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ORIGINAL ARTICLE

3D laparoscopy: technique and initial experience in 451 cases

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Abstract This study aims to show that 3D technology in laparoscopy promises to be an indispensable tool. The feasibility and safety of this surgical innovation has been shown. Our objective is to evaluate our initial experience performing 3D laparoscopic surgeries and determine if there is any benefit with respect to the time of surgery, time of morcellation, complications, and blood loss. Study design includes prospective analysis of 451 cases of 3D laparoscopy between September 2011 and August 2012 for total laparoscopic hysterectomy (TLH), laparoscopic myomectomy (LM), and other advanced surgeries. The setting of the study is in a tertiary endoscopic referral center. Between September 2011 and August 2012, 451 laparoscopic surgeries were performed using 3D HD camera and Einstein Vision telescope (Schoelly-Fibreoptic GMBH, Germany) (Fig. 1). An analysis was done showing various indications; the average time taken for surgery and morcellation (whenever indicated), the average blood loss, and the learning curve were determined. 3D TLH was done in 200 cases and was compared to the 200 cases in which 2D was used previously. The weights of specimens were comparable in both groups. The duration of surgery in 3D was less than 60 min in 132 cases, while only 110 cases with 2D took less than 60 min. This difference was statistically significant (p= 0.0316). Similarly, during laparoscopic myomectomy of 97 cases with 3D, 12 cases were done in less than 45 min, while only two cases were done in less than 45 min with the 2D system (p=0.0101). This was statistically significant. The weights of specimens in both groups were comparable. The total blood loss during surgery with 2D and 3D was comparable and not statistically significant in both groups of TLH and LM. We had two conversions to conventional laparoscopy: one ureteric injury (patient with 2.1 kg uterus with anatomical distortion) and one relook after 12 h for hematoma evacuation. The largest uterus removed was 4.87 kg. 3D HD laparoscopy is a quantum leap in minimally invasive gynecology. The tactile feedback is retained; the precision, accuracy, and depth perception are remarkable. The learning curve is short (less than five cases). The initial investment and recurring cost are low compared to robotic-assisted laparoscopies. The time taken for surgery as well as morcellation is less than in 2D HD laparoscopy. The possibility of complications may be less also.

Keywords 3D laparoscopy · Laparoscopic hysterectomy · Laparoscopic myomectomy · Gynecological surgery · Einstein Vision system · Minimally invasive · Depth perception

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Background

Despite the introduction of laparoscopic surgeries for two decades, most surgeons globally still perform conventional laparotomies for hysterectomies and myomectomies. Several reasons have been cited, e.g., lack of adequate training in residential programs, lack of adequate training opportunities outside the medical colleges, lack of teachers and mentors, and lack of desire to learn newer skills. However, perhaps the most important reason is that the 2D view on flat screen-laparoscopy is cerebrally intensive (Fig. 1).

The last two decades have been a glorious era for endoscopy in gynecology. The technological advances that have taken place in the last few years were unimaginable and have added to the safety, efficacy, and precision of laparoscopic

Fig. 1 3D Laparoscope system 65×86 mm (300×300 DPI)

procedures. The innovative advances including high-definition (HD) cameras, vessel sealing devices, the Harmonic Ultracision, electrical morcellator for solid organ tissue retrieval, and articulating instruments for single incision laparoscopy were all brilliant. But every once in a while, innovative technology takes a quantum leap.

Robotic-assisted laparoscopy and three-dimensional (3D) HD laparoscopy are a quantum leap and have taken laparoscopic surgery to a new orbit. In April 2005, the Food and Drug Administration approved the use of the da Vinci Surgical System for use in gynecological procedures.

The major limitation in laparoscopy was its 2D image. This resulted in the lack of depth perception thus increasing the strain for the surgeon and compromise on the safety of laparoscopy. The 3D HD technology is amazing. The precision, accuracy, and depth perception are incredible. It now seems like laparoscopic surgeons were operating with one eye closed! The 3D technology can enhance the skills of talented surgeons.

The question we need to answer is “Is it the use of robotics that can improve the quality of surgery and improve the learning curve?” or “Is it the 3D view on the screen that will enhance the skills of surgeons and improve the quality of advanced surgery?”

Although laparotomy may seem advantageous for the surgeon at first, with depth perception and tactile feedback from the tissue, the large abdominal incision, prolonged hospitalization, increased postoperative analgesic requirements, and higher morbidity are the disadvantages for the patient. Laparoscopic surgery enables faster recovery with shorter hospitalization, improved cosmesis, decreased blood loss, and less postoperative pain [1, 2].

The da Vinci Surgical System has some advantages compared to the conventional laparoscopic surgery, such as the three-dimensional vision, better ergonomics, higher degree of freedom of the robotic instruments, and reduction of tremor interference.

In recent years robotic surgery has been introduced in urological surgery, general surgery, cardiac surgery, and gynecological surgery. The da Vinci Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA, USA) provides robotic control of the laparoscope and all instrumentation. The system employs a 3D vision system and endowrist technology. Endowrist technology facilitates instrument rotation through tiny incisions. The robotic instruments replicate the surgeon’s hand, wrist, and finger movements. This allows for extended range of motion and improved manipulation while conducting laparoscopic procedures [3].

Several publications describe safety and feasibility of this approach. After the first excitement over the innovative and sophisticated technology has settled, there should also be some consideration for a critical assessment of the technique and costs, ideally with recommendations for further improvements by experienced laparoscopic surgeons [4]. It was demonstrated that it took approximately 50 robotic cases to develop consistent operative times and predictable outcomes [5]. Whereas when we used 3D HD laparoscopy, it took us about five cases to get absolutely used to the 3D image, i.e., two operative days.

The learning curve for established laparoscopic surgeons to adapt to 3D HD image on a 32-in. monitor is therefore approximately five cases. All the conventional straight instruments used in laparoscopy can be utilized. There is no recurring cost, and newer instruments can be used instantly.

Methods

All surgeries are performed under general anesthesia using laryngeal mask airway with the patient in modified lithotomy position [6]. The Veress needle is inserted at the Palmer’s point (a point 3 cm below the left costal margin in the midclavicular line) after ruling out splenomegaly.

The first blind 5-mm trocar–cannula is inserted in the left upper lumbar zone [7] lateral to the inferior epigastric vessels at the level of or above the upper limit of the uterus. A 5-mm telescope (2D HD system) is introduced through this port; and the peritoneal cavity, uterus, and adnexa are evaluated. A 10-mm port is inserted under vision at the supra-umbilical site or higher depending on the size of the uterus. Entry under vision avoids damage to major vessels directly beneath the insertion site. The 3D HD telescope with a fore-oblique 30° view is then attached to the 3D HD camera and inserted through the 10-mm cannula.

Two additional accessory 5-mm trocar–cannulas are inserted—one in the left lateral lower quadrant and one in the right lateral upper quadrant. An optional robotic arm with a remote control is available to attach the camera for prolonged surgeries or for tremor-free camera stabilization. The surgeon and the entire operation theater team wear polarized glasses to appreciate the depth perception on a 3D medical grade 32-in. monitor (Fig. 2).

The 30° fore-oblique view can give a directional view from anterior to posterior or from posterior to anterior. Most of the surgeries can be completed with the antero-posterior view. Only deep posterior uterine wall surgeries or abdominal wall surgeries need the postero-anterior view. All complex surgeries can be done using straight stick; powered endowrist type of instruments is now available for conventional laparoscopies. We have not needed them so far.

Findings

A total of 451 patients were treated using 3D HD laparoscopic system. Out of these, 260 patients had total laparoscopic hysterectomy (TLH), 105 patients had laparoscopic myomectomy, and the remaining surgeries were ovarian cysts, endometriosis, and colpo-suspensions.

3D TLH was done in 200 cases and was compared to the 200 cases in which 2D was used previously. The weights of specimens were comparable in both groups. The duration of surgery in 3D was less than 60 min in 132 cases, while only 110 cases with 2D took less than 60 min. This difference was statistically significant ($p=0.0316$; Table 1).

Similarly, during laparoscopic myomectomy of 97 cases with 3D, 12 cases were done in less than 45 min, while only two cases were done in less than 45 min with 2D system ($p=0.0101$; Table 2). This was statistically significant. The weights of specimens in both groups were comparable. The total blood loss during surgery with 2D and 3D was comparable and not statistically significant in both groups of total laparoscopic hysterectomy and laparoscopic myomectomy. Two patients had to be converted to 2D laparoscopy for angulated views that was difficult with 3D.

Fig. 2 Theatre set up with 3D glasses 108×72 mm (300×300 DPI)

Table 1 Duration of surgery in total laparoscopic hysterectomy and corresponding number of cases

System	Number of cases	
	Less than 1 h	More than 1 h
2D	110	90
3D	132	68

The p value 0.0316 was statistically significant

Discussion

The incidence of laparoscopy in advanced gynecological procedures is increasing although not dramatically. One of the reasons for this slow progress is the perceived long learning curves. The 3D view technology of conventional laparoscopy and robotic surgery promises to shorten this learning curve.

Physics of 3D

Principles of depth perception

Depth perception is the visual ability to judge the relative distance of objects and the spatial relationship of objects at different distances. As the three-dimensional world projects onto a two-dimensional retina, this projection on its own cannot provide depth information. The brain has to combine various monocular and binocular cues given by the eyes to recover the depth, distance, and three-dimensional shape of objects.

Stereopsis is the most important cue for depth perception. It is the consequence of interpapillary separation between the two eyes, 6 cm, which causes each eye to have a slightly different view of the same scene. This is called "retinal disparity". The brain is then able to combine the two views into a single 3D image—the process is called stereopsis. Stereoscopy (Greek, to look at a solid object) is the technique of creating or enhancing the illusion of depth in an image—by presenting two offset images separately to the left and right eye of the

Table 2 Duration of surgery in laparoscopic myomectomy and corresponding number of cases

System	Number of cases	
	Less than 45 min	More than 45 min
2D	2	98
3D	12	88

The p value 0.0101 was statistically significant viewer. Both the 2D offset images are then combined in the brain to give the perception of depth.

All laparoscopic surgeons using 2D images actually are operating with one eye closed. This is the reason that 2D laparoscopy is cerebrally intensive.

The 3D HD system by Schoelly has two cameras and two optical lens systems, which transmit two offset images on the medical 3D monitor (Figs. 3, 4, and 5). When the surgeon wears circular, polarized 3D glasses, the two images are merged by the brain into one and this gives the perception of depth. This also provides a clearer visualization of the relationship of organs in the peritoneal cavity in real-time suturing—especially making intra-corporeal stitching very comfortable. 3D HD is the way to go for all laparoscopic surgeons. Consider the fact that currently there are 30,000 three-dimensional screens internationally.

In the last few years, 3D movies grossed US$8.36 billion; six out of ten top hits were 3D movies. Avatar took 10 years to make. It is an audacious, awe-inspiring work of modern art blowing our minds out. 3D HD laparoscopy is audacious, awe-inspiring work of modern surgery which increases safety unbelievably.

Learning curve

A learning curve is defined both by the time (quickness) as well as the number of cases (trials) necessary to attain proficiency. The advent of new technology has brought new challenges and issues. The introduction of laparoscopy had posed the challenge of 2D images on a flat screen i.e., as if viewing with one eye closed. Hence, laparoscopy was considered cerebrally intensive. For the last decade, robotic surgery with its 3D view revolutionized laparoscopic surgery. Several publications discussed the benefits of 3D HD view and improved surgeon performance.

Change and technology are the key words in surgery today; where is the future of surgery headed? Since the “lap hysterectomy” revolution in 1989, no breakthrough has changed modern surgery more rapidly, definitively, or irrevocably than robotic and 3D laparoscopic surgery. A preliminary testing has suggested that the new generation, 3D system, used will be helpful for developing skills in laparoscopy for the novice surgeon [8]

The learning curve for some gynecologists was approximately 50 cases to develop consistent operative times and predictable outcomes. These learning curves were dramatically less than those reported for general surgeons and urologists who report learning curves for robotic-assisted laparoscopic prostatectomy to be 150–200 cases [9–11].

We experienced much shorter learning curves with the new Einstein Vision 3D HD system. We took approximately five cases i.e., two OR days to get used to the 3D vision on a 32-in. monitor using conventional instruments. This may also be due to the fact that our center is a dedicated gynecological endoscopy center with about 600 procedures being done every year. We have been operating for about 6 years now with 2D HD system. But, our belief is that the learning curve for 3D HD system will be very short for all laparoscopic surgeons and this system will enhance the skills of good surgeons. What we need to determine in the near

Fig. 3 3D camera head with telescope attached 108×72 mm (300×300 DPI)

Fig. 4 3D telescope 71×86 mm (300×300 DPI)

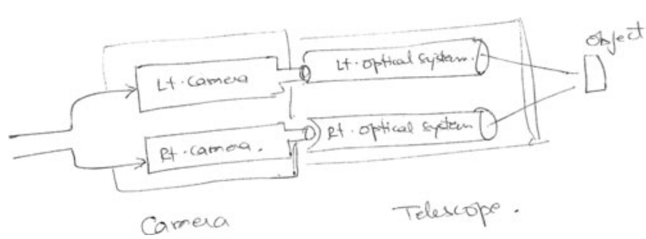

Fig. 5 Physics of a 3D telescope 108×40 mm (300×300 DPI)

future is how long it will take for a postgraduate surgeon who is beginning laparoscopy. Will the 3D HD system shorten his learning curve as compared to conventional laparoscopy and to what degree?

Although some authors suggest that robotics can be a useful method for shortening the learning curve in physicians performing minimally invasive gynecologic surgery, another study suggested that robotic surgery should not serve as a wholesale substitute for a skilled laparoscopic surgeon, especially in procedures where standard laparoscopy is routine [12].

Costs

Another important consideration is that the higher hospital costs associated with robotic surgery is specific to perioperative and postoperative costs (US$1,446 more than conventional laparoscopy) [13] and did not account for the acquisition costs.

The robotic unit costs between US$1 million and US$2.3 million and is associated with annual maintenance costs of US$180,000 a year (Intuitive Surgical Investor presentation Q4-2009). In comparison, the total cost of the 3D HD system, Einstein Vision, and the acquiring costs is about US$250,000 and the annual maintenance cost is US $25,000, while there is no recurring cost per patient.

Medicolegal issues

The advances in robotic-assisted surgery in gynecology evolved after most practicing gynecologists have already completed residency training. Postgraduate training of the new technology for gynecologists in practice is limited.

Therefore, gynecologists with insufficient training who perform robot-assisted surgery may potentially be at risk for liability. In addition to traditional medical negligence claims, plaintiff attorneys are seeking causes of actions for lack of informed consent and negligent credentialing. Thus, it is essential that gynecologists are aware of these potential liability claims that arise in a robot-assisted malpractice suit [14]. Surgical robotics instructors provide an essential service in improving the competency of novice gynecological surgeons in learning robotic surgery and advancing surgical skills on behalf of patients.

The role of a robotics instructor ranges from involving only pure verbal instruction to direct physical guidance during surgery of cases. Despite the degree of involvement, crossing over from a purely observational role to a more active involvement in teaching exposes the surgical robotics instructor to medical malpractice liability in the event of a surgical complication [15].

Limitations of robotic-assisted surgery

Other disadvantages of robotic-assisted surgery are lack of tactile feedback to the surgeon, inability to move the surgical table once the arms of the robot are fixed, and expenses related to the robot and its semi-disposable instruments [16].

Surgeons benefit from using the “robot” by sitting and from 3D view; in addition, the robot makes suturing faster to learn. It does not appear to make a significant difference in the outcome of the patient [17]. Women prefer both single-site and traditional laparoscopic incisions over robotic procedures. In as aesthetics are an important consideration for many women and clinical outcomes are similar, during the informed consent procedure, location and length of incisions should be included in the discussion of risks, benefits, and alternatives [18].

Complexity of surgery

We normally use the 30° telescope for our 3D HD surgeries. It is far more versatile than 0° telescope. The 30° telescope cannot be rotated while it is attached to the 3D HD camera. The standard view is anterior to posterior. However, the telescope can be detached, rotated at 180°, and refixed to the camera, giving a posterior to anterior view. This view is helpful when operating on the deep posterior aspect of the uterus or the anterior abdominal view.

Using the 30° telescope and the 3D HD system does not have a limitation to operate on complex pelvic surgeries. We have done a total laparoscopic hysterectomy where the uterus weighed 4.87 kg (10.71 lb) and performed all kinds of complex endometriotic surgeries. We had only two cases where we converted to 2D HD camera since we needed to view the uterus at odd angles, and the ability to rotate the telescope in the camera coupler helped us. The 3D HD telescope provided a brilliant view for suturing in most oddly located areas.

Benefits of 3D high-definition laparoscopy

- Depth perception
- Tactile feedback retained
- Accuracy
- Safety
- Surgical precision
- Improves hand–eye coordination
- Low capital expenditure
- Low maintenance recurring cost
- Conventional and new straight stick instruments can be used
- Shorter learning curve

Conclusions

Robotic-assisted laparoscopy is new to the field of surgery. Since its introduction, surgeons have been intrigued by it, and each discipline is trying to find its appropriate role. It appears to assist the less skilled laparoscopist in performing surgery that one might have not attempted. It might be the answer to the shortcomings of laparoscopy since it is being adopted by more surgeons. Robotic surgery simply acts as a bridge between laparotomy and advanced operative laparoscopy. It provides 3D vision and easier suture capability without tremor. Its disadvantages are the enormous cost, bulkiness, added time to assemble, and a new learning curve. It is acknowledged that the robot offers a potential advancement in minimally invasive procedures, particularly in complex or highly technical cases such as laparoscopic prostatectomy or certain cardiac cases. It is also acknowledged that robotic surgery is exciting because it is an innovative and cutting-edge technology. However, research indicates that this value proposition tends to be offset when robotics is used in cases where traditional laparoscopic approaches can achieve the same clinical outcomes, but at far less cost to the hospital.

Although subsequent generations of robots may represent the future, it is difficult economically to justify the exuberate uptake of robotic surgery for routine hysterectomies. The evolving literature on robot-assisted surgery in gynecology suggests that the surgical limitations of conventional laparoscopy can be overcome and that the skill level of the surgeon may be enhanced. At present, this seems to be the result of improved instrument, precision and dexterity, and 3D imaging [19]. "There's never been a study showing clinical superiority of the robotic surgery," says Dr. Marty Makary, a surgeon at the Johns Hopkins University School of Medicine in Baltimore. "The benefits of robotic surgery are due more to the laparoscopic approach than to the robot itself," Makary says. In our experience it is the 3D HD view with great depth perception and tactile feedback that will make laparoscopic surgery more acceptable, safe, and cost-effective. It improves surgical precision and hand–eye coordination, conventional and all straight stick instruments can be used, capital expenditure is less, and recurring cost and annual maintenance cost are less. In addition it will enhance the skills of a good surgeon and shorten the learning curve of a novice surgeon.

Conflict of interest The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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