REVIEW ARTICLE

Systematic Review of Laparoscopic Surgery and Simulation-based Training

[1]Juan U González-Tova, [2]Pallikonda S Madhulika

ABSTRACT

Introduction: We performed a systematic review to analyze the effect and to describe all available simulation-based training as well as the securing of laparoscopic surgery aptitudes during residency programs.

Materials and methods: This systematic review aimed to examine the effectiveness of simulation-based training to develop laparoscopic surgery skills using the published randomized controlled trials (RCTs) Searching in PubMed from 2014 till now. This review of the literature tends to the subject of whether laparoscopic recreation deciphers the gain of surgical abilities to the operation room (OR).

Results: According to this review, we found that specific learned skills could be reproduced in the OR. Reenactment-based preparing and laparoscopic surgery found that particular abilities could be translatable to the OR. Twenty one investigations revealed learning results measured in five behavioral classifications: Economy of development (8 ponders); suturing (3 examines); execution time (13 considers); mistake rates (7 thinks about); and worldwide rating (7 contemplates).

Conclusion: Simulation-based training can help to obtain obvious advantages of surgical aptitudes in the OR. This review proposes that simulation-based training is a successful approach to instruct laparoscopic surgery abilities, increasing reproduction of laparoscopic surgery aptitudes to the OR, and increment safety for patients. Nevertheless, more research ought to be directed to decide whether and how this training can become a part of surgical curriculum.

Keywords: Laparoscopic training, Simulation, Surgical skills.

INTRODUCTION

Laparoscopic approach has turned into a "gold standard" for a lot of common surgical procedures, e.g., cholecystectomies and appendectomies,[1] and is associated

[1]Professor, [2]Assistant Professor

[1]Department of Urology, Hospital Universitari de Vic, Barcelona Spain

[2]Department of General Surgery, Shri Sathya Sai Medical College and Research Institute, Chennai, Tamil Nadu, India

Corresponding Author: Juan U González-Tova, Professor Department of Urology, Hospital Universitari de Vic, Barcelona Spain, e-mail: Juan.uriagt@gmail.com

with less surgical trauma, faster postoperative recovery, shorter hospital stays, and better cosmetic results.[2] There is a common agreement that simulation-based training enhances information and formation[3] and that preparation outside the working room (OR) diminishes the danger of unfavorable surgical events.[4]

As the surgeon community establishes and keeps up new instructing strategies to prepare capable specialists, learning ways that exist outside the OR are turning into a prescribed strategy for creating laparoscopic surgery abilities.[5,6] Preparing outside the OR lessens the danger of unfavorable surgical events.[4,5,7] Simulation-based surgical aptitudes and methods enable unpracticed specialists to secure abilities through repetitive practice in a safe, nonthreatening condition, preceding experiencing the hazard and time pressures intrinsic in the OR.[8] Those in charge of planning training centers work with restricted proof to determine complex inquiries identifying with training, interpretation of abilities learned, and safety concerns about learning laparoscopic surgery.

Supervision by an expert during laparoscopic colorectal surgery aims at similar results among learners, according to a systematic review in 2006.[9] In an alternate review, investigators revealed that simulation training may not be a superior strategy than patients, corpses, and creatures for instructing surgical abilities,[9] yet the aptitudes learned by simulation-based preparation gave off an impression of being transferable to the OR. This review was restricted to 11 distributed investigations and was led in 2008.[10]

One study found that virtual reality training can supplement laparoscopic surgery training,[11] yet fluctuation crosswise over research outlines and clashing discoveries in the published results kept the affirmation of clear best procedures. Cook et al[12] considered technology-enhanced simulation training and reasoned that simulation training is related with vast impacts on clinician practices and mild consequences for patient care.

This systematic review aims to analyze the topic of whether laparoscopic simulation deciphers the gain of surgical aptitudes to the OR. The scope of this document is centered around the significance and pertinence identified with the gaining of surgical aptitudes, the interpretation of surgical abilities obtained outside of the OR, and enhancements concentrated on well-being for patients. A

review of available articles was completed to depict the effect of simulation-based training in light of the securing of laparoscopic surgery aptitudes and the reproducibility of these abilities to the OR. Training skills were surveyed for execution time; worldwide rating; suturing, cutting, and searing abilities; mistakes; and ergonomy.

MATERIALS AND METHODS

This systematic review aims to analyze the topic of whether laparoscopic simulation deciphers the gain of surgical aptitudes to the OR. The studies were recognized via seeking PubMed from the initiation of the database to December 2016 and Specific search: Simulation in Health Care, Annals of Surgery, Journal American Surgery, International Journal of Surgery, Surgery, Archives of Surgery, and The British Journal of Surgery from 2000 to December 2016. Different mixes of a few pertinent watchwords were utilized to recognize articles for audit (haptic or simulation or simulation education or simulation medicine or laparoscopic simulation or simulation training or translation and laparoscopic surgery).

Inclusion criteria required for inclusion in the review are of as follows:

• Utilization of a randomized controlled plan that incorporates at least one intervention group and one control group that either got no training or traditional training in the OR;
• Single-bunch pretest–posttest;
• Two group nonrandomized;
• Parallel group;
• Crossover designs;
• Utilize simulation-based training as the instructive intercession for showing laparoscopic surgery abilities;
• Interpretation of aptitudes was measured in the OR setting.

Simulation-based training was characterized extensively to incorporate gear that imitated the required conditions with adequate authenticity to fill in as training instrument. Cases of the test systems incorporated into this study were box trainers, PC programming, virtual reality systems, undertaking mentors, and high loyalty and static mannequins.

The exclusion criteria were:

• Articles that did not utilize simulation as the instructive mediation for learning laparoscopic surgery abilities.
• Interpretation of aptitudes was not measured in the OR setting.

A scope based on PRISMA[13] and Cochrane handbook[14] was utilized to survey the writing. The primary writer autonomously coded each of the articles found through the research. While checking on the results, a few abstracts gave enough detail and data identified with the strategies to decide whether the incorporation criteria were met; if not, the full composition was perused to decide whether the techniques met the consideration criteria. The original copies were dispensed with in light of the fact that the strategies did not meet the consideration criteria.

RESULTS

The outcomes detailed in this segment depend on the 20 articles that we decided met our inclusion criteria. A total of 21 studies were examined. All posttraining evaluations were translational to either a Porcine model or the OR, 9 (43%) led the posttest in a Porcine model, 12 (57%) led the posttest in the OR with patients.

In Table 1, we describe the types of simulators implemented in the 21 studies, manufacturers for the simulators, descriptions for the simulators, and performance skills the simulators provide. A total of 21 studies were assessed/reviewed; the specific simulators, members, assessments, and details of the 21 studies are provided in Tables 2 and 3.

Performance Time (n = 13 studies)

Performance time[1,5,7,8,15-22] was accounted for as the measure of time taken to play out the laparoscopic procedure at the posttest assessment. Of the 21 studies that surveyed whether the training intercession brought about the change of execution time, 13 (62%) investigations announced factually statistically significant improvement. For instance, in one study scientists announced that the control group took 58% longer to play out the surgery[23] and in another study specialists detailed that the control group, all things considered, played out the surgery twice the length of the intervention group (24 minutes when contrasted with 12 minutes, $p < 0.001$).[24] In yet another investigation the intervention group was 29% quicker in dismembering the gallbladder during a cholecystectomy than the control one.[24] Then again, two investigations[1,15] detailed no noteworthy changes in time between the intervention and control groups when execution time was measured.

Global Ratings (n = 7 studies)

Lobal appraisals were led utilizing the Objective Structured Assessment of Technical Skill (OSATS) rating scale.[6,7,17,25-29] The OSATS assessment tool assesses members on regard for tissue dissection, time and movement, instrument ergonomy, information of instruments, stream of operation, utilization of collaborator, and learning of methodology. GOALS rating scale[30]

Table 1: Laparoscopic training tools, definitions, and manufacturers

Type of simulation	Definition	Manufacturer
Box trainer Task trainer	A box that incorporates conventional laparoscopic equipment to perform basic skills, is versatile, and enables training on animal parts as well as synthetic inanimate models. A partial component of a simulator or simulation modality, for example, an arm, leg, or torso	Simulab Corporation Limbs and Things
MIST-VR	A virtual reality simulator with six different tasks to simulate maneuvers performed during laparoscopic cholecystectomy in a computerized environment	Mentice AB
LapMentor/LapMentor II	A virtual reality simulator consisting of a camera and two calibrated working instruments for which the motion of the instruments is translated to a two-dimensional computer screen for student practices	Simbionix Ltd.
LapSim	A computer-based simulator creating a virtual laparoscopic setting through a computer operating system, a video monitor, a laparoscopic interface containing two pistol-grip instruments, and a diathermy pedal without haptic feedback	Surgical Science
EndoTower	EndoTower software consists of an angled telescope simulator composed of rotating camera and telescopic components	Verefi Technologies, Inc.
MISTELS/FLS trainer	McGill Inanimate System for Training and Evaluation of Laparoscopic Skills—this inexpensive, portable, and flexible system allows students to practice in a virtual Endotrainer box	SAGES
SIMENDO VR	Computer software used to train eye–hand coordination skills by camera navigation and basic drills	Delta Tech
URO Mentor	A hybrid simulator consisting of a personal computer-based system linked to a mannequin with real endoscopes. Cytoscopic and ureteroscopic procedures are performed using either flexible or semirigid endoscopes	Simbionix Ltd.
Da Vinci Skills Simulator	A portable simulator containing a variety of exercises and scenarios specifically designed to give users the opportunity to improve their proficiency with surgical controls	Intuitive Surgical

measures execution in five spaces: Three of the areas are particular to laparoscopic surgery (e.g., depth perception, bimanual skill, and tissue dissection) and two of the spaces are bland (e.g., efficiency and autonomy). The standard Fundamentals of Laparoscopic Surgery (FLS) measurements[16] are the essential psychomotor abilities fundamental before figuring out how to perform and build up a laparoscopic surgical case. An alternate report revealed that global evaluation scores expanded and their standard deviation diminished in the intervention group when contrasted with the nonprepared group (p = 0.004).[25] Also, in the same article, 100% of intervention members achieved the passing score level whereas it was just 37.5% of the control group. Researchers did not locate any statistical significance between the two groups; nonetheless, the members with low benchmark execution expanded their scores altogether after simulation training.[31]

Suturing, Cutting, and Cautery Skills (n = 3 studies)

Three (14%) of the 21 examines detailed huge change on suturing, cutting, and cautering abilities[8,23,24] in the training group when contrasted with the control group. Researchers assessed that the trained members beat the control members in the execution of safe electrocautery (p < 0.01).[8]

Mistakes (n = 7 studies)

Seven (33%) of the investigations evaluate whether simulation-based training brought about a lessening in errors.[5,6,18,19,21,22,32] These were accounted for as clipping errors, dissection errors, tissue damage, incorrect plane for dissection, lack of progress, and instrument out of view. Each one of the seven investigations looked into articles for detailed statistical discoveries that the intervention diminished and the number of errors that happened. For instance, the intervention group made altogether less mistakes identified with tissue division (p = 0.008) and dissection (p = 0.03) with the control group creating three-fold the number of blunders.[23]

Ergonomics (n = 8 studies)

Eight of the examinations surveyed found that simulation-based training brought about an expansion in the ergonomics.[1,7,8,15,23,25,28,33] It was accounted for as camera navigation, efficiency of instrument, total path length, number of movements, navigation, and bimanual dexterity. The eight investigations (38%) revealed statistical significances that the intervention expanded the ergonomics. In particular, training was essentially identified with path length (p < 0.001) and aggregate number of developments (p = 0.009).[7] Interestingly, agents found no distinction in ergonomics between the control and intervention groups (p = 0.40).[1] In two distinct studies, specialists found that

Table 2: Study participants, prestudy data, simulation, features of training procedures, and assessment

Citation	Participants	Prestudy data collected	Simulation intervention	Additional training	Time between initial assessment and final assessment	Training time	Training tasks
Aggarwal et al[7]	19 novice surgeons	None	LapSim VR	None	Not specified Final assessment conducted over 4 weeks	Not specified	7 basic tasks; 3 levels of difficulty Skills for: Instrument navigation—Grasping Tissues—Clip
Ahlberg et al[5]	29 fourth-year medical students	None	MIST-VR	None	Not specified	3 hours	Six tasks simulate the maneuvers performed during a laparoscopic cholecystectomy
Andreatta et al[8]	19 surgical interns: (1) 10 in the training group, (2) 9 in the control group	Computer game experience	Simbionix LapMentor	None	Four weeks duration is not specified	At least 10 repetitions were performed in order to reach proficiency by trainees	30° camera navigation; eye–hand coordination; clipping and grasping; cutting; electrocautery; translocation of objects
Ahlberg et al[23]	13 surgical residents	Mental rotation, cognitive tests, verbal working memory, attitude toward simulator	LapSim	None	The first surgery performed within 2 weeks of baseline measurement. The last surgery performed within 6 months of the start	Maximum of 40 hours in 1 week	Grasping, lift grasp, cutting right, cutting left, clip application
Banks et al[35]	20 postgraduate year (PGY)1 residents	Laparoscopic experience	Task Trainer Laparoscopic BTL	None	4 months	Not specified, estimated to be approximately 4 hours	1 hour of didactics; 2 hours of hands-on teaching in the skills lab with three stations: (1) Suturing pig's feet; (2) knot tying board; (3) a lap simulator and an operative lap tower
Bennett et al[1]	70 medical students	Laparoscopic experience Interest in surgical specialty Angled laparoscope	Box trainer	None	6 weeks	10 minutes	Tutorial on camera simulator navigation
Gala et al[15]	44 residents (PGY1 and 2); 66 (PGY 3 and 4)	Baseline data laparoscopic Pomeroy Bilateral tubal ligation	Psychomotor board testing with a peg board test	Two times till mastery accomplished on all 5 validated laparoscopic simulators	Not reported	30 minutes with faculty member	Clipping, grasping, lifting, time, peg transfer, pattern cutting
Ganai et al[20]	19 third-year medical students: (1) 9 training group, (2) 10 control group	Laparoscopic cases observed or participated in were measured between baseline and performance	Endo Tower	None	3–4 weeks	1-hour sessions. Limit of 10 sessions per difficulty level (3 levels). Had to train to proficiency	Navigation around a complex geometric structure to achieve specific view of target objects

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Citation	Participants	Prestudy data collected	Simulation intervention	Additional training	Time between initial assessment and final assessment	Training time	Training tasks
Grantcharov et al[17]	16 surgical residents with limited laparoscopic experience	None	MIST-VR	None	14 days	3 hours	Task 1: Virtual sphere to box transfer; Task 2: Hand to hand transfer Task 3: Grasping the segments of virtual pipe Task 4: Grasp virtual sphere, touch tip of other instrument, withdraw and reinsert, and touch sphere again. Task 5: Virtual sphere was grasped, three plates appear on the surface of sphere, these are then touched by the other instruments Task 6: Combines actions of 4 and 5 with diathermy of the plates while holding the sphere
Hogle et al[25]	Study 1: (1) 6 trained; (2) 6 control Study 3: 10 trained; 11 control	Study 1 and 3: None	Study 1 and 3: LapSim	Study 1 and 3: None	Study 1: 1 month Study 3: 5 weeks	Study 1 and 3: None specified	Camera navigation, instrument navigation, coordination, grasping, lifting and grasping, cutting, clip applying
Hung et al[31]	24 robotic surgery trainees	Completed fewer than 10 robotic cases	Vinci Si	None	5 weeks	45 minutes	Run bowl and cut on circumferentially inked line on bowl Cut 2.5 cm inked line on anterior surface of bladder and water tight repair Resect Styrofoam tumor with a clean margin of renal parenchyma
Korndorffer et al[32]	17 surgical residents PGY1–5	Demographic video game ability	MISTELS	None	8 weeks	8 hours (8 weeks during 1-hour weekly sessions)	Trainees trained on suturing
Larsen et al[16]	21 first and second year students specializing in obstetrics/gynecology	None	LapSim Gyn	None	Unclear	7 hours and 15 minutes	Trained on "lifting and grasping" and "cutting" and performed salpingectomy sparing ovary 0 and 30° camera manipulation, hand–eye coordination, clipping, grasping and clipping, two-handed maneuvers, cutting, fulguration, and object translocation
Seymour et al[26]	16 PGY1–4 surgical residents Psychomotor ability tests	Visuospatial, perceptual	MIST-VR	Video demonstrating optimal procedure performance	No initial assessment other than ability tests	1 hour	Manipulate and diathermy task

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Citation	Participants	Prestudy data collected	Simulation intervention	Additional training	Time between initial assessment and final assessment	Training time	Training tasks
Stefanidis et al[21]	32 medical students: (1) 6 control group, (2) 13 trained group, (3) 13 trained group plus environment al and more complex	Demographic data Simulator experience Laparoscopic experience- NASA TLX work load	FLS video trainer model	Assessed on the trainer for retention before being assessed for transfer on Porcine model	Retention and transfer tests conducted on same day Average time between baseline and completion of training was 8.4 days	For group II average training time was 239 minutes For group III average training time was 329 minutes	Group II a: Trained to proficiency in lap suturing on an FLS video trainer model Group III: Trained until proficiency Perform the task in a constrained space Had to listen to OR noise through headphones Had to practice with shorter suture Had to start with a dropped whose tip was facing away from the FLS model These four conditions were introduced gradually
Stefanidis et al[22]	15 Novices	Demographics: Experience with surgery and simulators	Simulator	None	Not specified (approximately from 4–5)	Average training was 4.7 hours (1.2 SD) 41 reps (10 SD) Lasted 6 days (4 SD)	Laparoscopic suturing was assessed
Sroka et al[27]	16 Surgical residents (PGY1–3) with no prior fundamentals of laparoscopic surgery training: (1) 8 trained, (2) 8 control	None	MISTELS -Box Trainer	None	Mean time between pre and posttraining evaluations was 145 days	Average time training on the simulator was 450 minutes.	Peg transfer Circle cut Placement of a ligating loop Simple suture tied with extra and intracorporeal techniques
Van Sickle et al[24]	22 senior surgical residents (PGY3–6): (1) 11 control group, (2) 11 trained group (simulation and box trainer)	Demographic: Perceptual ability Previous laparoscopic surgery experience	MIST-VR -Box trainer	None	Not specified	Not specified	Suturing on the VR trainer and box trainer -Knot tying on the box trainer
Verdaasdonk et al[6]	19 surgical trainees (1st and 2nd year): (1) 10 control group, (2) 9 training group	None	SIMENDO VR simulator	None	1 week	Not specified	Double surgical knot tying
Zendejas et al[28]	50 PGY1–5: (1) 26 trained group, (2) 24 control group	Demographics: Video game ability	Guildford MATTU TEP task trainer	None	Approximately 10 days	Unclear	Trainees reduced the hernia sacs of right-sided indirect and femoral hernias and to position and tack a piece of 3.5 inches × 5 inches polypropylene mesh over the myopectineal orifice covering all potential right-sided hernia defects

SD: Standard deviation

Table 3: Published reference, context of final assessment, source of assessment, skills assessed posttraining, and results from studies

Citation	Contextual setting for final assessment	Source of final assessment ratings	Skills assessed posttraining	Results from research studies
Aggarwal et al[7]	Porcine model (pre on box trainer)	Two observers (OSATS global rating and a motion tracking device)	Change in operative performance: (1) Time taken; (2) total path length; (3) total number of movements The OSATS global rating scale	Trained group performed significantly better on time (p = 0.038), total path length (p = 0.001), total number of movements (p = 0.009), and overall rating scores (p = 0.001) Trained group demonstrated dexterity scores equivalent to expert levels
Ahlberg et al[5]	Porcine model			The performance with MIST-VR correlated with surgery skills. MIST-VR did not improve surgical skills. MIST-VR did predict surgical outcomes
Ahlberg et al[23]	Patients in OR (pre on a simulator)	Two observers (reliability greater 0.98)	Exposure errors, clipping and tissue division errors, and dissection errors Performance was broken up into phases: (1) Exposure of the cystic duct and artery; (2) clip placement followed by division of the cystic duct and artery; (3) gallbladder excision: Total time, path length, angular path, tissue damage, and max damage	Intervention group made significantly fewer errors The trained group made significantly fewer objectively assessed, intraoperative errors during the exposure portion of the procedure (p < 0.04), clipping and tissue division (p < 0.008), and dissection (p < 0.03). The control group made three times as many errors and used 58% longer surgical time
Andreatta et al[8]	Porcine model	Two surgeons (0.99 reliability)	30° Camera navigation: (1) Time, (2) Accuracy, (3) Efficiency of motion, 4) Instrumentation use eye–hand coordination: Two handed transfer of ski needle: (1) Time, (2) Efficiency of motion, (3) Instrument handling Eye–hand coordination: 0° camera navigation and one handed object transfer: (1) Time, (2) Accuracy, (3) 0° camera navigation skills, (4) Perceptual ability safe, placement of clips, and application of electrocautery (1) Clipping, (2) Electrocautery performance	Intervention group outperformed the control group in: Camera navigation skills (p < 0.05), efficiency of motion (p < 0.001), optimal instrument handling (p < 0.001), perceptual ability (p < 0.001), and performance of safe electrocautery (p < 0.01) Time and accuracy ratings on 30° navigation (p < 0.05), and eye–hand coordination two-handed transfer of ski needle (p < 0.001) was better in the trained group. Prior training with LapMentor leads to improved resident performance of basic skills in the animate OR
Banks et al[35]	Patients in OR (post only. Preassessment was done on simulator and then the training group performed on the simulator again before being evaluated in the OR)	Observers	Task-specific checklist: assessed 4 categories of skills: (1) Preoperative skills, (2) surgical technique, (3) laparoscopic technique, (4) laparoscopic BTL-specific skills Global rating scale: (1) Respires for tissue, (2) time and motion, (3) instrumental handling, (4) knowledge of instruments, (5) flow of operation, (6) use of assistants, (7) knowledge of the specific procedure – Pass/fail	Intervention group performed significantly better than control group on all three surgical assessment tools (p = 0.002, checklist; p = 0.003, global score; p = 0.003, pass rate; p = 0.003, posttest) and scored significantly better on the knowledge posttest (p = 0.009)
Bennett et al[1]	Patients in OR (post only)	Observers	Identification of all four target numbers and the ability to maintain correct orientation of the camera at each target and to properly position the post at each target for a maximum total score of 12 points Max time was 120 seconds	No difference in learning between groups (p = 0.40)
Gala et al[15]	Patients in OR	Observers	Time Competence levels of participants pre and post intervention Technical skills for both groups	Time the intervention group improved significantly higher (p < 0.01) Intervention group was significantly higher with competence levels (p < 0.01) The intervention group also had higher technical skills in the operating room (p < 0.03)

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Citation	Contextual setting for final assessment	Source of final assessment ratings	Skills assessed posttraining	Results from research studies
Ganai et al[20]	Porcine model (pre and post)	3 External observers (90%) and from Endo Tower simulator	12 structured scope navigation tasks in three phases: (1) Navigation within the peritoneal cavity, (2) Navigation around the retracted gallbladder, (3) Navigation around a suspended small intestinal loop	Intervention group was significantly better in object visualization (p < 0.05), scope orientation (p < 0.05), and horizon errors (p < 0.05)
Grantcharov et al[17]	Patients in OR	2 Senior surgeons rated 1 surgery (Cohen's kappa 0.71)	Economy of movement: (1) Unnecessary movements, (2) Confidence of movements Errors: (1) Respect for tissue, (2) Precision of operative technique	Intervention group showed greater improvement in error (p = 0.003) and economy of movement (p = 0.003) Intervention group was significantly faster than the control group when performing cholecystectomy (p = 0.021)
Hogle et al[25]	Study 1: OR patients Study 3: Porcine model (pre and post)	Study 1: Attending surgeon Study 3: Observer	Study 1 and 3: GOALS rating: (1) Depth perception, (2) Bimanual dexterity, (3) Efficiency, (4) Tissue handling and autonomy	Study 1 and 3: No significant differences were found between groups
Hung et al[31]	Porcine model	Three expert robotic surgeons blinded	GOALS: (1) Depth perception, (2) Bimanual dexterity, (3) Efficiency, (4) Tissue handling, (5) Participant autonomy to accomplish task	Groups I and II were comparable in prestudy surgical experience and had similar baseline scores on simulator and tissue exercises (p > 0.05) Overall baseline simulator performance significantly correlated with baseline and final tissue performance (p < 0.0001) Simulator training significantly improved tissue performance on key metrics for group I subjects with lower baseline tissue scores than their group II counterparts (p < 0.05) Group I tended to outperform group II on final tissue performance, although the difference was not significant
Korndorffer et al[32]	Porcine model (pre and post)	Observers	Time, accuracy errors, knot security	The training group and the control group demonstrated significant improvement in completion time, and overall score. The training group also demonstrated significant improvement in accuracy errors. The trained group performed significantly better in completion time and overall score when comparing posttest scores to the control group. Intervention group performed significantly better than control group
Larsen et al[16]	Patients in OR (post only, pre was on a VR simulator)	Observers	Primary outcome measure: (1) technical performance using the objective structured assessment of laparoscopic salpingectomy; (2) 5-item general rating scale and five-item task-specific rating scale. Time	Intervention group gained experience equivalent to 20–50 procedures The median score on general and task-specific scale reached 33 points for the trained group and 23 in the control group (p < 0.001) The median score for time was 12 minutes for the trained group and 24 minutes for the control group (p < 0.001)
Seymour et al[26]	Patients in OR (post only, pre was only ability tests)	Observers	Operative errors: (1) Lack of progress, (2) gallbladder injury, (3) liver injury, (4) incorrect plan of dissection, (5) burn nontarget tissue, (6) tearing tissue, (7) instrument out of view, (8) attending takeover	Intervention group was faster for gallbladder dissection (29% faster), and control group was more likely to fail to make progress (Z ≅ 2.677, p < 0.008) and more likely to injure the gallbladder or burn nontarget tissue (5 times more likely, chi-square = 4.27, p < 0.039) The mean number of scored errors per procedure was significantly greater in the control group than the trained group (p = −2.76, p < 0.006)
Stefanidis et al[21]	Porcine model (pre and post)	Objective scores based on time and errors using a published formula	Time errors	Intervention group performed substantially better than control group (p < 0.001) Proficiency-based simulator training results in improved operative performance

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Citation	Contextual setting for final assessment	Source of final assessment ratings	Skills assessed posttraining	Results from research studies
Stefanidis et al[22]	Porcine model (pre and post). A posttest was taken right after training was done, and then a retention test was taken after 5 months	Observers	Errors time	Intervention group outperformed control group (p < 0.001) Proficiency-based simulator training results in durable improvement in operative skill of trainees even in the absence of practice for 5 months
Sroka et al[27]	MISTELS and Box Trainer on patients in the OR	Attending surgeon or external evaluator	FLS ratings and GOALS ratings: (1) Depth perception, (2) Bimanual dexterity, (3) Tissue handling, (4) Efficiency, (5) Autonomy	FLS scores: Scores increased and SD decreased in the trained group as compared with the nontrained group (p = 0.004). At baseline no participant had reached the required FLS scores. Posttraining 100% of the trained group reached required scores and 37.5% of the nontrained reached required passing scores GOALS scores: The trained group improved significantly and clinically by a mean of 6.1 ± 1.3 (p = 0.0005 vs control, and p < 0.0001 vs baseline). Gender was examined as a covariate and results remained the same; trained group scores were significantly better than the control group (p = 0.001). Of the five individual domains evaluated by the GOALS rating structure, greater improvements were shown in the specific domains than the generic domains for the trained group (bimanual dexterity, p = 0.04; depth perception, p = 0.08; tissue handling, p = 0.04)
Van Sickle et al[24]	Patients in OR (post only)	2 surgeons (agreement > 0.80)	Suturing operative errors	Intervention group performed significantly faster (p < 0.003), made fewer errors (p < 0.01), and fewer excess needle manipulation (p < 0.05)
Verdaasdonk et al[6]	Porcine model (post only)	Two expert laparoscopic surgeons	Observer rated error assessments Global ratings of knot tying economy of movements Error assessments	Intervention group tied knots faster (30%, p = 0.034) and made fewer errors (33%) as compared with control group. Experimental group dropped the needle fewer times and made less frequent unnecessary contact with the tip of the needle against the tissue than the control group (p < 0.05). No significant differences in the scores assigned to the groups by the two experts (economy of movement p = 0.114; error assessment p = 0.148)
Zendejas et al[28]	OR (pre and post)	Observers and medical records	Operative performance by using a global rating using: (1) GOALS, (2) operating time, (3) proportion of procedure performed by the trainee, (4) need for overnight stay, (5) recurrence of inguinal hernia and chronic groin pain and complications	The trained group were on average 6.5 minutes faster than the control group (p < 0.0001) Resident participation was also different between the groups with the trained group performing more of the procedure than the control group (88 vs 73%) After correcting time to account for varying participation rates, the trained group performed the procedure 13.1 minutes faster The trained group had higher performance scores than the trained group (p = 0.001) Intraoperative and postoperative complicates and overnight stay were less likely in the trained group than the control group p < 0.05 When follow-ups with patients were conducted the number of patients who experienced a hernia recurrence or were evaluated for groin pain at least 3 months post repair there was no difference between the groups

the control bunches did not demonstrate significant differences contrasted with the intervention group as identified with ergonomics.[1]

DISCUSSION

This review of available laparoscopic publications and interpretation of aptitudes outlines the proof for the simulation-based training studies and learning surgical skills in a safe way for residents to be reproducible on patients in the OR. Those in charge of instructing and surveying surgical execution ought to consider ramifications of these discoveries in three noteworthy areas: (1) Training for capability or enhanced aptitudes honed in a controlled setting, (2) interpretation of new information into execution outside the reenacted setting, and (3) well-being and safety for patients. Laparoscopic surgery educational module might be altered or supplemented with the usage simulation-based training. Recreation can prompt enhanced evaluation, enhanced preparing, blunder diminishment, and the improvement of specialized abilities in laparoscopic surgery important to work on genuine patients.[24] Participants in the intervention group made less mistakes and were less inclined to harm the gallbladder or to burn nontarget tissue on genuine patients.[24] Simulation-based training allows for repeated practice of standardized tasks under reproducible conditions and enables the use of objective measures for assessment purposes[27] and students' feedback. Simulation-based training modules can possibly abbreviate the learning time for laparoscopic strategies contrasted with customary showing techniques in laparoscopic surgery.[26] Surgeons in training who got simulation-based educational modules essentially beat surgeons who got the standard educational programs on knot tying.[28] Moreover, surgical residents who had simulation-based training played out the suturing errand quicker, made less mistakes, and were more productive in handling the suture.[28] In general, surgeons who got simulation-based aptitudes exhibited speedier accomplishment of those abilities than their associates from the control group in a high-stakes condition.[17] Training educational programs identified with laparoscopic surgery aptitudes consider all the more learning open doors for junior specialists to hone with simulation-based training before entering OR condition; along these lines, taking into account the capability of abilities converting into the OR.

At long last, the studies in this review demonstrate that simulation-based training ought to be fused into surgical educational program particularly focusing on novel surgeons. By and large, simulation-based training programs are offered as a supplement to conventional surgical preparing and are voluntary.[34] At present, there is no standard or all-inclusive particular surgical educational program setup in surgical instructive projects; be that as it may, there has been a current change. The Fundamentals of Endoscopic Surgery was endorsed in March 2014 as an extra necessity for residents graduating in 2018 and after this is a simulation-based training program.

Additionally, inquiries about this are expected to decide the best longitudinal educational programs for fundamental and propelled abilities' procurement and exchange to the OR condition. Simulation-based training takes into account the beginner to take in the psychomotor aptitudes and spatial judgments essential for laparoscopic surgical abilities, enabling them to concentrate more on learning agent methodologies and taking care of intraoperative inconveniences while in the OR.[33] Preparing in capability-based abilities ought to be joined into an extensive surgical preparing and appraisal educational program for residents preceding working on genuine patients.[35] The strain to make surgical preparing more productive and more secure for patients is generous, and simulation-based training can possibly enhance surgical educational module.[18]

Translational effect was accomplished in the OR with live patients when simulation-based training was utilized for the instructive intercession. Researchers found that preparation in a reenacted domain prompted enhanced surgical execution on either animals or people.[5,6,18,23,24,26,28,35,36] Simulation-based training impacts the interpretation of laparoscopic surgery abilities to the OR. Because of these discoveries, simulation-based training can possibly give the foundational abilities important to future specialists to learn in a controlled domain and make an interpretation of those obtained aptitudes to the OR. With increments in innovation and the requirement for a standard surgical educational program, there is potential with recreation as an instructive apparatus to facilitate the interpretation of laparoscopic surgical aptitudes into the OR. All the more particularly, run-of-the-mill aptitudes that convert into the OR are suturing, camera navigation, and the control and manipulation of equipment.

Simulation-based Training

Simulation-based training can possibly prompt an expansion in tolerant security. Trainers who prepared with reproduction had less mistakes than control group[19,24] while in the OR. Members in the intervention group had less occurrences of the administering specialist assuming control over the procedure. These sorts of occasions can essentially influence clinical results, since they speak of potential mistakes in procedure, trading off patient security.[23] Utilizing simulation for training surgical abilities can profit the bigger objective of enhanced patient well-being in a few ways. With reproduction, students

can rehash a system or even a particular component of a methodology until the point that competency is illustrated. Beginner specialists enter the OR more adept to create ideal patient results and are better arranged to take part in surgical cases with live patients in the OR in the event that they already prepared on a test system. Reproduction can likewise give more chances to healing preparing to lessen ability rot.[27] Laparoscopic surgical test systems give chances to prepare different ideas integral to tolerant security. For instance, collaboration abilities can be prepared through specialists interfacing with camera pilots or medical caretakers in a recreated OR. Mimicking laparoscopic surgical hardware and interfaces can even be utilized to present, test, and prepare new gear or conventions before they are executed in the OR, prompting recognizable proof of potential idle dangers to security and evasion of restorative mistakes because of poor human frameworks incorporations.

As with any writing review, our audit and results are constrained by the information given in the first examinations. Our discoveries are restricted by the absence of depictions of the information gathering procedure and intercessions of the included investigations. Specifically, it was hard to perceive a significant number of potential covariates that were utilized as a part of the information examinations and additionally the planning among pre-and posttests once the intercessions were actualized. Also, a larger part of the examinations that detailed factual outcomes revealed the outcomes utilizing p-values. The absence of impact estimate revealing adds to the trouble in really understanding the size of the impact of these mediations on the obtaining of surgical abilities. Another restriction to this investigation is that just a single database was utilized to recognize all writing, information, or concentrates identified with a particular point. Therefore, excluding conference presentations, gathering introductions, other online web indexes, and reaching associates inside the field to recognize any potential missing examinations that might not have been included. Moreover, not every surgical diary was hand looked, recently those distinguished by one creator as to be key surgery diaries inside the field. The extent of our review is both a quality and restriction. Confining our extension to just RCTs expanded the solidness of the discoveries announced in the first examinations. Nonetheless, it is impractical to make firm determinations about the viability of the distinctive sort of reenactment in light of our discoveries. The same number of RCTs did not lead similar investigations between changing sorts of reproductions. In any case, we contend that our audit provides helpful understanding into the writing that inspects the adequacy of *simulation-based* laparoscopic training mediations. The requirement for more powerful examinations of

these training mediations should have been ready to give an unequivocal conclusion to the effect on surgical skills.

Simulation-based training can prompt evident advantages of surgical abilities in the OR. These advantages incorporate diminished procedural mistakes and in addition different impacts on general patient security. This review proposes that simulation-based training is a successful approach to educate laparoscopic surgery aptitudes, increment interpretation of laparoscopic surgical abilities to the OR, and increment safety. Notwithstanding, more research ought to be led to decide whether and how simulation can turn out to be separated from the surgical educational modules.

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