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Research Article

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Augmented Reality and Its Role in Abdominal Laparoscopic Surgical Training

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Abstract

Background: Laparoscopic surgery requires a more complex skill set than open surgery. Shortened training times and patient safety concerns dictate that these skills be acquired and developed outside the operating room. Subsequently, Augmented Reality (AR) based applications are increasingly used to support surgical training.

Objectives: To evaluate the feasibility and efficacy of Augmented Reality simulation training for laparoscopic abdominal surgery.

Methods: PubMed, Embase, and OVID were searched for relevant articles published between April 2013 to April 2018. Of the total of 1,348 studies screened, three studies were ultimately included for meta-analysis.

Results: The meta-analysis demonstrated a net proportion pooled rate of 1.29% (95% CI=-0.75-3.33) for placement error and 1.93% (95% CI=-0.63-4.49) for task performance time. In placement error analysis, the sample sizes totaled 52 for Augmented Reality trainers and 51 for conventional trainers. For task performance time analysis, sample sizes were 60 for Augmented Reality trainers and 59 for conventional trainers.

Conclusion: The meta-analysis showed there were no significant differences in the efficacy of Augmented Reality training versus conventional training. Not only are Augmented Reality training applications effective in improving placement error and task performance time, but these applications have few drawbacks and numerous benefits compared to traditional training methods. Augmented Reality tools are often cheaper and require less oversight from instructors. Incorporating Augmented Reality technology into surgical training curricula is both promising and necessary, but a unified platform for training must be first established.

Keywords: Augmented reality; Medical education; Surgical training; Simulation; Educational tools; Laparoscopic surgery training

Abbreviations: 2D: Two-dimensional; 3D: Three-dimensional; AR: Augmented Reality; ARHMD: Augmented Reality Head-Mounted Display; CMA: Comprehensive Meta-Analysis; FLS: Fundamentals of Laparoscopic Surgery; MD: Mean Difference; MINORS: Methodological Index for Non-randomized Studies; PGY: Postgraduate Year; PRISMA: Preferred Reporting Items for Systematic Reviews and MetaAnalyses; STAR: System for Telementoring with Augmented Reality; VR: Virtual Reality.

Introduction

Laparoscopic abdominal surgery requires a more complex skill set compared to open abdominal surgery. However, as a less invasive approach, laparoscopy offers significant benefits to patients including shorter hospitalization durations, significantly fewer surgical site infections, and quicker returns to oral intake [1,2]. Recent trends show an increasing number of laparoscopic surgeries performed each year as well as a subsequent rise in demand for surgeons trained in laparoscopic procedures [3]. Ever shortening training periods and increasing patient safety concerns dictate that these skills be acquired outside the operating room. Consequently, there is a growing need to develop more efficient and effective laparoscopic surgical training programs.

The consistent development of fundamental surgical skills requires establishing a systematic methodology for both training and performance assessment. Traditionally, these skills have been developed using box-trainer models which are impractical and expensive as they need replacement after each use, and they are limited by a lack of flexibility and variation of possible training case scenarios. Additionally, box-trainers are further complicated by the complexity involved in monitoring progress, and performance assessments are only obtainable via expert supervision or review of recorded video [4].

During the last decade, Virtual Reality (VR) simulation training was introduced and adopted by several surgical centers as an alternative tool for laparoscopic surgery skills training. VR tools use computer-generated, graphical representations of 3D anatomic structures on 2D displays which can be interacted with via manipulation of a mechanical interface capturing the necessary kinematic parameters. Based on growing evidence that computer-based simulation training leads to improved patient care, VR simulation is now a certified tool

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for teaching fundamental laparoscopic skills as well as advanced technical and cognitive skills. However, despite offering opportunities for flexible task training, VR learning environments are still merely representations of the tasks in reality as VR provides minimal tactile feedback to interaction with the simulation [5]. This lack of realistic feedback creates a learning deficit which, in turn, leads to an inability to react and adapt to the fluid reality of a real-world surgical environment [6]. By realistically representing possible nonideal medical scenarios, a variable training environment with proper immersion and tactile feedback would allow for the development of critical thinking and real-world adaptability.

To acquire stable crossover competency between training and the operating room, we need to create a training environment which demonstrates convincing working processes within a multitude of changing environments. Subsequently, Augmented Reality (AR) has been increasingly implemented in surgical training as the future of interactive, computer-based simulation training. AR applications have been developed not only for training and educating medical professionals [7], but also for use as a navigational tool during surgical procedures [8,9]. AR uses a digital, 3D interface overlaid onto the "real-world" environment. The virtual and physical elements are seamlessly blended in such a way that the user receives an immersive, interactive experience. Unlike VR which is experienced entirely within a digital environment, AR lies within the real world as an "augmentation" of reality.

While many studies and reviews have been done on the usage of VR for surgical training, there is a noticeable gap in knowledge regarding similar research on the usage of AR in laparoscopic surgical training. Our objectives in this systematic review and meta-analysis are to analyze studies published in the past 5 years specifically evaluating AR in laparoscopic abdominal surgical training and secondly to assess the efficacy of AR simulation training in comparison to conventional models of training (box-trainers and video trainers) and VR training for laparoscopic abdominal surgical skills.

Methods

Data sources

With the assistance of a professional librarian, we initially conducted a systematic literature review utilizing PubMed, Cochrane Database, and Web of Science to identify research relevant to our study. We used broad search terms: '(medical or surgery) AND (Augmented Reality) AND (educat* OR simulat* OR training)'. For manuscript selection regarding the assessment of AR applications, we searched PubMed, Embase, INSPEC, and PsychInfo for key terms: '(medical or surgery) AND (Augmented Reality) AND (educat* OR simulat* OR training)'. The electronic search was further supplemented by a manual review of the reference lists in the available relevant literature. The screening process and results are reported in Figure 1 following the PRISMA (Preferred Reporting Items for Systematic Reviews and MetaAnalyses) guidelines.

Data selection

Study eligibility: Our analysis focused on AR training tools for laparoscopic abdominal surgery, because our clinic specializes in laparoscopic abdominal operations and has an interest in furthering medical training and developing future surgical training technology. We included retrospective and prospective observational studies, single group studies with pre- and post- intervention assessments, randomized controlled clinical trials, and validation studies published in English between April 30, 2012 and April 20, 2018. We intentionally did not pursue a wider range as other systematic reviews had already been published in previous years, and we wished to focus on newer developments in the field.

We excluded grey literature, case reports, case series reviews, and other systematic reviews from the initial search. Additionally, we excluded conference proceedings, studies investigating internal validity, and manuscripts unrelated to education for medical professionals. As our objective was to analyze training for abdominal laparoscopy only, we excluded manuscripts regarding other training such as obstetric, gynecological, or urological procedures. Manuscripts addressing VR without discussing AR were also excluded from the analysis.

All studies were manually screened through review of both the title and abstract according to the aforementioned criteria. Any literature deemed 'relevant,' 'dubious,' or 'unknown' were further reviewed in their entirety.

Participants: Participants were grouped into two levels of experience. The first group was comprised of novices with little to no experience (i.e., pre-medical students, medical students, and surgical residents with minimal training who had not reached the "plateau phase" of the learning curve).

The comparison group used for validating these studies was comprised of experienced surgeons who had reached an expert level.

Intervention definition: For our study, we defined Augmented Reality applications as systems combining digital content with real-time user interactions tethered to a specific real-world time and location which result in a computer-generated, enhanced overlay of the real-world environment [10]. Training tools were defined as applications created and used for developing and improving the user's performance or skills.

Outcomes: Primary outcomes, changes in placement error and the length time needed to complete the task, were objectively recorded.

Assessment of study quality: The methodological index for non-randomized studies (MINORS) was used to assess the quality of observational studies and their methodological aspects: clearly stated aim, inclusion of consecutive participants, prospective collection of data, endpoint appropriate to the aim of the study, unbiased assessment of the study endpoint, follow-up period appropriate to the aim of the study, loss to follow up of less than 5%, prospective calculation of the study size, an adequate control group, contemporary groups, baseline equivalence of groups, adequate statistical analyses (Table 1). This index uses a 12-item scale scoring criterion with a maximum score of 16 points for non-comparative studies and 24 for comparative studies [11]. The data extracted was used to assess the validation steps achieved in a validation process. This approach allows for the accommodation of differences in study designs or data collection methods. Subsequently, this leads to the incorporation of the maximum number of studies which then yields the highest degree of representation of the population [11]. Studies that did not report the outcome of interest were excluded from analysis [12-18].

Author, Year, Country	**Clearly stated aim**	**Inclusion of consecutive participants**	**Prospective Collection of data**	**Endpoints appropriate to the aim of the study**	**Unbiased assessment of the study endpoint**	**Follow-up Period Appropriate To The Aim of the study**	**Loss To Follow Up Less Than 5%:**	**Prospective Calculation of the Study size**	**An Adequate control group**	**Contemporary groups**	**Baseline Equivalence of groups**	**Adequate Statistical analyses**
Zahiri, 2018, USA [18]	2	2	2	1	1	2	2	0	2	2	2	2
Rojas Munoz, 2018, USA [17]	2	2	2	2	2	2	2	0	2	2	2	2
Andersen, 2016, USA [15]	2	2	2	2	2	2	2	0	2	2	2	2
Vera, 2014, USA [14]	2	2	2	2	2	2	2	0	2	2	2	2
Lahanas, 2014, Greece [13]	2	2	2	1	1	2	2	0	0	0	0	2
Nugent, 2013, Ireland [12]	2	2	2	2	2	2	2	0	2	0	0	2

Table 1: MINORS (methodological index for non-randomized studies) for Risk of Bias Summary of the Included Studies. Key chart: 0-Not reported; 1-reported but inadequate; 2-reported and adequate.

Data extraction and statistical analysis

Two independent reviewers (JH and KH) screened titles and abstracts generated by the initial search for relevance. The reviewers performed data extraction from each selected citation. When ambiguity arose in determining outcomes, a third reviewer was consulted, and the outcome was determined by consensus (PRISMA). The following data points were extracted from all reports: first author and year of publication, participants' characteristics, number of participants, study method/design, AR simulator type, comparison group, intervention/surgical skill assessed, assessment method, and outcome assessment metric. For the meta-analysis, we extracted data regarding the change in the time needed to complete the task, total path length, error count, and scores. We conducted a meta-analysis for each outcome. For continuous outcomes (time to complete each task), the Mean Difference (MD) with 95% was calculated. The resulting data were analyzed as a meta-analytical estimate using Comprehensive Meta-Analysis (CMA) software.

Results

Study characteristics

The initial search yielded a total of 1,348 references. After excluding duplicates, 122 references remained. Of these, 99 references were also excluded, because they were not relevant to the study. The remaining 23 articles were reviewed in their entirety for relevance. Six studies were included in the systematic review. However, only three studies, with a total of 119 participants, had data for the same outcome points and were found to be eligible for the meta-analysis.

We evaluated the participants on the parameters of placement error and task performance time. In placement error analysis, the sample sizes totaled 52 for Augmented Reality trainers and 51 for conventional trainers. For task performance time analysis, sample sizes were 60 for Augmented Reality trainers and 59 for conventional trainers. The process used for data selection is summarized in Figure 1 (PRISMA).

A total of six studies were included in this systematic review (Table 2) [12-17]. The six which remained relevant for inclusion described different AR applications used to train medical professionals: FLS stimulator hardware, Augmented Reality Head-Mounted Display (ARHMD), System for Telementoring with Augmented Reality (STAR), Augmented Reality Telementoring Platform, an experimental setup equipped with AR sensors, and ProMIS (Table 1).

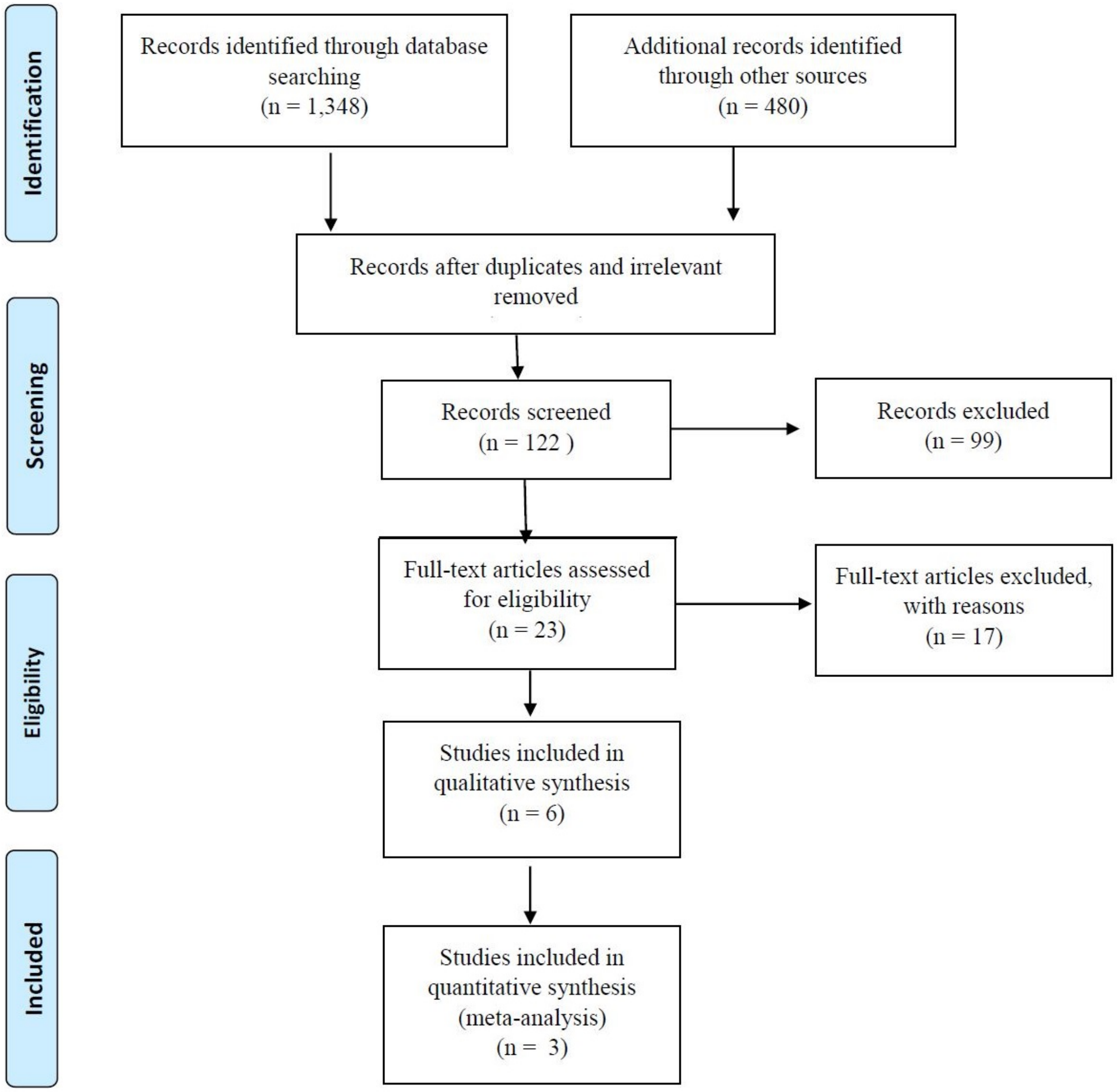


Figure 1: PRISMA Flow Diagram of Study Methods.

Author, Year, Country	**Participant characteristics**	**Participant number**	**Method**	**AR simulator**	**Comparison group**	**Intervention**	**Assessment method**	**Outcome assessment**
Zahiri, 2018, USA [18]	Novices	20	Observational prospective	FLS stimulator hardware	N/A	Peg transfer	Image recording, Electromyography	Time

Rojas Munoz, 2018, USA [17]	Novices	20	Observational prospective	Augmented Reality Head-Mounted Display (ARHMD)	Telestrator	Anatomical marking, Abdominal incision	Image recording	Time, Placement error
Andersen, 2016, USA [15]	Novices	20	Randomized control trial	System for Telementoring with Augmented Reality (STAR)	Telestrator	Port placement, Abdominal incision	Image recording, Google glass head-mounted display	Placement error, Focus shifts, Time
Vera, 2014, USA [14]	Novices	19	Randomized control trial	Augmented Reality Telementoring Platform	Video, Mentor	Laparoscopic suturing and knot-tying, Peg transfer	Chroma key technology, Image recording	Placement error, Focus shifts, Time
Lahanas, 2014, Greece [13]	Novices, Experienced surgeons	20	Observational prospective, Validation study	Experimental set up with equipped AR sensors	N/A	Instrument navigation, Peg transfer, Clipping	Image recording	Pathlength of tools, Time, Placement error
Nugent, 2013, Ireland [12]	Novices, PGY 1 surgical trainees, PGY 3-4 surgical trainees, Experts	80	Observational prospective, Validation study	ProMIS	N/A	Locating and coordinating, Object positioning, Sharp dissection	Image recording	Motion analysis, Time, Placement error

Table 2: Studies Included in Qualitative Synthesis.

Data evaluation

For evaluation of the applications' efficacy, three studies employed a novice group and a comparison group. The novice group's sample size totaled 136 participants and the comparison group was comprised of 29 participants. These three studies then further compared training on AR equipment with training on either VR equipment [15,17] or traditional video mentoring [14]. One other study employed experienced surgeons for validation rather than a comparison group [13].

Several researchers did not employ a comparison group [12,13,16]. Zahiri et al. examined the variable effects of time feedback in AR training on novices' performance [18]. However, the researchers concluded that time feedback was not significant for performance improvement. Two research groups conducted studies to assess and establish the construct validity of experimental AR equipment [13] and ProMIS [12]. Research by Lahanas et al. described a statistically significant difference in performance by both experienced surgeons and novices who used AR training. Lahanas et al. used experienced surgeons both for validating the experimental AR equipment and for use as a comparison group [13]. The authors concluded that the experimental equipment was valid and could differentiate between experts' and novices' performances regarding instrument navigation ($p<0.01$), peg transfer ($p<0.01$), and clipping ($p<0.01$).

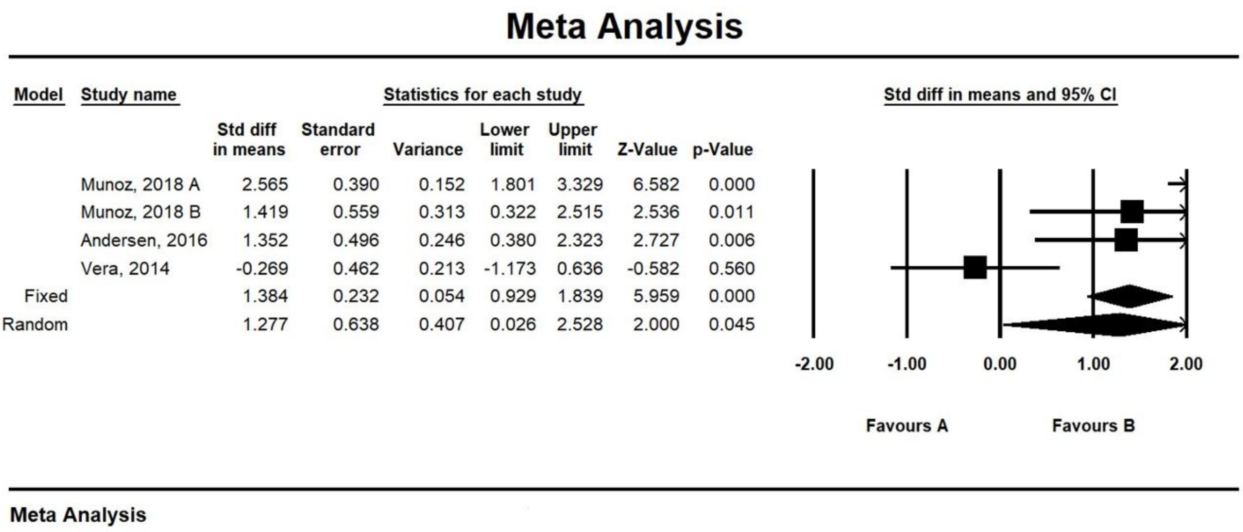
Nugent et al. used performance by expert surgeons as a standard for construct validation of AR applications and as a comparison group with four groups of varying experience levels (novice, PGY 1-2, PGY 3-4, expert). This study concluded that the equipment demonstrated a statistically significant difference in performance between all levels of experience with regards to the parameters of time ($p<0.001$), motion analysis ($p<0.001$), and error score ($p<0.001$). Additionally, Nugent et al. monitored the learning curves of novice surgeons on trials on the parameters of time, smoothness, pathlength, and error score. The researchers demonstrated that, with repetition, all novice surgeons significantly improved in performance for the metrics of time ($p<0.001$) and motion analysis ($p<0.001$) [12].

The surgical skills being evaluated were standard peg transfers [13,14,16], abdominal incisions [15,17], and suturing [14]. For assessment, most studies employed video/image recording and statistical software for analysis. Outcome assessments were defined in terms of time, focus shift, placement error, and economy of movement.

Rojas Muñoz et al., Andersen et al., and Vera et al. examined the effects of AR training on placement errors, focus shifts, and performance time compared to VR training [14,15,17]. Rojas Muñoz et al. found that AR trainers yielded significantly fewer placement errors and fewer focus shifts despite longer completion times [17]. Similarly, Andersen et al. found that compared with those using a conventional system, participants using an AR system completed tasks with fewer placement errors and fewer focus shifts but with longer completion times. Vera et al. also found that the AR group had fewer failures; however, unlike other studies, this group found that the AR group was faster than the comparison group. We conducted a meta-analysis summarizing their findings (Figures 2 and 3).

Meta-analysis of rates of change

Only three studies were included in calculation of meta-analytic rates. Although other studies provided valid measurements, they were not standardized and thereby incompatible for the purposes of comparison and calculation. Meta-analytic rates were calculated on these three studies with a base sample size of 119 as the three had comparable methods and outcomes (Figures 2 and 3).

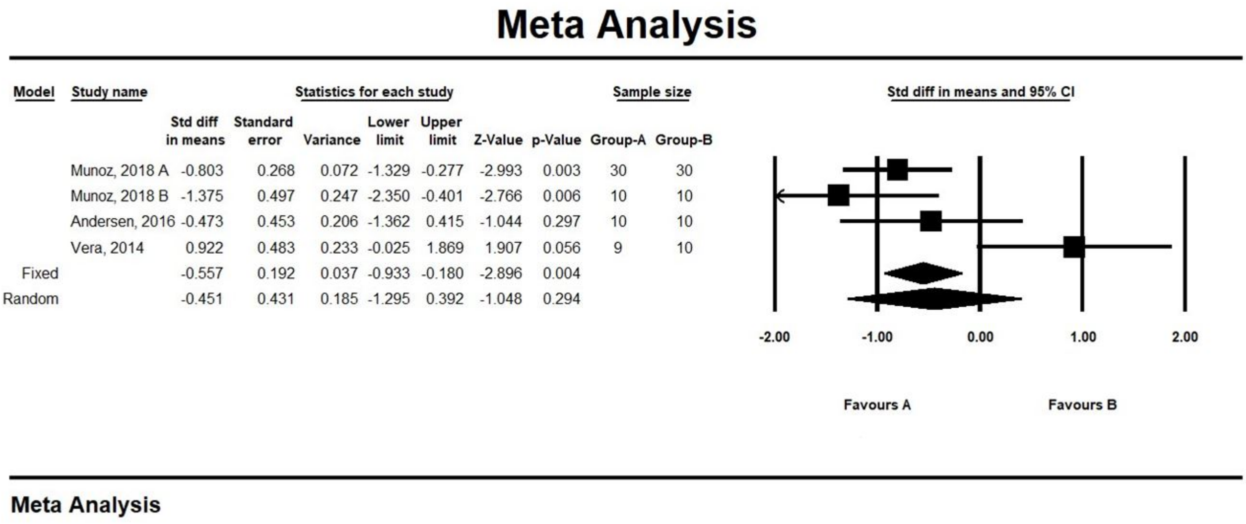


Meta Analysis

Model	Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Munoz, 2018 A	2.565	0.390	0.152	1.801	3.329	6.582	0.000
	Munoz, 2018 B	1.419	0.559	0.313	0.322	2.515	2.536	0.011
	Andersen, 2016	1.352	0.496	0.246	0.380	2.323	2.727	0.006
	Vera, 2014	-0.269	0.462	0.213	-1.173	0.636	-0.582	0.560
Fixed		1.384	0.232	0.054	0.929	1.839	5.959	0.000
Random		1.277	0.638	0.407	0.026	2.528	2.000	0.045

Figure 2: Placement Error.

The analysis demonstrated a net proportion meta-analysis pooled rate (random effect) of 1.29% (95% CI=-0.75-3.33) for placement error and 1.93% (95% CI=-0.63-4.49) for performance time of each task and focus shifts [14,15,17].



Meta Analysis

Model	Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Group-A	Group-B
	Munoz, 2018 A	-0.803	0.268	0.072	-1.329	-0.277	-2.993	0.003	30	30
	Munoz, 2018 B	-1.375	0.497	0.247	-2.350	-0.401	-2.766	0.006	10	10
	Andersen, 2016	-0.473	0.453	0.206	-1.362	0.415	-1.044	0.297	10	10
	Vera, 2014	0.922	0.483	0.233	-0.025	1.869	1.907	0.056	9	10
Fixed		-0.557	0.192	0.037	-0.933	-0.180	-2.896	0.004		
Random		-0.451	0.431	0.185	-1.295	0.392	-1.048	0.294		

Figure 3: Performance Time.

Discussion

We conducted a systematic review of studies published during the past 5 years on Augmented Reality (AR) applications used as training tools in abdominal laparoscopic surgical training. The results of the meta-analysis demonstrated that there were no significant differences between the Augmented Reality training and conventional training with regards to both error placement and performance time of the test procedures.

Our results showed there were no definitively measured disadvantages to using AR training. Additionally, our results indicated there were several advantages to using AR [12-17]. Our evaluation suggested that using AR training is a very promising technique to overcome a steep learning curve – especially at the level of novice surgeons-to ensure the safety of patients and to improve operating room times. However, we found that very few studies focusing on the validation and implementation of AR training were conducted in recent years.

The main disadvantages to using AR were high costs and the general absence of tactile feedback in existing AR applications. A recent randomized control trial conducted by Orzech et al. in Canada, reported an estimated the annual cost of training 5 resident surgeons using VR technology to be approximately $77,500 per year compared the conventional method cost of approximately $17,380 per year [18].

The main strengths of our study were the systematic approach we employed, and the thorough review of manuscripts performed by two independent reviewers. Certain limitations of our study are worth noting. We examined only the most recent publications (specifically within the past 5 years), because we aimed to evaluate only the most recent developments in this field. We focused specifically on laparoscopic abdominal surgical training creating a narrow scope on a concentrated subset of surgical procedure training.

Further studies are necessary to assess the impact of AR training on patient outcomes and on hospital costs. Future research would also focus on potential ways to reduce costs and the development of new Augmented Reality applications. Future AR simulation technology would ideally incorporate tactile feedback as well as a diverse set of flexible, realistic, training case scenarios.

Conclusion

The results of the meta-analysis demonstrated there were no significant differences in the efficacy of Augmented Reality training versus conventional training with regards to the parameters of placement error and performance time of the test procedures. Not only are Augmented Reality training applications effective in improving placement error and task performance time, but these applications also have few drawbacks compared to traditional training methods. Augmented Reality tools have many benefits; they are reusable and require less oversight from instructors.

The potential for future applications of Augmented Reality in abdominal laparoscopic surgical training is vast, and AR applications can be integrated into healthcare education in multiple ways. This technology can also be applied as a teaching tool for demonstration and navigation during surgical procedures. Incorporating Augmented Reality technology into surgical training curricula is both promising and necessary, but a unified platform for training must be first established. Further studies are necessary to assess the impact of AR training on patient outcomes and on hospital costs. Future research would also focus on potential ways to reduce costs and develop new Augmented Reality applications. Future AR simulation technology would ideally incorporate tactile feedback as well as reflect a realistic, fluid environment.

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References

1. Jaschinski T, Mosch C, Eikermann M, Neugebauer EA (2015) Laparoscopic versus open appendectomy in patients with suspected appendicitis: a systematic review of meta-analyses of randomised controlled trials. BMC Gastroenterol 15: 48.
2. Athanasiou C, Lockwood S, Markides GA (2017) Systematic Review and Meta-Analysis of Laparoscopic Versus Open Appendicectomy in Adults with Complicated Appendicitis: An Update of the Literature. World J Surg 41: 3083-3099.
3. Dua A, Aziz A, Desai SS, McMaster J, Kuy S (2014) National Trends in the Adoption of Laparoscopic Cholecystectomy over 7 Years in the United States and Impact of Laparoscopic Approaches Stratified by Age. Minim Invasive Surg.
4. Willaert WI, Aggarwal R, Van Herzeele I, Cheshire NJ, Vermassen FE (2012) Recent advancements in medical simulation: patient-specific virtual reality simulation. World J Surg 36: 1703-1712.
5. Wang X, Dunston PS (2007) Design, strategies, and issues towards an augmented reality-based construction training platform. ITcon 12: 363-380.
6. Wu H, Lee S, Chang H, Liang J (2013) Current status, opportunities and challenges of augmented reality in education. Comput Educ 62: 41-49.
7. Botden SM, Jakimowicz JJ (2009) What is going on in augmented reality simulation in laparoscopic surgery? Surg Endosc 23: 1693-1700.
8. Low D, Lee CK, Dip LL, Ng WH, Ang BT, et al. (2010) Augmented reality neurosurgical planning and navigation for surgical excision of parasagittal, falcine and convexity meningiomas. Br J Neurosurg 24: 69-74.
9. Chu MW, Moore J, Peters T, Bainbridge D, McCarty D, et al. (2012) Augmented reality image guidance improves navigation for beating heart mitral valve repair. Innovations (Phila) 7: 274-281.
10. Gallagher AG, Ritter EM, Satava RM (2003) Fundamental principles of validation, and reliability: rigorous science for the assessment of surgical education and training. Surg Endosc 17: 1525-1529.
11. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, et al. (2003) Methodological index for non-randomized studies (minors): development and validation of a new instrument. ANZ J Surg 73: 712-716.
12. Nugent E, Shirilla N, Hafeez A, O'Riordain DS, Traynor O, et al. (2013) Development and evaluation of a simulator-based laparoscopic training program for surgical novices. Surg Endosc 27: 214-221.
13. Lahanas V, Loukas C, Smailis N, Georgiou E (2015) A novel augmented reality simulator for skills assessment in minimal invasive surgery. Surg Endosc 29: 2224-2234.
14. Vera AM, Russo M, Mohsin A, Tsuda S (2014) Augmented reality telementoring (ART) platform: a randomized controlled trial to assess the efficacy of a new surgical education technology. Surg Endosc 28: 3467-3472.
15. Andersen D, Popescu V, Cabrera ME, Shanghavi A, Gomez G, et al. (2016) Medical telementoring using an augmented reality transparent display. Surgery 159: 1646-1653.
16. Zahiri M, Nelson CA, Oleynikov D, Siu KC (2018) Evaluation of Augmented Reality Feedback in Surgical Training Environment. Surg Innov 25: 81-87.
17. Rojas-Muñoz E, Cabrera ME, Andersen D, Popescu V, Marley S, et al. (2018) Surgical Telementoring Without Encumbrance: A Comparative Study of See-through Augmented Reality-based Approaches. Ann Surg.
18. Orzech N, Palter VN, Reznick RK, Aggarwal R, Grantcharov TP (2012) A comparison of 2 ex-vivo training curricula for advanced laparoscopic skills: a randomized controlled trial. Ann Surg 255: 833-839.