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Objective: To assess whether previous training in surgery influences performances on da Vinci Skills Simulator and da Vinci robot.

Materials and methods: In this prospective study, thirty-seven participants (11 medical students, 17 residents, and 9 attending surgeons) without previous experience in laparoscopy and robotic surgery performed all the da Vinci Skills Simulator exercises. Thirty-five then executed a suture using a da Vinci robot.

Results: The overall scores on the exercises at the da Vinci Skills Simulator show a similar performance among the groups with no statistically significant pair-wise differences ($p<0.05$). The quality of the suturing based on the unedited videos of the test run was similar for intermediate (7 (4, 10)) and expert group (6.5 (4.5, 10)), and poor for untrained group (5 (3.5, 9)), without statistically significant difference ($p<0.05$).

Conclusion: This study showed, for subjects new to laparoscopy and robotic surgery, insignificant differences in the scores at the da Vinci Skills Simulator and at da Vinci robot on inanimate models Keywords: da Vinci Skills Simulator; da Vinci simulator; robotic surgery simulator

Introduction

The da Vinci Surgical System by Intuitive Surgical (Sunnyvale, CA, United States) has been adopted extensively in clinical practice, exceeding 750,000 procedures in 2016 with about 4,000 installed systems [1]. Currently, this technology is used by all the major surgical specialties with gynecology, general surgery, and urology generating the highest volume. The increasing number of systems installed worldwide has generated a need for training of surgeons new to this technology. The ideal approach to address this problem has to include laboratory skills training to minimize training on patients [2]. Since it is impracticable and costly to use da Vinci robot as a training system (about $500/hour) in standard surgical skills laboratories, robotic simulators provide a compromise solution [3].

The advent of virtual reality (VR) simulators can be traced back to the early 90s and marked the involvement of computer science in surgical training [4]. VR simulators have since become established in surgical skills training labs as they enable repeated practice by surgical trainees with in-built objective metrics providing meaningful feedback until proficiency is obtained [4-5]. The validity of VR simulators in the training of operative skills for laparoscopic surgery, first indicated by a randomized control trial on 16 residents, has been confirmed by many subsequent studies [6, 7]. Currently, the Fundamentals of Laparoscopic Surgery (FLS), a joint educational initiative by the Society of American Gastrointestinal Endoscopic Surgeons (SAGES) and American College of Surgeons (ACS), offers a standardized set of exercises for dry-lab training in basic laparoscopic surgical skills [8-9]. An equivalent curriculum for robot assisted surgery, called Fundamentals of Robotic Surgery, was developed [10]. There are certain skills which the surgeon has to acquire for efficient and safe use of the da Vinci robot: maneuverability of the master interfaces, control of the camera and other robotic arms and clutching; as even the latest version of the robot does not have any force/ tactile feedback, although the excellent high definition (HD) true stereoscopic imaging compensates to some extent for this haptic loss.

At present there are five VR simulators for RAS: SEP (Surgical Education Platform) by SimSurgery (Oslo, Norway), RoSS (Robotic Surgical System) by Simulated Surgical Systems (San Jose, CA, USA), dV-Trainer by Mimic (Seattle, WA, USA), da Vinci Skills Simulator (dVSS) by Intuitive Surgical, and the recently introduced RobotiX Mentor by 3D Systems, Simbionix Products (Cleveland, OH, USA). The da Vinci Skills Simulator launched in 2011 is the only simulator which uses an identical console to that of the da Vinci robot and the software was developed by Mimic. The exercises available at the da Vinci Skills Simulator are the same as the dV-Trainer. Many studies on face, content, construct, concurrent, and predictive validity on those VR simulators were published [11].

The present study was designed to assess whether the da Vinci Skills Simulator can distinguish between different levels of training in surgery in subjects new to minimally invasive surgery, in particular robotic surgery. We also evaluated the correlation between performances at the da Vinci Skills Simulator and in a dry-lab session, requiring the execution of a standardized suturing task, at da Vinci robot.

Materials and methods

The design of the study is shown in Figure 1. A cohort of 37 subjects participated in this prospective study: 11 medical students, 17 surgical residents, and 9 attending surgeons (Table 1). The subjects were recruited by an open (unpaid) call. All of them had no previous experience in laparoscopy, robotic surgery, and at the da Vinci Skills Simulator. None of them was certified by the FLS program. The 17 surgical residents had a median experience in surgical training of 2 years (range: from 1 to 5) and were from: general surgery (n= 9), vascular surgery (n=2), thoracic surgery (n=5), and urology (n= 1). The attending surgeons had a median surgical experience of 10 years (range: from 4 to 25) and came from the following specialties: general surgery (n= 2), vascular surgery (n=1), urology (n= 1), otorhinolaryngology (n=1), and orthopedics (n=4).

They were classified according to the level of their training in surgery, as follows: untrained (students in medicine), intermediate (residents), and experts (attending surgeons). During session I, the participants were familiarized (15 minutes period) with the da Vinci master console and da Vinci Skills Simulator graphic user interface (GUI) and completed an initial demographic questionnaire before undertaking the exercises.

Participants executed 26 exercises of da Vinci Skills Simulator (software release: C60_P6_L1_B14), comprising the following subsets: EndoWrist Manipulation 1 (n=3), Camera and Clutching (n=6), EndoWrist Manipulation 2 (n=5), Energy and Dissection (n=4), Needle Control (n=2), and Needle Driving (n=6). Before the test, they received instructions on the set up, ergonomics of simulator console, on navigation through software menus, effective use of camera, and clutch pedals.

The console/ simulator was linked to a laptop through a frame-grabber (VGA2USB by Epiphan Systems, Palo Alto, CA, United States), enabling video recordings of the simulator sessions by all the participants. The system provided both synthetic scores (percentages) and analytic scores (metrics). The number of metrics parameters varies with the exercises but generally includes: time to completion, economy of motion, instruments collisions, excessive instruments force, instruments out of view, and master workspace range. All metrics were recorded and stored for subsequent analysis.

To assess whether the exercises were perceived as intuitive, the participants performed them without watching the instruction videos. An engineer experienced in surgical simulation (AM) was present during the session providing clarification to participants when needed. At the end of the session, each participant filled in a second questionnaires on their impressions of the simulator. The tests at simulator were all performed at EndoCAS, center for compute surgery, University of Pisa, Italy.

Then, participants perform suturing with the da Vinci robot on a silicone standardized model at Multidisciplinary Center of Robotic Surgery at Cisanello Teaching Hospital in Pisa. The task reflected one of the exercises of the da Vinci Skills Simulator (Dots and needle 1&2). It is illustrated in Figure 2. Each participant carried out a trial run followed by a test run (Figure 2). Videos were acquired of all suturing tasks performed by participants. Subsequently an expert surgeon (AC) reviewed blindly the videos of the test run and evaluated their task quality using observational clinical human reliability analysis (OC_HRA) with the overall result for each candidate expressed as a linear analogue scale ranging from one (poor) to ten (excellent) [12-14].

Statistical analysis was performed using IBM SPSS Statistics 22 (Chicago, IL, United States). Shapiro-Wilk test was used to check normal distribution of scores of simulator's tasks and time and OC_HRA assessment of suture. One way ANOVA test and Kruskall-Wallis test were used for statistical significance ($p < 0.05$) on data with respectively normal and non-normal distribution.

Results

Performances on the da Vinci Skills Simulator

The residents were the fastest to complete all the twenty-six exercises (140.8 ± 26.5 min), followed by the medical students (151.4 ± 37.4 min), and the expert surgeons(171.7.3 ± 47.2 min). Shapiro-Wilk revealed normal distribution on the majority of the tasks. A logarithmic transformation was applied to data with non-normal distribution. Five tasks (Ring walk 1, Ring walk 3, Match board 3, Ring and rail 1, and Energy switching 2) confirmed non normal distribution in spite of the logarithmic transformation. In Table 2 and Table 3 overall score of the tasks with normal and non-normal distribution are respectively reported. Overall, results show a similar performance among the three groups. Statistically significant difference was observed only in one task (Suture sponge 1, p=0.023).

All groups rated the simulator as very intuitive (range: 8.1–8.7 out of 10) and with good visual realism (range: 6.8–8.1 out of 10). The expert surgeons felt that the simulator was not useful enough to improve their surgical skills (4.9 ± 3.3 out of 10), whereas the intermediate one considered it to be quite useful (7.7 ± 1.7 out of 10). Energy and dissection 1&2 exercises were the favorite by the medical students (n=6), while Tubes was the favorite task by residents (n=4), and surgeons (n=5). Ring and rail 2 exercise was the least appreciated by the medical students (n=3) and residents (n=3), while Dots and Needles 1&2 for surgeons (n=4).

Performances of suturing task on the da Vinci robot

Two participants (one resident, and one attending surgeon) could not attend second session requiring a standardized suturing task on the real da Vinci robot. Hence 35 subjects performed the suturing task using the da Vinci robot at varying times after completion of session I (median = 41 days, range: 17-72). The participants were subdivided as follows: medical students (n=11), residents (n=16), and attending surgeons (n=8). Table 4 shows the execution time in seconds and the blinded independent grading of the quality of the suturing by the OC_HRA system expressed on a linear scale ranging from 1 = poor to 10 = excellent. Shapiro-Wilk revealed non normal distribution of data. The residents group obtained the shortest median execution time (601 s (400.75, 666.25)), followed by surgeons (682 s (515.75, 867.75)), and medical students (725 s (649, 862.5)). The quality of the suturing based on the unedited videos of the test run was similar for intermediate (7 (4, 10)) and expert group (6.5 (4.5, 10)), and poor for untrained group (5 (3.5, 9)). Kruskall-Wallis test revealed no statistical significant difference in both time of execution and OC_HRA scores ($p<0.05$) (Table 5). By using Spearman test a low correlation with time between test sessions was found for time to execute the suture ($\rho= 0.125$) and OC_HRA score ($\rho=0.006$).

Discussion

Since the use of an actual da Vinci robot is so costly for pre-clinical laboratory training (about $500 /hour), the acquisition of da Vinci Skills Simulator at a price of less than $100 000 seems on a priori grounds to be cost effective for familiarization with the master control interfaces, camera, clutching, and foot pedals of the master console of the da Vinci robot. However, this is contingent on evidence that this simulator can transfer the necessary skills to enable safe and efficient use of the da Vinci robot.

Most studies on validity of the commercial VR simulators for training in surgical robotics are limited to a subset of the available exercises. Studies on construct validity included subjects with different level of experience in surgical robotics [11]. The present study in contrast was designed to assess performances of participants, with surgical and non-surgical background but without previous experience in laparoscopy and surgical robotics, at the da Vinci Skills Simulator; and the transfer of the results at the simulator (session I) to dry-lab test (session II) during of execution of a suture with the da Vinci robot.

The performance data on the da Vinci Skills Simulator indicate similar scores between the groups irrespective of the degree of their surgical training. Residents and medical students were faster than attending surgeons to complete the session at the VR simulator. This probably reflects the different ages of the groups as young individuals are more used to computer interfaces, 3D movies, and VR systems like videogames (mean age: 25.7 years for medical students, 28.5 years for residents, and 42.7 years for surgeons).

In general the three groups found the simulator very intuitive to use and visually realistic. The expert group expressed interest in less repetitive but more challenging exercises.

In contrast to their performance at the da Vinci Skills Simulator, intermediate and expert groups performed better than the untrained one in the suturing task with the da Vinci robot, although the difference did not to reach statistical significance. Thus, the results of this study suggest a low correlation between performances at the da Vinci Skills Simulator and da Vinci robot in subjects with different level of surgical training but without experience in laparoscopy (manual and robot-assisted) and surgical simulators.

The main limitation of this study is the small number of participants enrolled in the various groups, and the uneven distribution of subjects within each group. Additionally, not all of them were able to participate in both sessions of the study. Although time between session at da Vinci Skills Simulator and the second at da Vinci robot ranged greatly from 17 to 72 days because of availability of participants, we found no correlation on time to execute the suture and OC_HRA score. This may suggest that time between VR simulation and dry-lab session had no influence on performances with da Vinci robot in a task on inanimate model. Larger studies are needed to investigate this aspect.

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Conflicts of interest

Dr. Franca Melfi is Official Proctor at the Multidisciplinary Center of Robotic Surgery at Cisanello Teaching Hospital.

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Table 1: Demographic data of participants

Group	Age (years)	Experience in Videogames (years)	Experience in Surgery (years)	Number of Interventions
Medical students (n=11)	25.7 ± 2.4	5.5 ± 7.5	–	–
Residents (n=17)	28.5 ± 2.1	3.8 ± 6.1	–	–
Attending surgeons (n=9)	42.7 ± 8.0	5.5 ± 8.6	11.8 ± 7.6	1638.9 ± 1616.4

Table 2: Scores at the da Vinci Skills Simulator: data expressed as mean and standard deviation for the tasks with normal distribution. One way ANOVA test used for analysis on significant difference.

	Medical students (n=11)	**Residents (n=17)**	**Attending surgeons (n=9)**	**p**
Pick and place	84.0 ± 5.6	80.1 ± 6.6	79.7 ± 7.3	0.236
Peg board 1	50.9 ± 15.3	55.2 ± 13.5	54.0 ± 13.3	0.728
Peg board 2	63.3 ± 14.5	61.8 ± 18.4	57.7 ± 10.9	0.720
Camera targeting 1	43.9 ± 20.8	40.1 ± 24.1	42.0 ± 21.0	0.909
Camera targeting 2	32.4 ± 14.3	38.0 ± 15.9	31.7 ± 12.7	0.471
Scaling	29.8 ± 8.5	40.3 ± 15.8	41.5 ± 14.1	0.097
Ring walk 2	31.0 ± 18.2	31.9 ± 18.9	21.9 ± 17.0	0.391
Match board 1	54.4 ± 11.7	47.0 ± 13.4	49.4 ± 11.6	0.322
Match board 2*	1.55 ± 0.05	1.59 ± 0.02	1.59 ± 0.04	0.624
Ring and rail 2*	1.40 ± 0.09	1.41 ± 0.04	1.28 ±0.09	0.388
Energy switching 1	43.8 ± 17.4	43.0 ± 20.6	47.1 ± 15.4	0.863
Energy dissection 1	49.2 ± 18.0	52.4 ± 18.9	51.5 ± 17.8	0.901
Energy dissection 2*	0.97 ± 0.15	1.28 ± 0.11	1.29 ± 0.08	0.171
Needle targeting	55.0 ± 29.4	49.2 ± 24.6	58.9 ± 15.7	0.612
Thread the rings	42.8 ± 26.4	45.7 ± 20.0	46.9 ± 18.8	0.908
Suture sponge 1	32.1 ± 16.6	46.9 ± 13.4	31.8 ± 18.0	0.023

Suture sponge 2	35.4 ± 14.4	42.0 ± 16.6	38.4 ± 12.5	0.525
Suture sponge 3	32.4 ± 17.0	34.2 ± 17.4	29.2 ± 21.6	0.805
Dots and needles 1	44.8 ± 16.5	44.8 ± 21.8	40.8 ± 18.9	0.867
Dots and needles 2	36.8 ± 20.6	38.1 ± 16.1	28.0 ± 16.0	0.365
Tubes	45.2 ± 16.7	44.4 ± 12.1	44.3 ± 21.3	0.990

*Data converted into normal distribution by using logarithmic transformation.

Table 3: Scores at the da Vinci Skills Simulator: data expressed as median (IQ1, IQ3) for the tasks with non-normal distribution. Kruskal-Wallis test used for analysis on significant difference.

	Medical students (n=11)	**Residents (n=17)**	**Attending surgeons (n=9)**	**p**
Ring walk 1	79 (67, 82,5)	74 (66, 81)	74 (54, 82)	0.675
Ring walk 3	3 (1, 7)	1 (0, 7)	2 (0, 6)	0.741
Match board 3	17 (15.5, 18.5)	17 (14, 30)	24 (21, 32)	0.105
Ring and rail 1	80 (56.5, 86)	76 (59, 87)	51 (41, 85)	0.621
Energy switching 2	70 (49, 72)	57 (33, 66)	60 (46, 62)	0.510

Table 4: Time of execution and score using OCHRA of suture task: data expressed as median (IQ1, IQ3). Kruskal-Wallis test used for analysis on significant difference.

	Medical students (n=11)	**Residents (n=17)**	**Attending surgeons (n=9)**	**p**
Time	725 (649, 862.5)	601 (400.75, 666.25)	682 (515.75, 867.75)	0.188
OCHRA (1=poor, 10= excellent)	5 (3.5, 9)	7 (4, 10)	6.5 (4.5, 10)	0.736

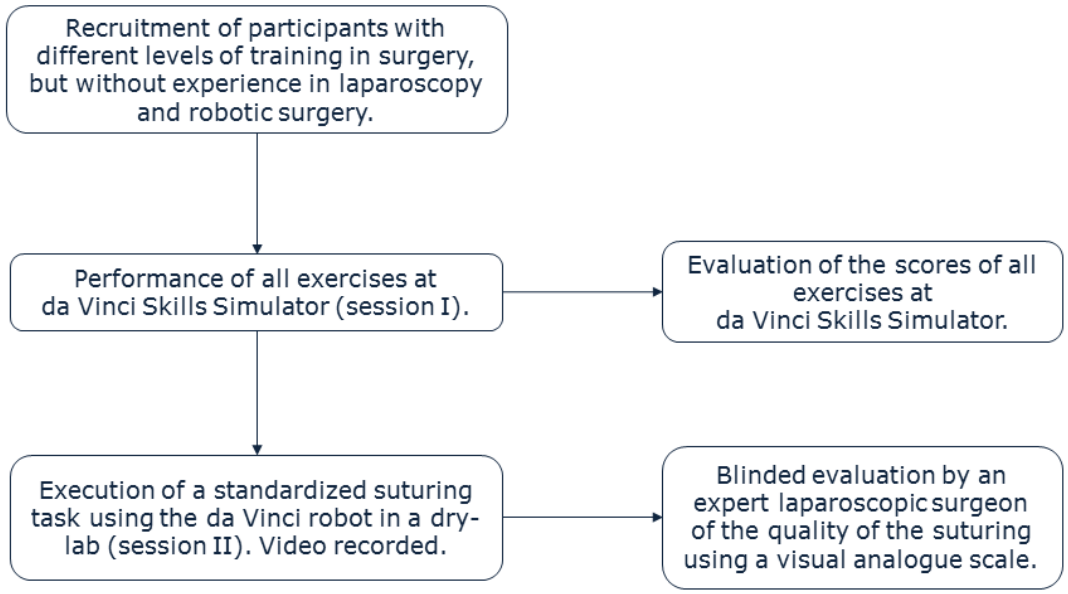

Figure 1. Study design.

Figure 2: Standardized suturing task with the da Vinci robot on silicone sample.