate the third dimension.

Experienced endoscopic surgeons use motion parallaxes (parallax = relative position of an object's image in a set of picture) as depth cues so there is no need for 3D systems. Unfortunately, there is always the possibility of incurring optical illusions and erroneous maneuvers.[8] In this scenario, efforts have been made to have systems that merge computer graphics and real images into a single world around the surgeon (augmented reality). These systems acquire depth information and produce 3D images, giving the surgeon a lot of depth cues of natural vision and improving visual ergonomics. Visual ergonomics identifies the parameters that influence visual performance. It also presents the criteria that have to be met in order to achieve an acceptable visual environment.[9]

The first laparoscopic 3D video system was developed in 1992 under the influence of the cinematography industry.[10] 3D movies are the result of using multiple camera angles during filming. Images from two perspectives are recorded and combined providing the illusion of depth.

Improving visual ergonomics is based on the understanding of how to show a small space of the body with magnification on a 3D monitor during surgery. As for cinema 3D cameras, the newest surgical 3D cameras let us record separate images of the same object from slightly different angles at one fixed viewpoint. In fact, the 3D HD (high definition) system has two charge-coupled device (CCD) image sensors located at the distal end of the laparoscope to provide the left and right images, respectively. These two image signals are processed by a specifically designed video system to generate a high-resolution 3D image, which is displayed on a 3D monitor and viewed through 3D glasses to provide realistic 3D images. If we use circular polarized 3D glasses, we can merge the two images into one, giving the perception of depth and a clearer view of the structures and their relationship.[5–10]

The 3D vision system extrapolates the pixel's position in three dimensions (*X*, *Y*, and *Z*) in order to obtain an accurate location of the object. There are different techniques to achieve the 3D machine vision: stereovision—the most commonly used, point clouds and 3D triangulation. Stereovision works as our brain, using two cameras (eyes) to capture images that are read by the software (brain). The software compares the differences between two images. The same process is used by our brain to give us perspective and judge distances. The cameras are calibrated so that the relative position between them (*X*, *Y*) is known, thus making the calculation of the vertical position (*Z*) possible.[5–11]

The distance between the right and left camera (interaxial) dynamically modifies the depth in a scene and the

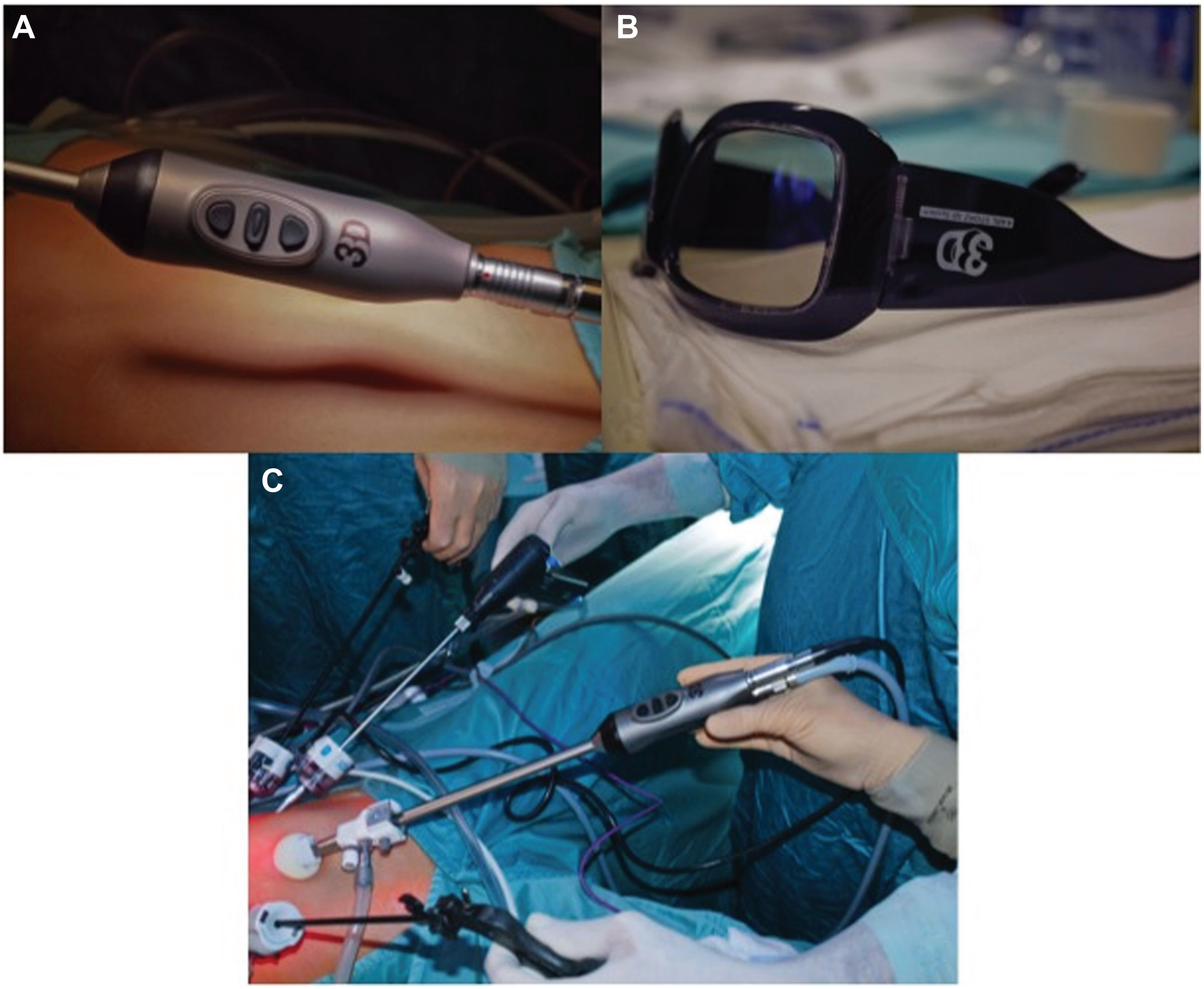

Figure 1. Laparoscopic 3D cholecystectomy performed at our Pediatric Surgery Department. The figures show part of the instrumentation used—3D laparoscope in (**A**); 3D glasses in (**B**); and the placement of trocars in the abdomen (**C**).

inwardly angled variation of the camera is responsible for the position of an object in relation to the screen (convergence). The simultaneous manipulation of convergence and interaxial permits the placement of objects within the 3D space controlling the depth. Magnification in depth is thus defined by the stereoscopic basis of the 3D camera.[2,5,8]

The first surgical video-system employed 3D monitors with standard resolution and low visual ergonomics and single-channeled laparoscope. Surgeons found the quality of the images was poor because of the heavy active shutter glasses. They also experienced side effects: tiredness, headaches, ocular fatigue, and nausea.[5,6,12] Moreover, earlier 3D system offered graded viewing conditions because of their lower resolution, brightness, and disparity plus the fact that the old software did not process 3D machine vision fast enough.

Recent technological advances have led to more flexible instruments, sophisticated high-resolution systems, and light polarizing glasses that are lighter and more comfortable. The most recent instruments are quicker, more accurate, and precise for surgical tasks and help shorten the learning curve. Picture quality and resolution, as well as image separation are thus improved not to mention the image refresh rate and brightness. Cameras are also upgraded—lens system alignment, packing of photo-sensors, and digital image processing. Autostereoscopic glasses-free displays have also improved, as well as multi-view autostereoscopic display which give a better depth perception thanks to multiple lenses.[9,11]

The major manufactures in this field are Olympus® Tokyo, Japan; Storz® Tuttlingen, Germany; and Vicking System® Westborough, Massachusetts.

The Olympus® Company has recently introduced a deflectable tip laparoscope with two lenses delivering HD3D video (Endoeye Flex 3D®). Thanks to its flexibility (100 degrees tip rotation in four directions), it provides a critical clinical view while maintaining image orientation, greater depth of field and optimal depth perception. It also uses specific sensors to maximize the 3D benefit by brighter, more light-sensitive image eliminating manual focusing. The structure allows a "plug and play" solution thanks to the all-in-one integrated lightweight design and an easy set up before surgery. Olympus® ensures compatibility with their 2D scopes.

These manufacturers also offer options for recording-editing and for operating room integration systems. Olympus® offers standard (IMH-10) or high-end recorder (IMH-20), enhancing connectivity as well as being able to record two separate signals simultaneously using Blue-ray, DVD, or USB HDD in parallel. It has a touch panel display and an editing software to create teaching tools. Storz® provides an integrated documentation system called AIDA®, which combines various functions used to capture still images, video and audio sequences, and spoken comments, using the touch screen keypad. Once the procedures are concluded, it saves all the data on DVD, CD-ROM, USB, HD, servers, etc. The Karl Storz IRIS® facilitates communication between the operating room and the physician's office, lecture hall and hospital network. The new Karl Storz IP-based system is called OR™.

Although these systems can be used in a wide range of situations, difficulties may arise. In fact, pediatric surgeons deal with pathologies of different origin (congenital and acquired) affecting all organs. Surgery may, therefore, be used in thoracic, abdominal, and retroperitoneal procedures. Each condition requires dedicated instruments.

Magnification is all-important because it improves tissue visualization; suture placement is more precise and easier, microsurgical instruments can be better positioned and anatomic details and smaller neurovasculature can be better appreciated.[7,9,11] 3D surgery allows surgeons to operate with much greater precision in a safer and faster way compared to 2D laparoscopy. The images displayed on the screen might include data acquired from a camera in another position, thus improving stereopsis. Some studies have attempted to evaluate the benefits of 3D HD visualization compared to 2D visual system.[11,13–16] Unfortunately, the number of these studies is limited, and the results are discordant.[8,14] More insight is needed to evaluate whether 3D systems are worth adopting. Some colleagues,[11,13–16] carried out comparative studies asking the surgeon (experienced and novice) to perform various tasks under either 3D or 2D conditions. The results were evaluated by subjective and objective measures. The participants were questioned about their general impression on the two visual systems. Outcome measures included total error rate and time for task completion. They concluded that 3D systems permit superior task efficiency and improved surgeon performance. The overall time to complete the procedure is reduced along with the total error rate. This might be related to the fact that 3D systems aid the detection of shapes, orientations, and positions of organs, helping the surgeon orient and perform complicated tasks and improving anatomical understanding. It seems that the statistically significant performance improvements and lower error rates are more frequent with novice surgeons. Subjective questionnaire results indicated that most surgeons are satisfied with 3D monitor.[11,13,15,16]

Table 1 summarizes the advantages of 3D HD visualization compared to 2D visual systems.

The distance between the laparoscope's front lens and the affected area, however, is not enough to achieve optimal

Table 1. Advantages of 3D.

Supports precise spatial orientation
Improves hand-eye coordination
Contributes to greater precision
Provides depth and volume
Benefits the entire surgical team
Helps reduce surgeon fatigue
Helps reduce procedure time

stereopsis. Human perception might be improved by operating in the "stereopsis comfort zone" so as to avoid retinal rivalry areas of objects that are too far away or too close.[15] This is achieved during MIS by spacing the left and right channels on the 3D monitor by about 6 cm (eye distance) and making the images congruent. Kunert and colleagues[13] give some hints for the practical use of 3D monitors in order to overcome possible inconvenience: make the operating room darker to counterbalance the not-so bright luminosity of the 3D mode; aim the camera depending on the presence (180° rotation) or absence (upright position) of a bichanneled laparoscope; look at the image first without glasses to assess the position of the objects; double check dirtiness of the optical channels by closing one eye at a time; retract the laparoscope or use an angulated one in case of violation of the stereoscopic window. Training is certainly another important topic for discussion. Despite technological improvements, training is still a major issue in the field of MIS. Several publications discuss the benefits of 3D HD systems over view and MIS skills. Most authors agree that 3D HD is able to improve performance resulting in faster procedures and higher precision without an increased mental workload.[5,14–16] Unfortunately, there have been limited investigations regarding the utility of 3D in MIS and the efficacy of 3D HD resolution has not been proven yet.[8,14]

High costs remain the main disadvantage of this new technology. Some points still require further discussion and surgeons should be extremely vigilant in patient selection, preoperative planning, and postoperative evaluation. This is why 3D systems are not widely used, and their application is still limited especially with children. In the long term, however, 3D systems are expected to be more widely used. Also, 3D HD technology is applied not only to laparoscopic surgery but also to microsurgery (allowing surgeons to operate "head up"), robotic surgery, medical events (congresses, forum, exhibitions, and fairs), video production, and live broadcast surgery in 3D via the Internet from the OR to the conference room.

In the future, a multidisciplinary approach will be achieved by combining our knowledge in different fields (technological, ergonomical, medical, psico visual motor, etc.), which will make edoscopic surgeons' cerebral rescaling and perception process easier.[8]

Author Contributions

Conceived and designed the experiments: FD, NC, and ML. Analyzed the data: FD and NC. Wrote the first draft of the manuscript: FD and NC. Contributed to the writing of the manuscript: FD and NC. Agree with manuscript results and conclusions: FD, NC, and ML. Jointly developed the structure and arguments for the paper: FD and NC. Made critical revisions and approved final version: ML. All authors reviewed and approved of the final manuscript.

REFERENCES

1. Fuchs KH. Minimally invasive surgery. *Endoscopy*. 2002;34(2):154–159.
2. Fuchs H, Livingston MA, Raskar R, et al. Augmented reality visualization for laparoscopic surgery. In Proceedings of the First International Conference on Medical Image Computing and Computer-Assisted Intervention, p. 934–943, 1998.
3. Kuebler JF, Ure BM. Minimally invasive surgery in the neonate. *Semin Fetal Neonatal Med*. 2011;16(3):151–156.
4. Blinman T, Ponsky T. Pediatric minimally invasive surgery: laparoscopy and thoracoscopy in infants and children. *Pediatrics*. 2012;130(3):539–549.
5. Izquierdo L, Peri L, Garcia-Cruz E, et al. 3D advances in laparoscopic vision. *Eur Urol Rev*. 2012;7(2):137–139.
6. Bhayani SB, Andriole GL. Three-dimensional (3D) vision: does it improve laparoscopic skills? An assessment of a 3D head-mounted visualization system. *Rev Urol*. 2005;7(4):211–214.
7. Durrani AF, Preminger GM. Three-dimensional video imaging for endoscopic surgery. *Comput Biol Med*. 1995;25(2):237–247.
8. Hofmeister J, Frank TG, Cuschieri A, Wade NJ. Perceptual aspects of two-dimensional and stereoscopic display techniques in endoscopic surgery: review and current problems. *Semin Laparosc Surg*. 2001;8(1):12–24.
9. Nakamoto M, Ukimura O, Faber K, Gill IS. Current progress on augmented reality visualization in endoscopic surgery. *Curr Opin Urol*. 2012;22(2):121–126.
10. Holler B. 3D video in endoscopic surgery: principles and first application. *Minim Invasive Ther Allied Technol*. 1992;1:57.
11. Wilhelm D, Reiser S, Kohn N, et al. Comparative evaluation of HD 2D/3D laparoscopic monitors and benchmarking to a theoretically ideal 3D pseudodisplay: even well-experienced laparoscopists perform better with 3D; *Surg Endosc*. 2014, Mar 21.
12. Yamauchi Y, Shinohara K. Effect of binocular stereopsis on surgical manipulation performance and fatigue when using a stereoscopic endoscope. *Stud Health Technol Inform*. 2005;111:611–614.
13. Kunert W, Kees T, Raestrup H, Buess GF. The shadow telescope vs 3D video system: evaluation in standardized tasks. *Int Congr Ser*. 2001;1230:1052–1055.
14. Held RT, Hui TT. A guide to stereoscopic 3D displays in medicine. *Acad Radiol*. 2011;18(8):1035–1048.
15. Storz P, Buess GF, Kunert W, Kirschniak A. 3D HD versus 2D HD: surgical task efficiency in standardised phantom tasks. *Surg Endosc*. 2012;26(5):1454–1460.
16. Smith R, Day A, Rockall T, Ballard K, Bailey M, Jourdan I. Advanced stereoscopic projection technology significantly improves novice performance of minimally invasive surgical skills. *Surg Endosc*. 2012;26(6):1522–1527.