SURGICAL GYNECOLOGY

3D Laparoscopy

Preliminary Experience from the Mannheim University Medical Centre, Heidelberg University, Department of Gynecology and Obstetrics

A. Hornemann, B. Tuschy, S. Berlit, M. Sütterlin

In May 2012, a laparoscopy system with 3D capability was introduced at the Mannheim University Medical Centre, Heidelberg University, Department of Gynecology and Obstetrics. This system offers a three-dimensional, high-definition (Full HD) view of the intraoperative site. In this article, users of the new technology report on their experience.

Within the field of gynecology, laparoscopy has evolved from a diagnostic tool into a surgical therapeutic discipline that is used to treat the vast majority of benign and malignant disorders of the pelvis. This minimally invasive approach offers excellent surgical outcomes and improved immediate postoperative quality of life compared to open abdominal surgery (1-3).

However, for prolonged surgical procedures, manipulating the camera can prove tiring for the assistants and is less than optimal for the operating surgeon. As a result, the image displayed may not depict the actual operating field, which, in addition to causing discord within the surgical team, can also put the patient at risk. Munro (4) reports that the best results are achieved with experienced, motivated, and fully focused assistants.

In 2004, Jaspers et al. (5) examined the role of the camera in laparoscopy and demonstrated the importance of smooth camera operation. They found that the use of static camera holders helped to eliminate physiological tremor and thereby guarantee focus on essential areas of the surgical site.

To date, monitors offering a two-dimensional representation have been the industry standard. For 3D visualization, two images have to be taken from slightly different perspectives, either using a stereo camera with two lenses or using two separate cameras. In surgical disciplines such as neurosurgery, equivalent systems (stereoscopic surgical microscope) have been in place for many years, and in visceral surgery, the use of surgical magnifying spectacles helps to give a three-dimensional perspective. Transanal Endoscopic Microsurgery (TEM, Richard Wolf GmbH, Knittlingen, Germany) also employs two eyepieces to facilitate stereoscopic visualization (6).

2D versus 3D

We are all familiar with different types of three-dimensional visualization in the form of holograms, 3D books, and also 3D movies at the cinema. At the cinema, however, we are more accustomed to viewing two-dimensional movies. Therefore, when an object or person on screen approaches in a 3D movie, you automatically flinch, because it is an unfamiliar experience and often seems very realistic. If we close one of our eyes, we can only see in two dimensions (monocular vision). We lose our depth perception and it can be difficult to accurately assess distances (of the objects we see around us for example). It is only through knowledge and experience that we are able to compensate for this deficiency; people who lose their sight in one eye, for example, are able to adapt to this successfully in their daily lives.

This same adaptation is required for endoscopic surgeons. Since the introduction of endoscopy in medicine, physicians and surgeons have been confronted with the absence of this third dimension and have had to adapt themselves to a reduced depth perception (7). The two-dimensional representation of a three-dimensional environment causes particular problems when learning laparoscopic skills. This is particularly true for complex tasks, such as laparoscopic intracorporeal suturing or the dissection of fine anatomical structures. In most cases, this deficiency can be compensated through knowledge, experience, and high-resolution visualization. Therefore it is regularly said that the third dimension is not an absolute necessity.

However, various studies have shown that the three-dimensional visualization of a site on the pelvi-trainer results in swifter and more precise surgical performance (8, 9). In both of these studies referred to above, results for inexperienced and experienced surgeons alike were significantly better with 3D visualization compared to 2D. For this reason, it is surprising that 3D visualization is only just starting to make an appearance on the market in a user-friendly form despite the fact that the technology has been around for many years. Richard Wolf GmbH, for example, had claims to have a 3D system suitable for laparoscopy since 1993. However, it has seen little demand and has also not yet been developed to a market-ready state (10).

The reasons for this lack of interest in 3D visualization in laparoscopy despite the scientifically proven benefits are most likely a result of the lower price of the 2D systems as well as their technological maturity. The increasing popularity of 3D visualization within the consumer electronics sector, with constantly improving quality and more affordable prices, appears finally to have awakened the interest of the medical technology sector.

As more and more manufacturers rush to develop 3D laparoscopy systems, it can be assumed that this technology will become increasingly prevalent within the clinical setting in the future. However, to date, there have been no prospective randomized clinical studies on 3D laparoscopy.

At the present time, *EinsteinVision* (Aesculap, Tuttlingen – a division of B. Braun Melsungen AG, Germany) is the only 3D Full HD robot-assisted camera system on the German market. Since 2012, this system has been trialled at the Department of Gynecology and Obstetrics, Mannheim University Medical Centre, Heidelberg University, in the setting of clinical research studies.

The 3D system manufactured by Storz (Karl Storz GmbH & Co KG, Tuttlingen) does not offer HD resolution and to date has only been subject to test operation. Olympus Winter & IBE GMBH (based in Hamburg, Germany) presented its 3D system with HD resolution on June 24, 2013. The system features a unique deflectable tip, which offers greater visibility of less accessible regions. The Viking 3DHD System (Viking Systems, Inc., Westborough/USA), currently the least well known in Germany, also offers HD resolution.

The *EinsteinVision* 3D System

At first glance, there is little discernible difference between the *EinsteinVision* laparoscopy tower and a two-dimensional system: It is mounted on a conventional mobile "endoscopy tower" and looks very much like a 2D system (see Fig. 1). On closer inspection, however, one cannot fail to notice the larger monitor (32") and the camera; an endoscopic camera with two lenses, the same as that used in the da Vinci robot-assisted surgical system promoted by Intuitive Surgical Inc. (Sunnyvale/USA). The 3D camera is noticeably bigger (approximately twice as big) and heavier, and is operated using a remote-controlled robotic arm (see Fig. 2). This 16 kg arm is docked to the operating table via a quick-release fastener and connected to the endoscopy tower, usually without the aid of any additional instrumentation. Within our department, this process takes less than 5 minutes. A sterile cover allows the arm to be easily integrated to the operating field, presenting no obstruction for the anesthetists and only occasionally obstructing the surgeon during his or her work.

Fig. 1: The Einstein Vision Endoscopy Tower. (The blurring on the large monitor is caused by the 3D display; polarization eyeglasses have to be worn to see the sharp, three-dimensional image)

The arm is controlled remotely and has to be calibrated at the start of surgery relative to the position of the umbilicus: It must be possible for the arm to be maneuvered in every direction around this point without exerting any pressure on the trocar or site of the incision. The arm can be moved by means of remote control in a ventral, dorsal, left, or right direction or moved closer and further away. The camera can be controlled by the surgeon, an assistant, or the OR nurse (see Fig. 3). What is notable when performing surgery in the pelvis region is that the 3D display on the large monitor is so precise that only a few camera movements are required and, in most cases, the surgeon can work with the overview image. Especially for complicated

Fig. 2: Remote-Controlled Robotic Arm

procedures, such as lymphadenectomies, there is usually no need to change the position of the camera at all during the procedure. In these more complex situations, the use of the robotic arm avoids involuntary camera movements that could divert the field of view away from the actual surgical site and cause potential surgical errors.

The camera is attached to the robotic arm via a click mechanism and the optic is inserted into the abdomen through the trocar. To experience the 3D effect, it is necessary to wear polarization eyeglasses ("3D eyeglasses"). The polarization eyeglasses are big enough to be worn over the spectacles of spectacle wearers. Alternatively, spectacle wearers can use clip-on 3D eyeglasses (similar to clip-on sunglasses) that can be attached to their own spectacles.

Within the abdominal cavity, the 3D visualization is immediately apparent and greatly facilitates orientation. To gain an initial overview of the epigastric region, it is first advisable to maneuver the camera by hand without using the robotic arm. The perception of depth is particularly evident when viewing into the pelvis. The Full HD, highly magnified display allows a greater distance to be maintained using the 3D optics than is possible using traditional 2D optics. This and the smooth-running holding arm reduces the risk of laparoscope contamination, meaning that this will only require cleaning in exceptional cases (5). The ultra-sharp, three-dimensional visualization permits the reliable identification of structures that are often more difficult to visualize (retroperitoneal structures such as the ureter can usually be located using a transperitoneal approach; a venous hemorrhage site can in some cases be easier to localize etc.).

Fig. 3: OR Nurse Controlling the Camera

The robotic arm moves the camera as smoothly as possible. We feel that the main advantage of this robotic-assisted camera system is that the surgeon alone decides where to direct the laparoscope. The viewing direction remains under the full control of the surgeon. There are none of the unavoidable artifacts that regularly occur on the image when the camera is being operated by a human (as a result of repositioning the hand, weakness, shaking etc.). Once the camera position has been set, the remote control can usually be handed over to the assisting nurse, who can then perform small camera adjustments as directed by the surgeon. This means that operations can be performed in a single surgeon setting, which we consider to be the second major advantage of this system for institutions with limited human ressources. Fundamental camera position changes (naturally) require more time than is required when operating the camera manually.

3D Laparoscopy at Mannheim University Medical Centre, Heidelberg University, Department of Gynecology and Obstetrics

Since May 2012, we have performed more than 100 complex laparoscopic procedures using the 3D system. The procedures took place within the context of various scientific research projects to evaluate the new technique (preliminary experience with 3D laparoscopy, laparoscopic hysterectomy in 2D versus 3D, solo surgery) as well as monthly training events for visiting surgeons.

We were able to substantiate the postulated advantages of this technology, although there are some disadvantages that are worthy of note (see table, p. 654). For instance, malfunctioning optics can cause problems with the stereoscopic information and, in extremely rare cases, cause headache, dizziness, and even nausea. In one of the procedures, we experienced such a malfunction, with the surgeon experiencing a headache. In this case, the optics were found to be damaged (most likely caused during transport) and had to be replaced.

We mostly mounted the robotic arm on the operating table just below patient shoulder height. There are three interchangeable camera holder attachments for different types of surgery. For surgery in the region of the pelvis, we found the shortest attachment to be the best; this was not found to be obstructive in combination with the robotic arm.

Even during the first few procedures, as a result of more precise visualization and robot-assisted camera manipulation, we found in virtually all cases that , a third incision was not necessary and, because of this, in many cases the need for a second surgeon. Even with increasingly more complicated procedures, it became evident that two trocars were usually sufficient when using the *Einstein-Vision* system and, in most cases, there was no longer a need for surgical assistance. The procedures performed included, besides of various types of hysterectomies and operations of the ovary, an extended radical hysterectomy (Piver III), pelvic and paraaortic lymphadenectomy, as well as sacrocolpopexy, cervical sacropexy, and uterine sacropexy. For surgeons who work in an outpatient

Experience with *EinsteinVision* 3D Laparoscopy with Holding Arm System

Advantages	Disadvantages
More precise visualization of structure	3D eyeglasses required (clip-on eyeglasses required for spectacle wearers)
Better spatial orientation	Time required for setup (holding arm) and camera calibration
Smoother camera operation	30° view cannot be rotated separately (only in combination with camera)
Rare soiling of optics	Price (around three times that of a 2D system)
(Even complex) procedures possible without assistance of a second surgeon (solo surgery)	Depending on the positioning of the robotic arm this can be perceived as obstructive

The experience of the Department of Gynecology and Obstetrics, University Medical Centre, Mannheim, Heidelberg University, serves to confirm the postulated advantages, although there are some noteworthy disadvantages.

setting in particular, being able to perform surgery without assistance can be of considerable value.

The improved visibility of the structures, thanks to the 3D Full HD visualization, means that surgeons who are still in training can also work alone under the supervision of their instructor (consultant or specialist surgeon), who can point out exactly which structures require dissection on the monitor.

We have repeatedly observed how the additional three-dimensional visual information can help inexperienced surgeons to learn more complicated procedures with confidence.

For paraaortic lymphadenectomies, it helps to position the camera above the symphysis pubis. Even using a 30° laparoscope, the angle is still very steep at the navel, which sometimes leads to condensation forming, especially during longer procedures. Gravity then causes this to run down the scope, contaminating the lens. This issue is also encountered in conventional laparoscopy, however, and can be resolved by attaching an additional optical trocar above the symphysis. Note, however, that this requires recalibration of the robotic arm.

Conclusion

As humans, we are designed to use stereoscopic (or binocular) vision. Two-dimensional (monocular) visualization therefore conflicts with our natural physiology, which explains why performing surgery in two dimensions requires a longer learning curve and greater concentration. The additional visualization of the third dimension is of significant benefit to surgeons, making their work much easier. It is to be anticipated that through the significant technical advances in 3D visualization, 2D laparoscopy will be consigned to history in a few years.

Literature

1. Cho YH, Kim DY, Kim JH et al.: Laparoscopic management of early uterine cancer: 10-year experience in Asan Medical Center. Gynecol Oncol 106 (2007) 585-590.
2. Kalogiannidis I, Lambrechts S, Amant F et al.: Laparoscopy-assisted vaginal hysterectomy compared with abdominal hysterectomy in clinical stage I endometrial cancer: safety, recurrence, and long-term outcome. Am J Obstet Gynecol 196 (2007) 248 e241-248.
3. Walker JL, Piedmonte MR, Spirtos NM et al.: Laparoscopy compared with laparotomy for comprehensive surgical staging of uterine cancer: Gynecologic Oncology Group Study LAP2. J Clin Oncol 27 (2009) 5331-5336.
4. Munro MG: Automated laparoscope positioner: preliminary experience. J Am Assoc Gynecol Laparosc 1 (1993) 67-70.
5. Jaspers JE, Breedveld P, Herder JL et al.: Camera and instrument holders and their clinical value in minimally invasive surgery. Surg Laparosc Endosc Percutan Tech 14 (2004) 145-152.
6. Buess G, Theiss R, Gunther M et al.: Endoscopic surgery in the rectum. Endoscopy 17 (1985) 31-35.
7. Nicolau S, Soler L, Mutter D et al.: Augmented reality in laparoscopic surgical oncology. Surg Oncol 20 (2011) 189-201.
8. Honeck P, Wendt-Nordahl G, Rassweiler J et al.: Three-dimensional laparoscopic imaging improves surgical performance on standardized ex-vivo laparoscopic tasks. J Endourol/Endourological Society 26 (2012) 1085-1088.
9. van Bergen P, Kunert W, Buess GF: The effect of high-definition imaging on surgical task efficiency in minimally invasive surgery: an experimental comparison between three-dimensional imaging and direct vision through a stereoscopic TEM rectoscope. Surg Endosc 14 (2000) 71-74.
10. www.richardwolfusa.com/company/about-us/milestones.html

Conflicts of Interest
There are no conflicts of interest.

Representing the Authors

Amadeus Hornemann, MD, MPH, PhD
Mannheim University Medical Centre, Heidelberg University, Department of Gynecology and Obstetrics
Theodor-Kutzer-Ufer 1-3
68167 Mannheim, Germany
amadeus.hornemann@umm.de

The German version of this article was published in Frauenarzt 2013; 54: 650–654

in vivo *28*: 111-116 (2014)

Full High-definition Three-dimensional Gynaecological Laparoscopy – Clinical Assessment of a New Robot-assisted Device

BENJAMIN TUSCHY[1], SEBASTIAN BERLIT[1], JOACHIM BRADE[2], MARC SÜTTERLIN[1] and AMADEUS HORNEMANN[1]

Departments of [1]Obstetrics and Gynaecology, University Medical Centre Mannheim and [2]Medical Statistics and Biomathematics, Medical Faculty Mannheim, Heidelberg University, Mannheim, Germany

Abstract. *Aim: To investigate the clinical assessment of a full high-definition (HD) three-dimensional robot-assisted laparoscopic device in gynaecological surgery. Patients and Methods: This study included 70 women who underwent gynaecological laparoscopic procedures. Demographic parameters, type and duration of surgery and perioperative complications were analyzed. Fifteen surgeons were postoperatively interviewed regarding their assessment of this new system with a standardized questionnaire. Results: The clinical assessment revealed that three-dimensional full-HD visualisation is comfortable and improves spatial orientation and hand-to-eye coordination. The majority of the surgeons stated they would prefer a three-dimensional system to a conventional two-dimensional device and stated that the robotic camera arm led to more relaxed working conditions. Conclusion: Three-dimensional laparoscopy is feasible, comfortable and well-accepted in daily routine. The three-dimensional visualisation improves surgeons' hand-to-eye coordination, intracorporeal suturing and fine dissection. The combination of full-HD three-dimensional visualisation with the robotic camera arm results in very high image quality and stability.*

Laparoscopic surgery has become standard treatment for various malignant and benign gynaecological diseases. Since its introduction, minimally-invasive surgery has been limited by the lack of depth of perception and spatial orientation due to the two-dimensional (2D) visualisation of the intra-abdominal environment. Hence indirect references, such as the motion of the laparoscope, size of anatomical structures and changes in shading and structure, are used to achieve sufficient depth perception. This requires for great expertise on the part of the surgeon and mental processing of the 2D image into a 3D image in order to perform complex tasks, such as intracorporeal suturing or accurate dissection, successfully (1). Since the early 1990s, many 3D systems have been developed and several studies dealing with 3D visualisation in *ex vivo* settings have been carried out, reporting inconsistent results (2). Early prototypes suffered several technical flaws and some authors criticised the quality of 3D imaging, as a result of low resolution in older-generation 3D technologies. The efficiency of high-definition (HD) resolution in laparoscopic video systems has not been definitively proven, although it is commonly assumed, and all new laparoscopic systems are equipped with HD technology (3). Reports of 3D laparoscopy in clinical settings are scarce. Storz *et al*. showed a significant difference in favour of 3D visualisation using the "*Einstein Vision*®" system (B. Braun, Aesculap AG, Tuttlingen, Germany) compared to a 2D laparoscopic system in an *ex vivo* setting (4). Hence aim of this investigation was to report our experience with a novel full HD 3D robotic-assisted laparoscopic system, and surgeons' perception of this new device.

Patients and Methods

A total of 70 women underwent gynaecological 3D laparoscopy between 06/2012 and 12/2012 at the University Medical Center Mannheim, and were included in this report. Women were prospectively enrolled. The Einstein Vision® system was used for all procedures. This 3D full-HD imaging system consists of a 10 mm outer diameter 30˚ stereoscopic endoscope, a digital 3D full-HD camera, and a 32-inch 3D full-HD monitor. The endoscope was handled by a robotic arm attached to one (usually the right) side of the operation table and covered by a sterile cover preoperatively. This 16-kg heavy arm has a three-joint aluminium structure. Movement instructions for the robotic arm and camera system are given by the assisting physician, or by the assisting nurse according to the instruction of the surgeon, using the remote control. In

Correspondence to: Benjamin Tuschy, MD, University Medical Center Mannheim, Department of Obstetrics and Gynaecology, Theodor-Kutzer-Ufer 1-3, D-68167 Mannheim, Germany. Tel: +49 6213832286, Fax: +49 6213833814, e-mail benjamin.tuschy@umm.de

Key Words: Gynaecological laparoscopy, 3D, full HD, clinical assessment.

Table I. *Characteristics of the participating physicians (n=15).*

Level of training	Spectacle wearer n=6	Male n=9	Female n=6	Overall number of performed laparoscopic surgeries			
				<20	20-50	50-200	>200
Junior physician (n=8)	1	4	4	5	3	0	0
Consultant (n=4)	2	2	2	1	1	1	1
Senior physician (n=2)	2	2	0	0	0	0	2
Head of Department (n=1)	1	1	0	0	0	0	1

general, the camera can be moved to the left, right, up, down, forward and backward. For every procedure, common laparoscopic instruments (B Braun) were used. All laparoscopic surgeries were performed under general anaesthesia. A 10-mm optic trocar was inserted beneath the umbilicus and two 5-mm trocars respectively one 5 and one 10-mm trocar were placed laterally in the lower abdomen. If necessary, an additional 5-mm trocar was inserted suprapubically. In the case of laparoscopic supracervical hysterectomies (LASH) or fibroid resection, a 12-mm trocar was used for incorporation of the morcellator. Intraoperative pressure was at a maximum of 15 mmHg. Surgeons and nurses had to wear special glasses in order to achieve a 3D view on the screen. After surgery, surgeons and assistant physicians completed a standardised questionnaire regarding this novel laparoscopic device. Results were assessed in a standardised itemised scale (Likert scale). Demographic parameters such as patient age, body mass index (BMI) and previous abdominal surgeries, were collected before surgery. Type of surgery, intra- and postoperative complications, duration of surgery and overall hospital stay were evaluated.

Statistics. All data were stored in an MS Excel sheet. After careful review for false data entry, the data were imported into the SAS environment (Version 9.2, SAS Institute Inc., Cary, NC, USA). Data are presented as the mean±standard deviation.

Results

All procedures were successfully performed with this novel device. Thirty patients underwent LASH and seven total laparoscopic hysterectomy (TLH). Seven women had bilateral laparoscopic adnexectomy, 14 laparoscopic myomectomy and two women underwent diagnostic laparoscopy. Fifteen physicians with different levels of training participated in this trial (Table I). Surgical parameters are shown in Table II. Concerning patients' characteristics, the mean age of the participating women was 45.5±10.1 years (range=30-74 years). The mean BMI was 26.8±5.3 kg/m^2 (range=19-46 kg/m^2). Thirty-seven percent (26/70) of investigated patients did not have prior abdominal surgery. Thirty-one percent (22/70) had undergone prior laparoscopic surgery, 19% (13/70) had had a laparotomy once and 13% of the participants (9/70) had undergone laparotomy more than once. There were no severe intra- or post-operative complications in the study collective. All surgeons achieved a 3D vision by wearing special glasses. Concerning their evaluation of the 3D glasses, three persons (3/15; 20%) stated impairment by wearing the special glasses and found that the glasses were disturbing during surgery. Thirteen of the participants (87%) stated that 3D visualisation improved hand-to-eye coordination, and all physicians were of the opinion that 3D visualisation improved the detection of anatomical structures (*e.g.* ureter, vessels) (*Table III*). All physicians (7/7) who performed intracorporeal suturing stated that 3D visualisation facilitated this complex task. Each participant (9/15, 60% strongly agreed; 6/15, 40% agreed) would prefer full-HD 3D visualisation in standard laparoscopic procedures in comparison to conventional 2D device. All physicians (12/15, 80% fully-agreed; 3/15, 20% agreed) stated that the robotic arm produced a more stable image compared to a human assistant, and the majority (9/15, 60% strongly agreed; 3/15, 20% agreed) were of the opinion, that the robotic arm allows for more relaxed working conditions (Table IV). Overall evaluation of the 3D visualisation in combination with the robotic arm revealed that improved image stability and image quality seem to be the major benefits of this novel device (Table V). Furthermore, there wer e no severe intra- or post-operative complications in our study collective. All patients received pain relief according to a fixed schedule, and low-molecular weight heparin for thromboprophylaxis.

Discussion

Due to a steady increase in the number of minimally-invasive procedures, surgeons are increasingly faced with the disadvantages of 2D imaging systems. The loss of depth perception is of particular interest in complex procedures, such as laparoscopic intracorporeal suturing or dissection of pelvic and para-aortic lymph nodes. The first report of a 3D laparoscopic device in human surgery was published in 1993 by Becker *et al.* (5). The first 3D laparoscopic systems were limited by poor image quality, eyestrain and cumbersome laparoscopic devices. In 1996, Volz *et al.* stated that the 3D laparoscopic system of that time had advantages for microsurgical procedures but was unsuitable for surgery of

Table II. *Type of laparoscopic surgery performed.*

Type of surgical procedure n=70	Duration of surgery (min) Mean±SD	Duration of hospital stay (days) Mean±SD	Number of incisions
Diagnostic procedures (n=2)	39.0±15.6	0	1
Ovarian cyst exstirpation (n=5)	127.5±18.7	1.6±1.1	3-4
Uterine fibroid resection (n=14)	90.1±34.8	1.9±0.5	3-4
Salpingo-oophorectomy (n=7)	99.1±63.0	2.1±0.9	3-5
TLH (n=7)	100.6±28.8	2±0	3
LASH (n=30)	96.0±34.9	2.1±0.5	3-5
Other (n=5)	78.8±27.1	2±0	3

Other: Adhesiolysis, salpingectomy, laparoscopic chromopertubation, colposacropexy; multiple procedures per patient were possible. TLH, Total laparoscopic hysterectomy; LASH, laparoscopic supracervical hysterectomy; SD, standard deviation.

Table III. *Assessment of the 3D visualisation; n=15.*

Surgeons' responses regarding the handling of the Einstein Vision System	Strongly-agree	Agree	Neither agree nor disagree	Disagree	Strongly-disagree
3D Glasses are disturbing	0	3 (20%)	1 (7%)	0	11 (73%)
	In comparison to 2D laparoscopy				
3D Visualisation causes nausea	0	0	0	1 (7%)	14 (93%)
3D Visualisation is fatiguing for the eyes	0	1 (7%)	3 (23%)	1 (7%)	10 (67%)
3D visualisation causes headache	1 (7%)	0	0	0	14 (93%)
3D Visualisation improves hand-to-eye coordination	10 (67%)	3 (20%)	1(7%)	1 (7%)	0
3D Visualisation may extend the laparoscopic operative spectrum	8 (53%)	7 (47%)	0	0	0
3D Visualisation improves detection of anatomical structures	12 (80%)	3 (20%)	0	0	0
3D Visualisation facilitates fine dissection*	8 (77%)	5 (33%)	0	0	0
3D Visualisation facilitates intracorporal suturing*	6 (86%)	1(14%)	0	0	0
3D Visualisation improves my concentration	5 (33%)	4 (27%)	2 (13%)	1 (7%)	3 (20%)
3D Visualisation improves enjoyment of work	10 (67%)	3 (20%)	1 (7%)	0	1 (7%)
I would prefer 3D to 2D visualisation in standard procedures	9 (60%)	6 (40%)	0	0	0
3 D Visualisation should be used more in laparoscopy	11 (73%)	4 (27%)	0	0	0
3D Visualisation is dispensable	0	0	1 (7%)	1 (7%)	13 (87%)

*Two surgeons did not perform fine dissection; eight surgeons did not performed intracoporeal suturing.

the uterus or adnexal masses (6). This conclusion can be attributed to the low quality of the early generation of 3D laparoscopic systems. In our study, all surgeries were completed successfully, with consistently positive assessment by surgeons, and no conversion to laparotomy or 2D visualisation was necessary. This reflects the development of better visual and laparoscopic techniques and the fact that previous technical flaws were eliminated. Our investigation shows that the full-HD 3D laparoscopic device used here is comfortable and suitable even for extensive laparoscopic surgery. The loss of spatial depth using a 2D system can be compensated for by the experience of the surgeon and by the ability of the human brain to process additional information (secondary spatial depth cues) to achieve spatial orientation (4). In the 3D visualisation, the mental workload previously required for transformation of indirect references, such as motion of the laparoscope, size of anatomic structures and changes in shading and texture, can be used for enhanced concentration. This may result in a significant gain in precision for difficult surgical tasks and significantly increase the speed of tasks, as shown by Storz *et al*. in an *ex vivo* setting (4). In the future full-HD 3D approaches might offer the possibility not only of performing surgery faster but also performing them with more safety due to easier identification of anatomical structures. Phantom task setups simulate partial surgical procedures but do not reflect the complexity of real clinical conditions. To the best of our knowledge, this is the first clinical report of gynaecological laparoscopic

Table IV. *Assessment of the robotic arm.*

	Strongly-agree	Agree	Neither agree nor disagree	Disagree	Strongly-disagree
The robotic arm bothers me during surgery	0	0	1 (7%)	4 (27%)	10 (67%)
The robotic arm offers a more stable image compared to human assistance	12 (80%)	3 (20%)	0	0	0
Directing the camera with the remote control is easy	5 (33%)	6 (40%)	3 (20%)	1 (7%)	0
The robotic arm results in more relaxed working conditions	9 (60%)	3 (20%)	2 (13%)	1 (7%)	0
I would prefer a robotic arm in standard laparoscopic procedures	5 (33%)	3 (20%)	5 (33%)	2 (13%)	0

Table V. *Overall assessment of the Einstein Vision® system.*

	Overall assessment				
	Very good	Good	Adequate	Deficient	Dissatisfying
Image quality	12 (80%)	3 (20%)	0	0	0
Image stability	13 (87%)	2 (13%)	0	0	0
Overall convenience of 3D laparoscopy	10 (67%)	5 (33%)	0	0	0
Overall convenience of the robotic arm	5 (33%)	8 (53%)	2 (13%)	0	0

surgeries performed with a 3D robot-assisted laparoscopic system in HD quality. Previous studies showed that the error rates in *in vitro* settings were increased and that more movements of the laparoscopic instruments were necessary to complete laparoscopic tasks successfully using 2D visualisation (2, 7). Interestingly, the more complex the tasks, the more 3D visualisation enhanced task performance, independently of the laparoscopic experience of the surgeon (8). Kong *et al.* stated that 3D systems could help physicians to perform surgical procedures more accurately and safely, which is confirmed by our findings that all participants rated, 3D visualisation as improving detection of anatomical structures and facilitating complex laparoscopic procedures. Except for one person in our study, who was affected by headache and eye fatigue, no one felt visual discomfort or suffered nausea. These favourable results regarding visual comfort may be partially attributed to the full-HD visualisation. Higher dizziness rates were reported in earlier studies dealing with 3D laparoscopy but without the usage of full-HD visualisation (2). The beneficial results in our study regarding full HD visualisation in 3D are consistent with the results of other investigations dealing with HD quality both for 2D and 3D laparoscopy (4, 9). Hagiike *et al.* showed that HD visualisation compared to conventional standard visualisation provides a superior image and leads to a reduced time for laparoscopic knot tying (9). The combination of full HD and 3D visualisation is favourable regarding time and error rate compared to full-HD 2D laparoscopy, as shown by Storz *et al.* (4). The physicians who were negatively-affected by wearing the special glasses for 3D vision did not wear glasses in daily life. Therefore, it is not surprising that wearing glasses in the unusual setting of the operation theatre during surgery was rated as disturbing. As previously shown by Honeck *et al.*, the use of a laparoscopic device, as also used in our series, leads to a significant benefit regarding missed grasps and the loss of working materials in an *in vitro* setting (1). So it is not surprising that the majority of surgeons felt an improvement of the hand-to-eye coordination and all of them believed that 3D imaging may widen the operative spectrum of laparoscopic surgery. Additionally, the robotic camera arm is particularly useful for performing complex tasks when more than two hands are needed. On the occasions in which the assistant physician would normally have to handle the camera, they can now assist actively with two laparoscopic instruments or in other ways. Besides these advantages, there are some disadvantages to be noted. A major drawback of the system used in this study is the significantly higher acquisition costs compared to standard laparoscopic systems. Studies dealing with 3D laparoscopy report inconsistent results and investigations in clinical settings with 3D full-HD laparoscopy are scarce (4, 10). Our results show that a broad range of gynaecological surgery could be performed successfully and 3D visualisation in combination with a robot-assisted laparoscope holder reached high satisfaction rates. We are aware of the limitations of our study. The questionnaire used in the present study reflects subjective impressions of the participating surgeons and no direct comparison of 2D *versus* 3D approaches were performed. Moreover, the evaluation of a novel technique is affected by the surgeon's level of experience and their subjective attitude towards innovation. Nevertheless our study included surgeons with different levels of training, giving a detailed assessment of a novel laparoscopic system. We believe that this technique seems to be a promising and innovative alternative to conventional laparoscopic devices. This is strengthened by the fact that all participants stated they would prefer 3D in standard gynaecological laparoscopic procedures and that 3D visualisation should be used more frequently. Nevertheless, it remains debatable if robot-assisted 3D systems should be used in short, uncomplicated or purely diagnostic procedures, bearing in mind the time required for attachment of the robotic arm, costs of the system and tight surgical schedules. Whether this technique will become more popular, as has already been shown in the steadily-increasing number of 3D cinema movies and 3D products in the home entertainment segment, remains to be seen.

References

1 Honeck P, Wendt-Nordahl G, Rassweiler J and Knoll T: Three-dimensional laparoscopic imaging improves surgical performance on standardized ex-vivo laparoscopic tasks. J Endourol *26*: 1085-1088, 2012.

2 Kong SH, Oh BM, Yoon H, Ahn HS, Lee HJ, Chung SG, Shiraishi N, Kitano S and Yang HK: Comparison of two- and three-dimensional camera systems in laparoscopic performance: A novel 3D system with one camera. Surg Endosc *24*: 1132-1143, 2010.

3 Van Bergen P, Kunert W and Buess GF: The effect of high-definition imaging on surgical task efficiency in minimally invasive surgery: An experimental comparison between three-dimensional imaging and direct vision through a stereoscopic TEM rectoscope. Surg Endosc *14*: 71-74, 2000.

4 Storz P, Buess GF, Kunert W and Kirschniak A: 3D HD *versus* 2D HD: Surgical task efficiency in standardised phantom tasks. Surg Endosc *26*: 1454-1460, 2012.

5 Becker H, Melzer A, Schurr MO and Buess G: 3-D Video techniques in endoscopic surgery. Endosc Surg Allied Technol *1*: 40-46, 1993.

6 Köster S, Volz J and Melchert F: Indication for 3D laparoscopy in gynaecology. Geburtshilfe und Frauenheilkunde *56*: 431-433, 1996.

7 Taffinder N, Smith SG, Huber J, Russell RC and Darzi A: The effect of a second-generation 3D endoscope on the laparoscopic precision of novices and experienced surgeons. Surg Endosc *13*: 1087-1092, 1999.

8 Wagner OJ, Hagen M, Kurmann A, Horgan S, Candinas D and Vorburger SA: Three-dimensional vision enhances task performance independently of the surgical method. Surg Endosc *26*: 2961-2968, 2012.

9 Hagiike M, Phillips EH and Berci G: Performance differences in laparoscopic surgical skills between true high-definition and three-chip CCD video systems. Surg Endosc *21*: 1849-1854, 2007.

10 Buchs NC, Volonte F, Pugin F, Toso C and Morel P: Three-dimensional laparoscopy: A step toward advanced surgical navigation. Surg Endosc, 2012.

Received September 29, 2013
Revised November 7, 2013
Accepted November 8, 2013