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Title: Comparison of learning curves and skill transfer between classical and robotic laparoscopy according to the viewing conditions: Implications for training

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Abstract: Background: The purpose of this study was to evaluate the perceptual (2D versus 3D view) and instrumental (classical versus robotic) impacts of robotic system on surgical skill acquisition and, in a second time, to determine whether skills were transferred between conventional laparoscopy and robotic system.
Methods: 40 medical students without any surgical experience were randomized into four groups (classical laparoscopy with 3D-direct view or with 2D-indirect view, robotic system in 3D or in 2D) and repeated a complex motor task 6 times. Afterwards, they performed 2 trials with the same technique but in the other viewing condition (perceptive switch). Finally, subjects performed last three trials with the other technique (technical switch). Subjects impressions were surveyed by a questionnaire.

Results: Our study showed better performance and improvement in 3D view than in 2D view whatever instrumental aspect. Participants reported less mastery, familiarity, self-confidence and more difficulty in classical laparoscopy with 2D indirect view than in the other conditions.
Conclusions: Robotic surgery improves surgical performance and learning particularly by 3D view advantage. However, performances after switches emphasize the need to adapt and pursue training also with conventional laparoscopy in order to prevent risks in conversion procedure.

Conflict of Interests Statement

FINANCIAL DISCLOSURE: we certify that we have no commercial associations that might pose a conflict of interest in connection with the submitted article. All funding sources supporting the Work and all institutional or corporate affiliations of the authors are acknowledged.

*** Cover Letter**

Liège, 18th of January 2006

Please find enclosed our manuscript entitled "**Comparison of learning curves and skill transfer in classical and robotic laparoscopy according to the viewing conditions: Implications for training**" that we would like to submit to the *American Journal of Surgery*.

Our manuscript reports a laboratory study on the impact of da Vinci robotic technique on learning curves and subjective impression of novice subjects (medical students). This manuscript has been seen and approved by all authors.

We thank you in advance for your comments about this paper.

Best regards,

Introduction

The fundamental change, produced by new technology, in how surgeons perform operations has educational implications related to learning curves and patient safety [1]. Traditionally, surgeons have honed their skills in the operating rooms through hands-on experience with veteran mentors [2]. This manner of teaching effectively trains surgeons in traditional open surgical techniques, but is costly in terms of time, resources and patient morbidity [3]. Over the past decade, minimally access surgery has revolutionized general surgery, posing new obstacles for surgeons attempting to acquire laparoscopic skills [4]. Indeed, laparoscopic surgery requires specialized training and practice in order to acquire new skills to operate, to manipulate tissues with long instruments and a new knowledge of anatomy and spatial orientation [5,6]. Moreover, classical laparoscopic surgery is generally a two-dimensional surgery. The loss of depth perception and spatial orientation are the main drawbacks for the novice to overcome when facing the television monitor [7]. Advanced complicated laparoscopic surgery requires precise manipulation of the instruments. The success of surgery, the operating time, and the morbidity rate are directly related to the manipulation skills and are responsible for the well-described "learning curve" [1,8,9].

However, minimal invasive surgery was introduced and adopted in a rapid form without precise appreciation of the long learning curve that constitutes the only existing path to overcome all these difficulties [10]. Furthermore, very few studies have been done regarding the surgical skills education and competency testing associated with the use of new and sophisticated technology [11]. In order to avoid the problems that occurred at the introduction of laparoscopic surgery, several recent studies laid stress upon the need to understand how new technology affects learning curves in order to establish appropriate training and assessment [10,11]. Our objective was to answer this question by evaluating learning curves in a comparative study between classical and robotic laparoscopy. Our study analysed the perceptual and instrumental impacts of robotic technology on learning surgical performance of novice subjects using a standard and ecological surgical task developed and validated in several studies (bench models [12,13,14]). In this paper, we used a new generation of 3D system, the da Vinci robotic system. This robotic system allows to regain three-dimensional visualization of the operative field and the degrees of instruments movement freedom lost in classical laparoscopy. Three-dimensional camera system may improve the efficiency, shorten the learning curve and reduce the operating time [7]. However, the literature shows contradictory results about the benefits brought by the 3D vision: some studies showing best motor performances with 3D vision [14-19] while others failed to obtain difference of performance between 2D and 3D [7,20-22]. In order to precisely identify the nature of the skills and learning involved with the robotic system, we differentiated and independently studied the influence of the three-dimensional view (afferent component) comparing 2D and 3D view and the influence of movement freedom restoration (efferent component) comparing classical laparoscopy with robotic system. To our knowledge, this is the first study that compares learning curves between da Vinci system and classical laparoscopy according to the viewing condition. Moreover, in a second time, we evaluated the transfer of acquired skills to the other viewing condition (perceptive switch: 2D versus 3D) and to the other technique (technical switch: classical laparoscopy versus robotic system). These two switches allowed us to study how participants adapted their strategy to the change in depth perception (loss or gain of binocular depth perception) and to the change in technique. Evaluating performance after a technical switch is highly relevant to understand the risk associated to a change in procedure (for example, a conversion procedure when the surgeon has to revert to a classical method) and to determinate an adequate surgical training with the different technologies.

Finally, we also studied the impact of the use of technology on subject's self-confidence, satisfaction and facility during the learning, knowing that these factors influence performance, motivation and new technology acceptance in operating room [23,24]. To avoid any bias from earlier laparoscopic experience in our comparison between classical and robotic laparoscopic techniques, we only selected medical students without any experience in open, minimally invasive or robotically assisted surgery.

Methods

Materials

The Da Vinci system consists of two primary components: the surgeon's viewing and control console and, a moveable cart with three articulated robot arms. The surgeon is seated in front of the console, looking at an enlarged three-dimensional binocular display on the operative field while manipulating handles that are similar to "joysticks". Manipulation of the handles transmits the electronic signals to the computer that transfers the exact same motions to the robotic arms. The computer interface has the capacity to control and modify the movements of the instrument tips by downscaling deflections at the handles (by a factor between 5:1 to 2:1). It can eliminate physiologic tremor, and can adjust grip strength applied to the tools. The computer generated electrical impulses are transmitted by a 10-meter long cable and command the three articulated "robot" arms. Disposable laparoscopic articulated instruments are attached to the distal part of two of these arms. The third arm carries an endoscope with dual optical channels, one for each of the surgeon's eyes. As the 3D visualization can be changed to 2D, we used 3D and 2D options.

We used a pelvitrainer for the classical laparoscopic condition (from Ethicon®). The optical system consists of the laparoscope, camera, light source and video monitor (Storz endoskope®). The camera was always controlled by the same observer.

Subjects

This study was approved by the ethical committee at the University Hospital Centre of Bruxelles. Informed consent was obtained from each participant. Forty medical students (22 women and 18 men, mean age 24.23 ± 2.56 years) without any prior surgical experience were selected. All subjects underwent standard acuity examination (with Ergovision and Visuotest from Essilor®) and only those with either normal or corrected-to-normal vision were included. As shown in table 1, they were randomly divided into four groups: the first using classical laparoscopy with indirect view (2D screen), the second using classical laparoscopy with direct view, the third using the robotic system in 3D and the fourth using the robotic system in 2D. Subjects were unaware of the existence of 2D and 3D options of the robotic system, and then unaware of the advantages or difficulties related to their experimental condition.

Our four experimental conditions allowed us to differentiate two dimensions (see Table 1): one we called "perceptive", afferent component, where the type of vision (binocular versus monocular) was the main within-technique difference (between 2D and 3D viewing conditions with the same technique) and another we called "instrumental", efferent component, where the freedom degree for instrument movement was the main between-technique difference (between robotic system and classical laparoscopy). This experimental plan allowed us to more precisely study the influence of new technology on learning curves and particularly to answer the question: is the impact of this robotic system explained by the benefit of 3D view (in this case, we should observe predominant effect of perceptive dimension and thus difference between 2D and 3D) or by the recovery of movement freedom (in this case, we should observe predominant effect of instrumental dimension and thus difference between classical and robotic system)?

Procedure

Experiment consisted of three successive phases:

1. Learning curves: subjects repeated 6 times the task in one of the four experimental conditions.
2. Perceptive switch: subjects performed 2 trials with the same technique as in the first phase but in the other viewing condition (2D versus 3D).
3. Technical switch: subjects performed 3 trials with the other technique (classical versus robotic system).

Task

The task involved passing in succession a needle, with a thread attached, through rings placed in different heights and depths. This task required depth perception and wrist articulation skills [12]. It also developed skills at needle transfer and thus two—handed coordination and ambidexterity. Rings route resumed a lot of useful and usual fine movements required in minimal invasive surgery (grasping needle, curving and introducing it…) and notably reproduced all the complexity of the suture gesture (except the knot). By all these aspects, this task seemed to be a very efficient and accurate way to evaluate minimal invasive systems.

For each trial, we calculated a performance score that was the number of rings in which the subjects went through with the needle in 4 minutes. All procedures were video recorded and accuracy was evaluated by three independent observers: for each trial, an error score was constituted by the total of failures (failure to grasp needle in one attempt, dropping the needle, missing the ring) and an ambidexterity score corresponded to the total number of alternative use of left and right instruments.

Questionnaires

After determined trials (1, 2, 6, 7 and 9), participants evaluated their performance and answered a questionnaire about feelings of mastery and familiarity with the technique and their feeling of performance satisfaction, self-confidence and difficulty on a 4-point Likert scale.

After the technical switch, subjects were asked to compare the two techniques (robotic versus classical laparoscopic system) on a 4-point Likert scale about their general performance, speed of execution task, gesture accuracy, gesture quality, image quality, site view, instrument utilization, spatial orientation, comfort, action visibility, difficulty, concentration, feedback quality and anticipation.

Statistical analysis

Learning curves for performance score, error score, ambidexterity score and answers to the questionnaire were analysed by a repeated measures analysis of variance (Statistica 6.1). We used Newman-Keuls test for *post hoc* comparison. T student test was used to analyse answers to the final questionnaire comparing classical laparoscopy and robotic system. Significance was defined as e p value less than 0.05.

Results

1. *Learning curves*

Performance of all subjects improved from their first to sixth trial but learning curves were significantly different between the four conditions ($p<0.005$, see Fig.1): 3D view (classical and robotic laparoscopy) allowed a great and fast improvement whereas, the improvement was very weak in classical laparoscopy with 2D-indirect view. From the first trial, performances with robotic system in 3D (5.36±0.56) and in classical laparoscopy with 3D-direct view (4.75±0.52) were significantly better than with the robotic system in 2D (2.2±0.58, respectively $P<0.005$ and $P<0.01$) and the worst performance was obtained in classical laparoscopy with 2D-indirect view (0.9±0.58, respectively $P<0.0005$, $P<0.001$). As shown in Fig. 1, these differences persisted and increased trial after trial with a better performance with 3D view (robotic or classical laparoscopy) than with robotic system in 2D ($P<0.005$ in the first trial, $P<0.0005$ in the sixth trial) and classical laparoscopy with 2D-indirect view ($P<0.0005$ in the first trial, $P<0.0001$ in the sixth trial). The difference between robotic system in 2D and classical laparoscopy with 2D-indirect view also persisted but decreased trial after trial ($P<0.005$ in the first trial, $P<0.05$ in the sixth trial).

Concerning the performance quality (Table 2), from the first trial, error score was significantly higher in 2D-view conditions (laparoscopic and robotic) than in 3D-view conditions and did not evolve during the trials. In the first trial, ambidexterity score was significantly higher in classical laparoscopy with direct view than with robotic system in 3D ($P<0.05$) and higher in 3D-view conditions than in 2D-view conditions ($P<0.0005$). From the second trial, difference of ambidexterity score was only between 2D and 3D-view conditions, independently of the instrument aspect, and significantly evolved in all conditions until the sixth trial ($P<0.05$, Table 2).

Concerning answers to the questionnaire, feelings of mastery ($P<0.00005$), familiarity ($P<0.0000$), satisfaction ($P<0.005$), self-confidence ($P<0.01$) and difficulty ($P<0.05$) significantly evolved in all conditions during the trials. As shown in Table 3 (trials 1, 2, 6), subjects significantly reported in general less mastery, familiarity, self-confidence and more difficulty in classical laparoscopy with 2D-indirect view than in other conditions. Satisfaction was not significantly different between the four conditions.

2. Perceptive switch

After the perceptive switch (Fig. 1, trial 7), subjects performed significantly better with 3D view (robotic system, 8.44±3.24, and classical laparoscopy, 7.78±2.33) than with 2D view (robotic system, 4.42±2.39, $P<0.05$, and classical laparoscopy, 3.25±1.7, $P<0.005$). The gap between the trials 6 and 7 was significant in all conditions: performance significantly decreased from 3D to 2D condition in classical ($P<0.0005$) and robotic ($P<0.0005$) system and significantly increased from 2D to 3D condition in classical ($P<0.0005$) and robotic ($P<0.005$) system. The performance improvement between trials 7 and 8 was not significant in any condition.

Similar results were obtained concerning error score with a significantly higher score in 2D-view conditions than in 3D-view conditions (Table 2). Concerning ambidexterity score, no significant difference was obtained between the four conditions (Table 2).

When we compared subjective evaluation between trials 6 and 7 (Table 3), feelings of familiarity, mastery, self-confidence significantly decreased for subjects switching from 3D to 2D with classical (respectively, $P<0.005$, $P<0.0005$, $P<0.001$) and robotic (respectively, $P<0.05$, $P<0.005$, $P<0.01$) system and significantly increased for subjects switching from 2D to 3D only in classical laparoscopy (respectively, $P<0.05$, $P<0.01$, $P<0.05$). Feeling of satisfaction significantly decreased only for subjects switching from 3D to 2D with the robotic system ($P<0.01$). No significant difference was obtained in the switch from 2D to 3D with the robotic system and in difficulty evaluation.

3. Technical switch

After the technical switch (trial 9, see Fig. 2), performance decreased in all conditions, reaching the same score as the first trial (in classical laparoscopy, performance was slightly worse than in the first trial). We obtained a significant difference between all conditions ($P<0.000005$) except between classical laparoscopy with 3D-direct view (3.78±1.64) and robotic system in 2D (2.38±1.3), best performance was obtained with robotic system in 3D (5.55±2.77) and worst performance was in classical laparoscopy with 2D-indirect view (0.3±0.48). The improvement during these last three trials was significant only in classical laparoscopy with 3D-direct view ($P<0.05$). In trial 10 ($P<0.001$), performance was significantly better in 3D view (robotic system in 3D, 6.56±3.05 and classical laparoscopy with direct view, 5.5±3.25) than in 2D view (robotic system in 2D, 2.67±1.5 and classical laparoscopy with indirect view, 1.37±1.06). In trial 11 ($P<0.00005$), performance was significantly different between all conditions except between robotic system in 2D (3.5±2.38) and classical laparoscopy with 2D-indirect view (1±1), with a significantly better performance in classical laparoscopy with 3D-direct view (11.67±2.08) than with robotic system in 3D (7.8±1.09).

Error score was significantly higher in classical laparoscopy with 2D-indirect view than in the 3D-view conditions (Table 2). This high error score in classical laparoscopy with 2D-indirect view, decreased in the following trial to reach a score similar to the 2D robotic system score (20.17±3.54). Ambidexterity score was significantly higher in the 3D-view conditions than in 2D-view conditions (Table 2).

After the technical switch, subjects in classical laparoscopy with 2D-indirect view significantly reported worse feelings of mastery, familiarity, satisfaction, self-confidence and difficulty (Table 3, trial 9). The same negative evaluations about familiarity and difficulty feelings were reported by subjects in classical laparoscopy with 3D-direct view. Robotic system did not differ between 2D and 3D in any subjective evaluation.

Final questionnaire comparing the two techniques showed significant difference for all items except for the concentration and the feedback quality, perhaps these questions were to abstract or not understood by subjects (Table 4).

Comments

1. First phase: learning curves

The need to compare learning curves obtained with different technologies and to determinate impact of several factors (depth perception, dexterity…) on surgical training has been pointed out by recent studies [10,11,25]. Indeed, our study showed that learning curves were different according to the technique and the viewing condition. In 3D-view conditions, learning curves of robotic and classical laparoscopy followed a similar pattern, with better performance and greater improvement than robotic system in 2D and classical laparoscopy with indirect view. In 2D-view conditions, we observed an improvement during the first three trials with the robotic system while in classical laparoscopy, the improvement was really small and progressive. Moreover, the gap in performance between 3D-view conditions (robotic system in 3D and classical laparoscopy with direct view) and 2D-view conditions (robotic system in 2D and classical laparoscopy with indirect view) grow up trial after trial. This finding of best performance with a 3D view whatever the instrumental aspect (classical or robotic), emphasizes the persistent and increasing impact of perceptive advantage brought by binocular vision that overlaps the instrumental difficulty. On the contrary, in 2D-view conditions, performances and improvement were better with the robotic system than in classical laparoscopy. This result suggests that unlike the 3D view, instrumental benefit influences and facilitates performance in 2D view.

No accuracy progress was observed in any condition during all trials but ambidexterity score improved in all conditions particularly in 3D-view conditions, subjects using both hands with more facility. In parallel, participants generally reported less mastery, familiarity, self-confidence and more difficulty in classical laparoscopy with 2D indirect view than in the other conditions. However, these impressions positively evolved in all conditions, indicating an increase in the satisfaction and in the control sensation of the situation.

2. Second phase: perceptive switch

After the perceptive switch, as expected, subject's performances were affected by the 2D-3D change. In the two trials of this phase, the performance and error scores were only differentiated by the perceptive dimension, with better performance in 3D view (classical and robotic system) than in 2D view. Furthermore, performances were stable without any positive or negative evolution during the two trials. Perceptive switch had also an strong impact on subjective evaluation: a positive impact on subjects switching from 2D to 3D and a negative one on subjects switching from 3D to 2D. As in the previous phase, subjects reported more mastery, familiarity, self-confidence and satisfaction when they used 3D view (classical or robotic system) than when they acted with 2D view. These results again emphasized the role of perceptive dimension (see Table 1), differentiating between 2D and 3D whatever the instrumental dimension.

3. Third phase: technical switch

In the final phase, after the technical switch, the performances in all conditions decreased to the same score as in the first trial. Moreover, the performances did not much improve in this final phase, participants showing difficulty to adapt their movements to the other technique: with the robotic system, subjects kept conservatory strategy used in classical laparoscopy and showed difficulty to move the camera, and with classical laparoscopy, manipulation of long and rigid instruments seemed to be the most difficult obstacle to overcome, producing a very high error score in classical laparoscopy with 2D-indirect view. However, the improvement and best performance in the last trial in classical laparoscopy with direct view showed that 3D view allowed to efficiently overlap instrumental difficulty in classical laparoscopy.

Moreover, a supplementary factor has to be taken into account for the difference between classical laparoscopy with direct and indirect view: in classical laparoscopy with indirect view, the eye-hand orientation axis is deviated because the subject does not look in the same direction as he acts while in classical laparoscopy with direct view the eye-hand axis is re-established. This modification of the perception-action axis can explain a part of difference observed between the two conditions, but its impact is difficult to exactly estimate. Recent studies have shown that angle and direction of looking affect the quality of endoscopic surgery [26,27]. The optimal position of monitor appeared to involve a reasonable angle relative to the operating area (45°) while performance decreased with greater angle (90° [26]). In our study, the angle in classical laparoscopy with indirect view was 90°. This factor could particularly influence performance during the perceptive switch where the improvement between classical laparoscopy with indirect and direct view was more significant than between 2D and 3D robotic system.

In conclusion, the findings after a technical switch led to two highly relevant observations: the skills acquired with a specific technique were not transferred to another technique, suggesting that skills acquired within each technique were not identical, and moreover, the learning with a specific technique could prevent learning and adequate use of another technique. Previous study suggested that robotic system could be an ideal training tool for residents and fellows because of the greater impact of the learning curve [25]. However, our study moderates this suggestion emphasizing the difficulty to transfer skills learned with robotic system to classical laparoscopy.

General conclusion

In this study, 3D view led to better performance and greater improvement than 2D view whatever the instrumental advantage may be. The difference in learning curves between the different conditions confirms the hypothesis that the learning process in the da Vinci system is shorter than in classical laparoscopy [10] but our study specify that this shortness is particularly due to the 3D view. All these findings emphasize the need to adapt the training tasks to the used technique (for example, the weak learning effect in classical laparoscopy with 2D indirect view suggests to begin with more simple and basic tasks, as already advocated [28]). Moreover, the difficult skill transfer after the technical switch suggests that the two techniques involved or trained not exactly identical skills, and lays stress on the necessity to pursue training with the different techniques in order to prevent gap in the performance and thus the operating risk if conversion procedure occurs. In our study, classical laparoscopy with direct view had not clinical relevance but was only used in order to better understand cognitive and visuo-motor mechanisms involved in the learning of a complex surgical task. Participants were novice and did not achieve an expert level at the end of the trials, it is then possible than other cognitive and visuo-motor processes are involved in expert practice.

Finally, we showed a benefit of the training in the improvement of the performance but also in the feelings of mastery, familiarity, satisfaction, self-confidence and facility, essential factors of well-being, motivation, accurate performance and new technology acceptance in operating room [23,24]. By all these characteristics, this study encourages the use of bench models in training of surgical skills in parallel to traditional learning.

Acknowledgments

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Figure(s)

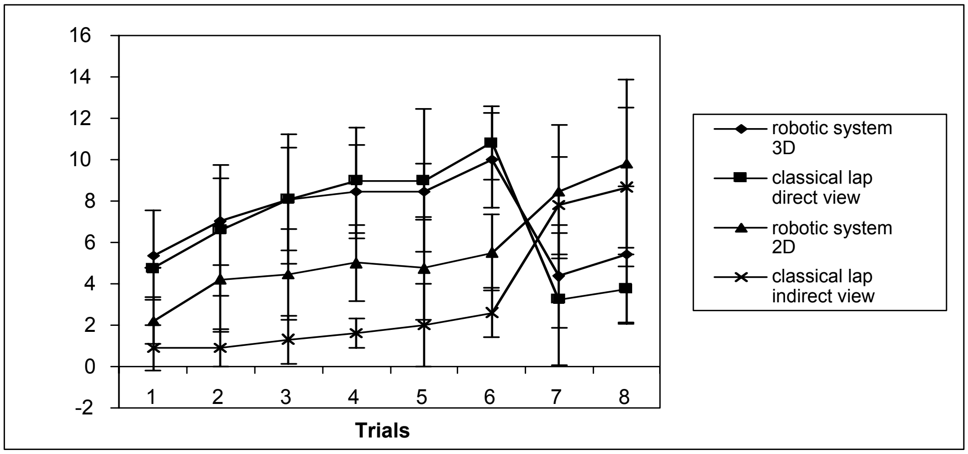

Fig.1. Learning curves for performance scores in the first six trials and in the perceptive switch (trials 7 and 8)

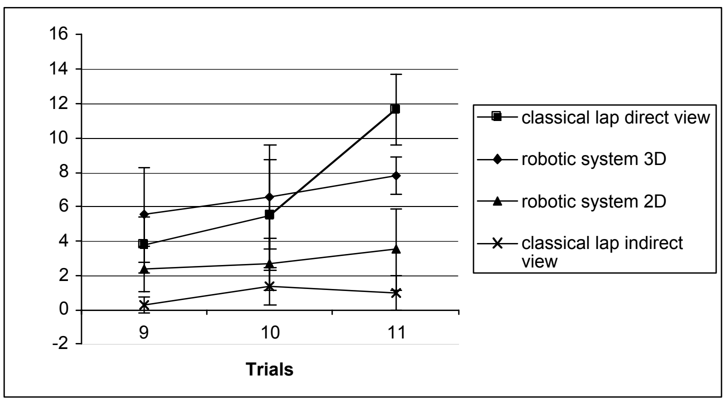

Fig.2. Learning curves for performance scores after the technical switch

Table(s)

Table 1
Number of subjects in each condition according to both dimensions

		Instrumental dimension	
		Classical laparoscopy	Robotic system
Perceptive Dimension	2D	10 subjects	10 subjects
	3D	10 subjects	10 subjects

Table 2
Error scores and ambidexterity scores in trials 1, 2, 6, 7 and 9 (interobserver reliability, Cronbach's alpha = 0.86)

	Classical laparosc With indirect view	**Classical laparosc With direct view**	**Robotic system in 2D**	**Robotic system in 3D**	**P value**
Error score					
Trial 1	20.12±2.29	9.03±3.14	18.89±5.1	11±4.3	*P*<0.0000 (1,2-3,4)
Trial 2	20.87±5.74	10.33±1.53	17.75±6.98	12.67±4.66	*P*<0.05 (1,2-3,4)
Trial 6	20.56±5.66	8.67±1.53	17.292±4.15	8.67±4.87	*P*<0.0001 (1,2-3,4)
Trial 7	22.67±4.73	11±8.66	22.11±5.28	11.63±7.25	*P*<0.01 (1,2-3,4)
Trial 9	30.43±9.55	13.08±4.58	23.67±8	10.5±4.37	*P*<0.0005 (1,2-3,4)
Ambidexterity score					
Trial 1	3.02±2.33	15.67±10.21	4.67±3.24	9.38±4.24	*P*<0.001 (4-3-1,2)
Trial 2	4.62±2.44	17.54±2.64	6.25±3.49	9.33±3.7	*P*<0.0001 (1,2,3-4)
Trial 6	7.06±2.5	23.05±7.23	7.86±4.18	17.56±5.68	*P*<0.00001(1,2-3,4)
Trial 7	9.33±2.08	14.04±7.81	7.11±3.95	11.63±7.25	*NS*
Trial 9	2.86±2.54	13.07±7.43	5.78±2.77	9.87±4.05	*P*<0.005 (1-3,4;2-4)

Table 3
Feelings scores of mastery, familiarity, satisfaction, self-confidence and difficulty for trials 1, 2, 6, 7 and 9

	Classical laparoscopy With indirect view	Classical laparoscopy With direct view	Robotic system in 2D	Robotic system in 3D	P value
Trial 1					
Mastery	1.22±0.44	1.83±0.72	1.89±0.78	2±0.7	*NS*
Familiarity	1.33±0.5	2.25±0.96	2.11±0.78	2.33±1	$P<0.05$
Satisfaction	1.44±0.53	2.17±1.03	1.78±0.83	2.33±0.87	*NS*
Self-confidence	1.44±0.73	2±0.95	2±0.87	2.56±0.73	$P<0.05$ (3-1)
Difficulty	3.67±0.5	3±0.74	3±0.74	2.78±0.67	$P<0.05$ (2,3,4-1)
Trial 2					
Mastery	1.44±0.53	2.25±0.75	2.33±0.87	2.56±0.53	$P<0.01$ (2,3,4-1)
Familiarity	1.56±0.53	2.5±0.79	2.33±0.87	2.78±0.67	$P<0.01$ (2,3,4-1)
Satisfaction	1.78±0.67	2.33±0.87	2.22±0.67	2.11±0.6	*NS*
Self-confidence	1.67±0.7	2.25±0.61	2.44±0.88	2.56±0.53	$P<0.05$ (2,3-1)
Difficulty	3.67±0.5	2.83±0.72	2.78±0.83	2.67±0.7	$P<0.05$ (2,3,4-1)
Trial 6					
Mastery	1.78±0.67	2.72±0.65	2.22±0.67	2.56±0.53	$P<0.05$ (3,4-1)
Familiarity	2±0.7	2.9±0.7	2.33±0.7	2.78±0.67	$P<0.05$ (1-4)
Satisfaction	2.11±0.78	2.9±1.04	2.22±0.67	2.56±0.53	*NS*
Self-confidence	1.89±0.78	2.72±0.79	2.44±1.13	2.56±0.53	*NS*
Difficulty	3.22±0.83	2.36±0.92	3.22±0.44	2.44±0.88	$P<0.05$ (1-3)
Trial 7					
Mastery	1.75±0.5	2.56±0.88	1.56±0.73	2.78±0.97	$P<0.05$ (3,4-1)
Familiarity	1.75±0.5	2.77±0.67	1.67±0.7	3±0.7	$P<0.005$ (3,4-1,2)
Satisfaction	2±0.82	2.67±0.5	1.22±0.44	2.89±0.78	$P<0.0005$(3,4-1,2;1-2)
Self-confidence	1.75±0.5	2.67±0.7	1.56±0.73	3.11±0.78	$P<0.0005$ (3,4-1,2)
Difficulty	3±1.41	2.67±0.7	3.33±0.7	3±0.7	*NS*
Trial 9					
Mastery	1±0	1.71±1.11	1.75±0.46	2.27±0.79	$P<0.005$ (2,3,4-1)
Familiarity	1±0	1.43±0.53	2.12±0.64	2.55±0.93	$P<0.0005$ (2,3-1,4)
Satisfaction	1±0	1.43±0.53	1.87±0.64	2.18±0.98	$P<0.005$ (2,3-1)
Self-confidence	1±0	1.86±0.69	1.75±0.7	2.45±0.93	$P<0.0005$ (2,3,4-1)
Difficulty	3.9±0.32	3.57±0.53	2.87±0.64	2.64±0.8	$P<0.0005$ (2,3-1,4)

1= classical laparoscopy with indirect view; 2= robotic system in 2D; 3= robotic system in 3D; 4= classical laparoscopy with direct view

Table 4
Answers to questionnaire comparing the two techniques (classical and robotic laparoscopy)

	Classical laparoscopy	Robotic system	T and P Value
General performance	2±1.06	3±1.05	2.83; <0.01
Speed of performance	1.94±0.96	2.89±0.94	3; <0.005
Gesture accuracy	1.82±0.95	3.42±0.69	5.81; <0.05
Image Quality	1.8±0.79	2.98±0.89	3.38 <0.05
Site view	2.23±1.15	3.05±0.78	2.52; <0.05
Instrument utilization	1.87±0.96	3.42±0.84	5.09; <0.00005
Spatial orientation	1.88±0.78	3.31±0.88	5.12; <0.00005
Comfort	1.53±0.62	3.53±0.61	9.68, <0.000000
Concentration	2.24±0.9	2.37±1.12	No significant
Feedback quality	2.35±1.17	2.74±0.87	No significant
Action visibility	2.12±1.08	3.11±0.8	3.05; <0.005
Anticipation	2.23±0.97	2.89±0.96	2.07; <0.05
Complexity	2.98±1.02	1.96±1.01	2.29; <0.05
Gesture quality	1.88±0.78	3.32±0.58	6.28; <0.00000