Low versus high level of physical resemblance in simulation for the acquisition of basic surgical skill: a meta-analysis

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ABSTRACT
Background Many studies explored the use of simulation in basic surgical education, with a variety of devices, contexts and outcomes, with sometimes contradictory results.
Objectives The objectives of this meta-analysis were to focus the effect that the level of physical resemblance in a simulation has on the development of basic surgical skill in undergraduate medical students and to provide a foundation for the design and implementation of a simulation, with respect to its effectiveness and alignment with the learning outcomes.
Study selection We searched PubMed and Scopus database for comparative randomised studies between simulations with a different level of resemblance. The result was synthesised as the standardised mean difference, under a random effect model.
Findings We selected 12 out of 2091 retrieved studies, reporting on 373 undergraduate students (mean of subjects 15.54±6.89). The outcomes were the performance of simple skills and the time to complete a task. Two studies reported a scoring system; seven studies reported time for a task; and three studies reported both. The total number of measures included in the meta-analysis was 456 for score and 504 for time. The pooled effect size did not show any significant advantage in a simulation of a high level of physical resemblance over a lower level, both for the scoring system (−0.19, 95% CI −0.44 to 0.06) and for time (−0.14, 95% CI −0.54 to 0.27).
Conclusion Simulations with a low level of physical resemblance showed the same effect as the simulation using a higher level of resemblance on the development of basic surgical skills in undergraduate students.

INTRODUCTION
'The earlier surgical skills training starts the better'. This was one of the 12 tips Kneebone[1] listed more than 20 years ago, highlighting the importance of an early beginning of surgical training in a medical curriculum. Actually, many international curricula[2] and core competence inventories[3] include basic surgical skill as a component of professional competence. Clerkship remains the cornerstone of surgical undergraduate education,[4 5] conjugated with cognitive methods like case-based learning.[6] The development of more technical surgical skills is also based on methods like the boot camps,[7] special programmes[8] or simulation.[9 10]

Simulation is a highly effective training method, and many factors influence its effectiveness.[11]

Among the others, many authors focused on the level of fidelity in various clinical domains.[12–14] Hamstra *et al*[15] questioned the term 'fidelity' and argued that the concept of fidelity is multidimensional. They suggested using the terms physical resemblance, to denote the physical structure of the device used in simulation, and functional task alignment, to denote the coherence of the whole context of simulation with the expected learning outcomes. Finally, they recommended giving more emphasis to the transfer of learning, that is, the ability to apply the skill trained in a context to a different context. The use of simulation in surgical education has been extensively studied, mainly in postgraduate training for mini-invasive surgery. In this regard, five meta-analyses have been published,[16–20] but none of them explored the effect of simulation in the development of surgical skill in undergraduate students, despite many studies exploring the use of simulation in this field, with a variety of devices, context and outcomes.

There are theoretical reasons—discussed in the next section—to hypothesise that the leaning outcomes included in the class of basic surgical skill can be achieved with a low level of physical resemblance. The objective of this meta-analysis was to review and synthetise the available evidence about the effect that the level of physical resemblance in a simulation has on the development of surgical skill in undergraduate medical students, with the goal to provide a foundation for the design and implementation of simulation, both with respect to the optimal use of resources and to the alignment to the task.

The design of this meta-analysis has been registered in the PROSPERO database (CRD42019128061).

Theoretical background
In this section, first, we give a definition of basic surgical skill and of undergraduate student, then we consider some of the educational theories that can predict the role of the characteristics of simulation in its effectiveness and we briefly discuss them.

We considered as basic surgical skills both simple tasks like gowning and gloving, suturing, knot tying[2 21] and a set of psychomotor abilities like dexterity and coordination of the two hands, or the ability to work with a 2-D view. This last set of skills is important because of the increasing importance that minimally invasive surgery has.[22] We considered as undergraduate students those attending
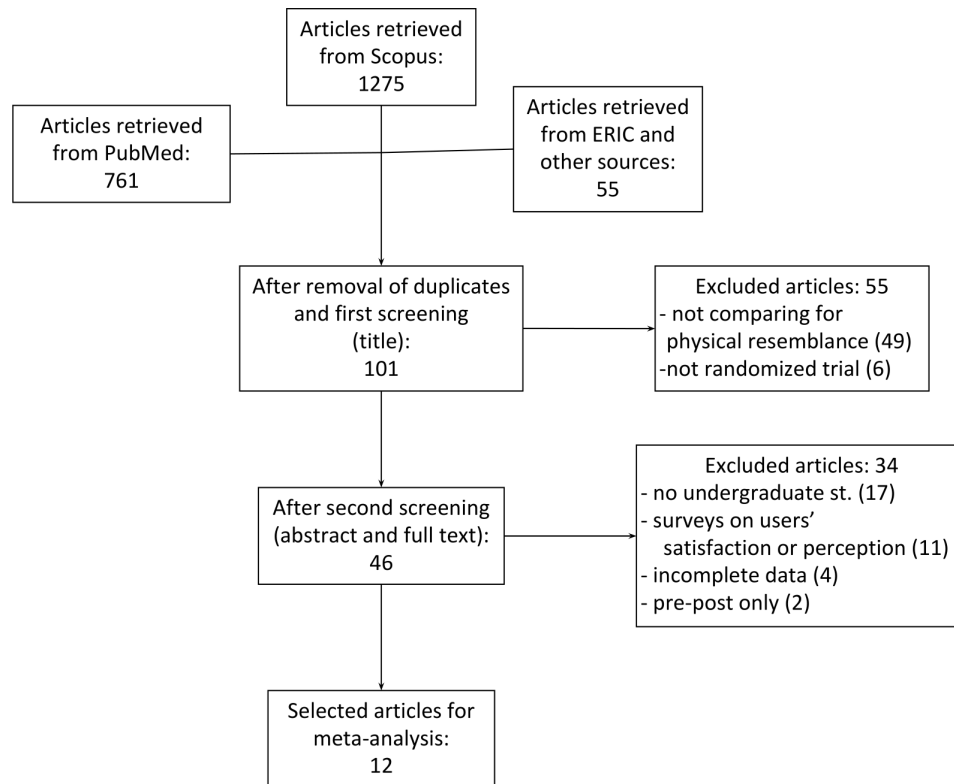
Figure 1 Flowchart of the search of articles.

a medical school according to the general model described by Wijnen-Meijer et al.[23]

Behaviourism is one of the most frequent theoretical positions to frame simulation. It posits that the outcome of learning is the modification of behaviour, regardless of the implicated cognitive mechanisms. Teaching is then providing an adequate stimulus to obtain the desired response.[24] An effective training starts from easy tasks and progresses through an intentional sequence up to proficiency. Deliberate practice and mastery learning are typical behaviourist instructional methods. Also, the use of a part-task trainer in simulation is justified in a behaviourist approach.

Cognitivism is a class of theories that explore the mental mechanisms in learning. In this class, situated cognition theory maintains that learning emerges from the interplay of the individual cognitive process and the social, cultural and physical environment in which the process takes place.[25] This theory justifies the effectiveness of simulations with a high level of physical resemblance, in which the action takes place in an environment that recalls the real professional situation. Another relevant contribution of the cognitivist perspective is the concept of mental workload. Our mind has a limited capacity of working memory, and an overload of cognitive and sensory information can alter mental performances like learning or taking clinical decisions. Naismith and Cavalcanti[26] reviewed the effect of cognitive load in simulation, showing that an excess of load impairs learning.

The learning model known as the challenge point framework[27] builds on both behaviourist and a cognitivist perspectives. This model describes the relationship between the performance and the difficulty of a task, defined as the physical or cognitive challenge posed by a motor problem. The model proposes a progression from simpler to more difficult tasks as the most effective strategy for learning.

Based on these premises, if basic surgical skills are the building blocks of a specific professional competence to be further developed in the future of graduate education, then we hypothesise that a simulation aligned to these basic outcomes and based on a low level of physical resemblance is as effective as simulation with a higher level of resemblance and that reproduces a realistic professional context.

MATERIALS AND METHODS

We planned, conducted and reported this study according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards of quality.[28]

Study eligibility

This meta-analysis considered trials in which undergraduate students were randomised to use different equipment for the simulation of surgical skills. For laparoscopic simulation, we considered a simulation in which either immersive virtual reality or 3-D vision was used as having a higher level of physical resemblance than the simulations in which a box trainer was used, either with direct vision or based on a conventional video system. For non-laparoscopic simulation, a high physical resemblance was defined as the use of a biological model as opposed to the use of a simplified synthetic model. We excluded studies about endoscopic skill (gastroscopy and bronchoscopy) because these skills did not fit with the definition we gave of basic surgical skills. Studies comparing simulation with a no-intervention or no-simulation group were excluded. In studies with three arms, we considered only the two arms comparing devices that we interpreted as high or low resemblance. The articles had to provide the figures needed to compute the overall effect size, and the considered outcome measures were both any scoring system for skill and time for a task. We selected articles in any language, without time limits.

Table 1 Characteristics of the selected studies

Article	Subjects	Skill	Comparison	Outcome	Measure	Result
Brinkman et al[30]	18 vs 18	Laparoscopic cholecystectomy in a pig model	BT versus VR trainer	Performance score	GOALS five custom items	BT better than VR
Denadai et al[31]	12 vs 12	Simple interrupted sutures and subdermal interrupted sutures	Synthetic versus animal bench model	Performance score Efficiency	Global Rating Scale Mean number of stitches in given time	No significant difference
Hassan et al[36]	15 vs 15	Laparoscopic psychomotor skill	BT versus VR	Time	Seconds	VR better than BT
Kanumuri et al[37]	8 vs 8	Laparoscopic suturing and knot tying	Computer enhanced versus VR	Time	Seconds	No significant difference
Kotari et al 2002[38]	11 vs 13	Laparoscopic psychomotor skill	Pelvic trainer versus VR	Time	Seconds	No significant difference
Lehmann et al[39]	12 vs 12	Laparoscopic psychomotor skill	Conventional video trainer versus VR	Time	Seconds	No significant difference
Lin et al[40]	40 vs 20	Laparoscopic suturing and knot tying	Direct vision training versus video-based training	Time	Seconds	Video-based better than BT
Madan and Frantzides[34]	14 vs 17	Laparoscopic psychomotor skill	Conventional video trainer versus VR	Performance score Time	Custom metrics Seconds	No significant difference
Nemani et al[32]	6 vs 7	Laparoscopic pattern cutting task	Fundamentals of Laparoscopic Surgery (BT) versus Virtual Basic Laparoscopic Skills Trainer (VR)	Performance score Time	Custom metrics Seconds	No significant difference
Tanoue et al[33]	20 vs 20	Laparoscopic psychomotor skill Suturing and knot tying	BT versus Procedicus MIST (VR)	Efficiency* Time	Errors Movements Seconds	BT better than VR
Van Bruwaene et al[35]	21 vs 21	Laparoscopic suturing	BT versus VR	Time	Seconds	BT better than VR
Youngblood et al[41]	17 vs 16	Three laparoscopic tasks in a pig model	Tower Trainer (BT) versus LapSim (VR)	Performance score Time	Custom global score Seconds	VR better than BT

BT, box trainer; VR, virtual reality.

Sources and search strategy

We searched PubMed, Scopus and ERIC electronic databases. For PubMed, the search strategy used different combinations of Medical Subject Headings (MeSH) terms like (simulation training(MeSH Terms)), (surgery(MeSH Terms)), (education, medical, undergraduate(MeSH Terms)) with free text strings like "suturing", "knot", "basic skill", "fidelity". For Scopus and ERIC, we adopted a similar strategy based on the same keywords.

We also used the references of the retrieved reviews to look for other possible relevant articles.

The search was updated until June 2020. The result of the queries was uploaded into the Zotero reference management system.

Study selection

After removal of duplicates, the two authors (FC and GP) independently checked each title and abstract to identify eligible studies. We retrieved then a full-text copy of each selected article for a final decision on the fulfilment of the eligibility criteria. Any disagreements on the selection were resolved by discussion among the authors.

Data collection process

We analysed each selected article to extract the relevant information, according to the Patient Intervention Comparison Outcome model and the information was recorded in a form. In this meta-analysis, the subjects were undergraduate students; as already defined, the intervention was the description of the used device, the comparison was the level of resemblance, and the outcome was the set of trained skills, with their measure. When a study reported more than one outcome (eg, both score and time), the outcomes were separately recorded. When a study reported more than one measure for the same outcome, all the values

were used to compute the overall effect size if they pertained to different tasks. If they were elements of a global score (like in GOALS score), only the total score was recorded. Finally, data were entered into the Review Manager software (RevMan V.5) by Cochrane collaboration.

Risk of bias

The quality of the evidence provided by the selected articles was assessed according to the GRADE guidelines,[29] embedded in the RevMan software. The authors independently assessed the articles using the GRADE rules (study limitations, imprecision, inconsistency, indirectness and publication bias) and computing the score according to the four GRADE quality levels, from high to very low. Any disagreement on the evaluation of quality of an article of one grade or more were resolved by discussion among the authors.

The publication bias was assessed with the funnel plot, observing if the distribution of the outcome measures was symmetrical around the midline.

Synthesis of results

We classified the studies according the two outcomes of scoring system and time for a task. The synthesis was computed as the standardised mean difference of effect. Variability was expressed as 95% CI. We adopted the random effect model because we expected a moderate to high heterogeneity among studies. Heterogeneity was expressed with the I^2 statistic, which describes the percentage of variation across studies. It has been suggested that a value below 40% represents low inconsistency; between 40% and 60% represents moderate inconsistency; and over 60% represents high inconsistency. We used the RevMan V.5 software for all statistical calculations and for the generation of the forest plots.
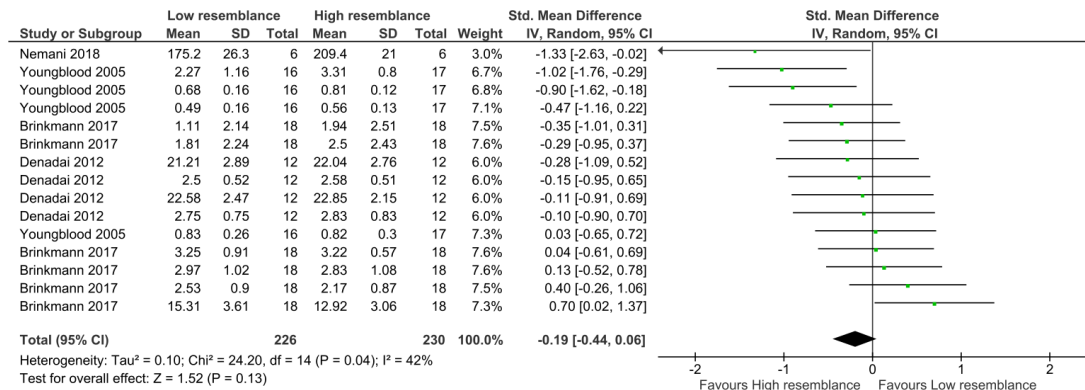
Figure 2 Forest plot of the comparison between simulations with a high versus low level of physical resemblance for the outcome score. The pooled effect size is represented by the black diamond. CI, confidence interval; IV, interval variable.

RESULTS

Flow of search

Our initial search found 2091 articles. One hundred and one met the inclusion criteria after the first screening, but after reading the abstract and the full text, only 12 were eligible for the meta-analysis. They were all written in English. Figure 1 shows the flow of search and the reasons to discard the articles not fulfilling the inclusion criteria. Nine studies reported time as the outcome; three reported a scoring system; and two reported both outcomes.

Study characteristics

Overall, the selected 12 studies were randomised trials, reporting on 373 undergraduate students (mean of subjects 15.54±6.89). All the students were defined as 'novice students', without any previous experience of surgery. The four studies reported a scoring system as the outcome, measured from one to six different items; the 10 studies reported time for a task measured the time for one to four different tasks. Hence, the total number of measures included in the meta-analysis was 456 for score and 504 for time.

Five studies trained simple laparoscopic psychomotor skill, like pick and place jacks or thread the rings; five studies trained basic laparoscopic tasks (suturing and knot tying or cutting); one study trained part of a laparoscopic cholecystectomy; and one study trained simple interrupted and subdermal interrupted sutures. Table 1 summarises the characteristics of the included studies.

Study quality

Overall, the quality of the selected studies was from moderate to high: participants were randomised; we could not detect selection bias; some studies reported two different outcomes; other studies reported incomplete data for one of the outcomes, and this outcome was not considered in the meta-analysis. These studies were anyway considered for the outcome with complete data. A frequent bias was that the blinding of outcome assessment was not reported. The sample size was generally small; only two studies enrolled more than 40 students. The distribution of outcomes in the funnel plot was symmetric, both for scoring system and for time, so we could infer the absence of a publication bias.

Comparison of scoring systems

Four studies measured the skill as the outcome with a scoring system. Two of these studies[30][31] used a validated score (GOALS and the Global Rating Scale); two[32][33] used an original scoring system. One more study used a scoring system, but the article did not report the detailed figures,[34] so it was not possible to use it for the calculation of the pooled effect size. One study reported a significant larger effect size for high resemblance[35]; one study reported the superiority of low resemblance[30]; the other two[31][32] could not show any significant difference.

The pooled effect size (figure 2) was small and did not show any significant advantage of a simulation with a high level over a low level of resemblance (-0.19, 95% CI -0.44 to 0.06). Heterogeneity was moderate ($I^2=42\%$).

Comparison of time for a task

Ten studies measured time to complete a task as the outcome.[32–41] All of them expressed the measure in seconds for the task, but tasks were rather different: simple tasks like touching a target with a grasper[39] or cutting a shape,[31] or more complex like a part of a procedure (place a stitch with two ties).[33] For this reason, the heterogeneity was high ($I^2=79\%$). Three studies reported a significant larger effect size for high level of resemblance[36][40][41]; two studies reported the superiority of a low level[33][35]; all the other studies could not show any significant difference.

The pooled effect size (figure 3) was small and did not show any significant advantage of a simulation with a high over a low level of physical resemblance (-0.14, 95% CI -0.54 to 0.27).

DISCUSSION

Our result suggests that the use of a higher or lower level of physical resemblance in simulation does not have a different effect on learning of the simple tasks that constitute the basic surgical skills. We found the same effect both on skill, measured with a score, and on the time needed to complete a task.

This finding is coherent with the starting hypothesis we did, derived from learning theories. The way in which 'the environment feature reproduced in the simulation matches the "real world" feature'[42] is important from a cognitive point of view, because learning is enhanced by a simulation environment that recalls the real professional environment in which knowledge and skill will be used.[22] Nevertheless, the skills reported in the studies we summarised in this meta-analysis were only psychomotor skills and basic technical elements, part of a more complex procedure; hence, it is not surprising that we could not find a significant difference in effectiveness between simulations based on a different level of physical resemblance.

Beyond the obvious consideration on the balance between cost and result, an unnecessary level of resemblance, specially
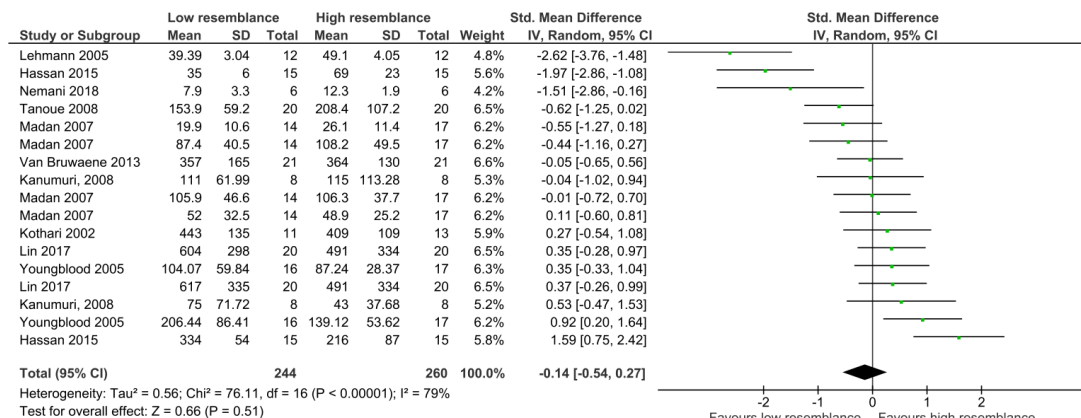
Figure 3 Forest plot of the comparison between simulations with a high versus low level of physical resemblance for the outcome time. The pooled effect size is represented by the black diamond.

at the beginning of a technical training, can produce a cognitive overload that is detrimental for an effective learning.[43] This is a possible explanation for the finding of the studies that reported a better outcome for a low level of resemblance. On the contrary, the role of a simulation based on a high level of physical resemblance is fundamental in transferring basic skills to a full procedure, as shown by many studies at the residency level.[16–20] Hence, we are not arguing that the simulation of surgical procedures with advanced and immersive technology should not be used, but that the devices and the context should always be aligned with the expected learning outcomes and with the level of expertise of the trainee.

The main limit of this meta-analysis is the rather small sample size of the considered studies. The pooled sample size was of 373 students; the calculations were done on a higher number of measures, and this could have introduced a bias because the same student was considered more than once. Nevertheless, most studies were coherent with the pooled effect size and with the conclusion of no difference in the comparison we did. Inconsistency among studies was from moderate to high, and this is why we adopted a random effect model that should compensate the heterogeneity.

Despite these limits, we believe that this meta-analysis offers a relevant and reliable indication on the use of simulation in the training of basic surgical skill for undergraduate students.

CONCLUSION

Simulation with a low level of physical resemblance and the related low cost is a viable option for teaching and learning basic surgical skill at the undergraduate level. Further research should address the identification of the other elements that can contribute to a successful simulation, like peer feedback and self-regulated learning.

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REFERENCES

1 Kneebone RL. Twelve tips on teaching basic surgical skills using simulation and multimedia. *Med Teach* 1999;21:571–5.
2 Davis CR, Toll EC, Bates AS, *et al*. Surgical and procedural skills training at medical school - a national review. *Int J Surg* 2014;12:877–82.
3 Cumming A, Ross M. The Tuning Project for Medicine--learning outcomes for undergraduate medical education in Europe. *Med Teach* 2007;29:636–41.
4 Chai AL, Matsushima K, Sullivan ME, *et al*. Acute care surgery education in US medical schools: a systematic review of the current literature and report of a medical student experience. *J Surg Educ* 2020;77:316–22.
5 Tribble CG, Walters D. Preparing for the Lurch into a surgery clerkship. *Heart Surg Forum* 2019;22:E172–9.
6 Adamas-Rappaport WJ, Waer AL, Teeple MK, *et al*. A comparison of unguided vs guided case-based instruction on the surgery clerkship. *J Surg Educ* 2013;70:821–5.
7 Neylan CJ, Nelson EF, Dumon KR, *et al*. Medical school surgical boot camps: a systematic review. *J Surg Educ* 2017;74:384–9.
8 Miller S, Shipper E, Hasty B, *et al*. Introductory surgical skills course: technical training and preparation for the surgical environment. *MedEdPORTAL* 2018;14:10775.
9 Acton RD. The evolving role of simulation in teaching surgery in undergraduate medical education. *Surg Clin North Am* 2015;95:739–50.
10 Willis RE, Van Sickle KR. Current status of simulation-based training in graduate medical education. *Surg Clin North Am* 2015;95:767–79.
11 Issenberg SB, McGaghie WC, Petrusa ER, *et al*. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. *Med Teach* 2005;27:10–28.
12 Cheng A, Lockey A, Bhanji F, *et al*. The use of high-fidelity manikins for advanced life support training--A systematic review and meta-analysis. *Resuscitation* 2015;93:142–9.
13 Beal MD, Kinnear J, Anderson CR, *et al*. The effectiveness of medical simulation in teaching medical students critical care medicine: a systematic review and meta-analysis. *Simul Healthc* 2017;12:104–16.
14 Li MM, George J. A systematic review of low-cost laparoscopic simulators. *Surg Endosc* 2017;31:38–48.
15 Hamstra SJ, Brydges R, Hatala R, *et al*. Reconsidering fidelity in simulation-based training. *Acad Med* 2014;89:387–92.
16 Alaker M, Wynn GR, Arulampalam T. Virtual reality training in laparoscopic surgery: A systematic review & meta-analysis. *Int J Surg* 2016;29:85–94.
17 Guedes HG, Câmara Costa Ferreira ZM, Ribeiro de Sousa Leão L, *et al*. Virtual reality simulator versus box-trainer to teach minimally invasive procedures: a meta-analysis. *Int J Surg* 2019;61:60–8.

18 Goolsby C, Branting A, Ausman J, *et al*. Systematic review of live tissue versus simulation education for prehospital trauma providers. *Mil Med* 2017;182:e1824–33.

19 Lui JT, Hoy MY. Evaluating the effect of virtual reality temporal bone simulation on mastoidectomy performance: a meta-analysis. *Otolaryngol Head Neck Surg* 2017;156:1018–24.

20 Gurusamy KS, Aggarwal R, Palanivelu L, *et al*. Virtual reality training for surgical trainees in laparoscopic surgery. *Cochrane Database Syst Rev* 2009:CD006575.

21 Agha RA, Papanikitas A, Baum M, *et al*. The teaching of surgery in the undergraduate curriculum--reforms and results. *Int J Surg* 2004;2:74–6.

22 Frountzas M, Pergialiotis V, Prodromidou A, *et al*. Familiarization of undergraduate medical students with the two-dimensional vision of laparoscopic surgery: preliminary results of a prospective follow-up study. *J Gynecol Obstet Hum Reprod* 2018;47:237–40.

23 Wijnen-Meijer M, Burdick W, Alofs L, *et al*. Stages and transitions in medical education around the world: Clarifying structures and terminology. *Med Teach* 2013;35:301–7.

24 Skinner B. The science of learning and the art of teaching. *Harvard Educ Rev* 1954;24:86–97.

25 Artino AR. It's not all in your head: viewing graduate medical education through the lens of situated cognition. *J Grad Med Educ* 2013;5:177–9.

26 Naismith LM, Cavalcanti RB. Validity of cognitive load measures in simulation-based training: a systematic review. *Acad Med* 2015;90:S24–35.

27 Guadagnoli M, Morin M-P, Dubrowski A. The application of the challenge point framework in medical education. *Med Educ* 2012;46:447–53.

28 Moher D, Liberati A, Tetzlaff J, *et al*. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med* 2009;151:264–9.

29 Balshem H, Helfand M, Schünemann HJ, *et al*. Grade guidelines: 3. rating the quality of evidence. *J Clin Epidemiol* 2011;64:401–6.

30 Brinkmann C, Fritz M, Pankratius U, *et al*. Box- or virtual-reality trainer: which tool results in better transfer of laparoscopic basic skills?-a prospective randomized trial. *J Surg Educ* 2017;74:724–35.

31 Denadai R, Oshiiwa M, Saad-Hossne R. Does bench model fidelity interfere in the acquisition of suture skills by novice medical students? *Rev Assoc Med Bras* 2012;58:600–6.

32 Nemani A, Ahn W, Cooper C, *et al*. Convergent validation and transfer of learning studies of a virtual reality-based pattern cutting simulator. *Surg Endosc* 2018;32:1265–72.

33 Tanoue K, Ieiri S, Konishi K, *et al*. Effectiveness of endoscopic surgery training for medical students using a virtual reality simulator versus a box trainer: a randomized controlled trial. *Surg Endosc* 2008;22:985–90.

34 Madan AK, Frantzides CT. Prospective randomized controlled trial of laparoscopic trainers for basic laparoscopic skills acquisition. *Surg Endosc* 2007;21:209–13.

35 Van Bruwaene S, Schijven MP, Miserez M. Maintenance training for laparoscopic suturing: the quest for the perfect timing and training model: a randomized trial. *Surg Endosc* 2013;27:3823–9.

36 Hassan SO, Dudhia J, Syed LH, *et al*. Conventional laparoscopic vs robotic training: which is better for naive users? A randomized prospective crossover study. *J Surg Educ* 2015;72:592–9.

37 Kanumuri P, Ganai S, Wohaibi EM, *et al*. Virtual reality and computer-enhanced training devices equally improve laparoscopic surgical skill in novices. *JSLS* 2008;12:219–26.

38 Kothari SN, Kaplan BJ, DeMaria EJ, *et al*. Training in laparoscopic suturing skills using a new computer-based virtual reality simulator (MIST-VR) provides results comparable to those with an established pelvic trainer system. *J Laparoendosc Adv Surg Tech A* 2002;12:167–73.

39 Lehmann KS, Ritz JP, Maass H, *et al*. A prospective randomized study to test the transfer of basic psychomotor skills from virtual reality to physical reality in a comparable training setting. *Ann Surg* 2005;241:442–9.

40 Lin C-C, Huang S-C, Lin H-H, *et al*. Naked-eye box trainer and training box games have similar training effect as conventional video-based box trainer for novices: a randomized controlled trial. *Am J Surg* 2018;216:1022–7.

41 Youngblood PL, Srivastava S, Curet M, *et al*. Comparison of training on two laparoscopic simulators and assessment of skills transfer to surgical performance. *J Am Coll Surg* 2005;200:546–51.

42 Chiniara G, Cole G, Brisbin K, *et al*. Simulation in healthcare: a taxonomy and a conceptual framework for instructional design and media selection. *Med Teach* 2013;35:e1380–95.

43 Chauvin SW. Applying educational theory to simulation-based training and assessment in surgery. *Surg Clin North Am* 2015;95:695–715.