**Table 3.** *Simulator-based training and learning curve studies.*

| Study | Setting and participants | Simulator | Procedure | Methods | Assessment method | Results | LOE |
|---|---|---|---|---|---|---|---|
| Tuggy (1998) | Single center, randomized, 5 novice endoscopists in the simulator group, 5 controls | AccuTouch | Sigmoidoscopy | 5 And 10 hours VR sigmoidoscopy training on the simulator versus no training | Improvement of performance during patient based sigmoidoscopy | Significantly shorter procedure times, no difference in times in red-out or completeness of mucosal inspection | ⊕⊕⊕∘ |
| Gerson (2003) | Single center, randomized, 9 novices in simulator-trained group, 7 in control group | AccuTouch | Sigmoidoscopy | Unsupervised training on the simulator versus patient-based training | 5 Patient-based sigmoidoscopies per trainee evaluated by supervisor and patients | Patient-based trained group completed significantly more cases, completed more cases independently, and performed more successful retroflexion. There was no difference in procedure times and patients satisfaction or discomfort | ⊕⊕⊕∘ |
| Eversbusch (2004) | Single center, randomized, 2 groups; group I: 8 experienced endoscopists (>200 procedures), 10 intermediate (<50 procedures), 10 novices. Group II: 10 novices psychomotor training versus 10 novices control. | GI Mentor | Dexterity and colonoscopy | Group I: learning curve psychomotor training using EndoBubble task 10 times. Group II: VR colonoscopy followed by psychomotor training versus no training and again VR colonoscopy | Improved performance during VR colonoscopy | No learning curve during psychomotor training for experts, short learning curve for intermediate experienced and a longer learning curve for novices. Statistically significant improved performance during VR colonoscopy on all parameters after psychomotor training versus control. | ⊕⊕⊕∘ |
| Giulio (2004) | Multicenter, randomized, 22 novices | GI Mentor | EGD | 10 hours unsupervised training on the simulator versus no training | 20 Patient-based gastroscopies per trainee evaluated by non-blinded supervisors | Significantly more complete examinations, less need for assistance and more positive scores by supervisors in the simulator trained group | ⊕⊕⊕∘ |

| Study | Setting and participants | Simulator | Procedure | Methods | Assessment method | Results | LOE |
|---|---|---|---|---|---|---|---|
| Mahmood (2004) | Single center, 26 Novices performing VR colonoscopies on the AccuTouch Immersion Medical simulator | AccuTouch | Colonoscopy | 38 trials of 5 consecutive VR colonoscopies. Performance measures are recorded by the simulator | Improvement of performance measures on the simulator in the absence of feedback | In the absence of feedback there was no learning effect measured on the simulator after repetitive training | ⊕⊕⊕○ |
| Sedlack (2004) | Single center, randomized, 4 novices to VR colonoscopy training versus 4 controls | AccuTouch | Colonoscopy | VR colonoscopy training for 6 hours | Patient-based assessment of colonoscopy performance using standardized assessment forms by experts and patient survey on discomfort | Study group outperformed controls on all parameters except insertion time during first 15 procedures and on 3 parameters (depth of insertion, independent completion and ability to identify landmarks) after 30 colonoscopies (P<0.05) | ⊕⊕⊕○ |
| Sedlack (2004) | Single center, randomized, 19 novices versus 19 controls | AccuTouch | Sigmoidoscopy | 19 Novices receiving 3 hours of simulator-based training prior to patient-based sigmoidoscopy versus 19 controls | 1 Week of patient-based sigmoidoscopy. Assessment of performance using a standardized assessment form by supervisors and patients survey on discomfort | Median patient discomfort scores were significantly lower in the study group (P<0.01). No differences in procedural performance as judged by supervisors | ⊕⊕⊕○ |
| Ahlberg (2005) | Single center, randomized, 12 novice colonoscopists with only gastroscopy experience | GI Mentor | Colonoscopy | VR colonoscopy training to a predefined expert level on the simulator versus no training | Patient-based colonoscopy | Significantly improved performance in the simulator-trained group (P=0.0011) and 4.53 times more likely to reach the cecum | ⊕⊕⊕○ |
| Cohen (2006) | Multicenter, randomized, 45 novices | GI Mentor | Colonoscopy | Randomized to no simulator training versus 10 hours of unsupervised simulator training | Assessment of technical and cognitive performance as well as patient discomfort during the first 200 consecutive patient- | Simulator group had significantly higher objective competency rates during the first 80 cases. The overall number needed to reach a 90% | ⊕⊕⊕⊕ |

| Study | Setting and participants | Simulator | Procedure | Methods | Assessment method | Results | LOE |
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| | | | | | based colonoscopies | competency level was 160 cases in both groups | |
| Barthet (2007) | 17 novice trainees performing EUS | Live porcine model | EUS | Visualizing anatomical landmarks, perform FNA and celiac neurolysis | Pre- and post-test assessment of performance | Increased performance after training in both diagnostic (visualization) and therapeutic procedures (time to complete and precision, not the rate of technical errors) | ⊕⊕∘∘ |
| Buzink (2007) | Single center, 35 novices and 5 expert endoscopists | GI Mentor | Dexterity and colonoscopy | All participants performing a predefined protocol colonoscopy and hand-eye coordination tasks | Assessment by simulator construct repeating predefined tasks on the simulator itself | Novices significantly improve performance in the early learning curve by training on the GI Mentor II, whereas experts do not | ⊕⊕⊕∘ |
| Maiss (2007) | 27 Novices randomized to intensive simulator training versus controls | CompactEASIE Simulator | Haemostasis | 14 Novices are trained 12 times in a 7 months period in endoscopic skills, injection therapy, clipping and band ligation | Final assessment by blinded experts | Study group performed significantly better on all tasks as judged by blinded experts. Results were comparable to similar studies performed in New York and France. | ⊕⊕⊕∘ |
| Park (2007) | Single center, randomized, 12 novices receiving simulator-based training versus 12 controls | AccuTouch | Colonoscopy | All participants performed baseline VR colonoscopy. SG received 2-3 hours of training on the simulator | Patient-based assessment by blinded experts using GRS. Scores were compared to simulator performance metrics | SG had a significantly higher GRS. Only 2/8 simulator performance metrics correlated with GRS (procedure time and time in red-out) | ⊕⊕⊕⊕ |
| Ferlitsch (2010) | Single center, randomized, 28 novices, 14 received simulator training prior to patient-based gastroscopy training | GI Mentor | EGD | 5 to 20 hours of VR simulator training in upper GI endoscopy and training games with the first 2 hours supervised | Patient-based gastroscopy with standardized assessment of performance by the unblinded supervising expert on time taken, | Time and technical accuracy was significantly better in the simulator-trained group ($P<0.05$) in the early learning curve, after 60 procedures time was still significantly different. | ⊕⊕⊕∘ |

| Study | Setting and participants | Simulator | Procedure | Methods | Assessment method | Results | LOE |
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| | | | | | technical and diagnostic accuracy and blinded patients evaluation on discomfort and pain. | Diagnostic accuracy and patient discomfort or pain was not different in any point of time. | |
| Haycock (2010) | Multicenter, randomized, blinded, 36 novice colonoscopists | Endo TS-1 | Colonoscopy | 16 hours VR colonoscopy training versus patient-based training | Patient-based and simulator-based assessment | No differences in performance between subjects and controls during patient-based assessment. Subjects performed significantly better in simulator-based assessment. | ⊕⊕⊕⊕ |
| Kruglikova (2010) | Single center, randomized, 22 novices | Accutouch | Colonoscopy | Simulator training with concurrent feedback versus no feedback | Post-training simulator-based assessment | Subjects reached proficiency levels significantly faster than controls. This effect diminished during the retention/transfer tests | ⊕⊕⊕∘ |
| Kruglikova (2010) | Single center, 30 female novices, 10 nurses, 10 endoscopy nurses, 10 residents | AccuTouch | Colonoscopy | 10 repetitions of same VR task on the simulator | Comparing first and last colonoscopy task to each group and expert reference | Residents performed the tasks faster with a similar learning curve pattern, other parameters were equal. | ⊕⊕⊕∘ |
| Snyder (2010) | Single center, randomized, 8 proctored versus 5 unproctored trainees | AccuTouch | Colonoscopy | Both groups performed VR colonoscopy assessment: baseline directly after training & after 4.5 months | A combined proficiency score of 10 (best performance on all parameters) was the maximum score and considered proficient | All participants improved to proficient level post-training. Retention scores after 4.5 months were unchanged for all participants | ⊕⊕⊕∘ |
| Kaltenbach (2011) | Single center, pilot study, 3 trainees | Mechanical colon model | Colonoscopy | Half-day one-on-one training using a colon model with ScopeGuide imaging creating different loops during the trainees | Colonoscopy performance was appraised (non-blinded) before and after the training | Performance scores and CIRs improved significantly | ⊕⊕∘∘ |

| Study | Setting and participants | Simulator | Procedure | Methods | Assessment method | Results | LOE |
|---|---|---|---|---|---|---|---|
| | | | | colonoscopy learning curves | | | |
| Lim (2011) | Multicenter, randomized, 16 trainees in ERCP | ERCP Mechanical Simulator - EMS | ERCP | 2 Sessions of hands-on training in selective bile duct cannulation on the EMS for the study group | Patient-based ERCP with cannulation success rates, cannulation times and blinded supervisor assessment | Significant higher cannulation success rates in less time in the study group. Same competency scores for both groups | ⊕⊕⊕⊕ |
| Van Sickle (2011) | Multicenter, prospective, 41 novice endoscopists | GI Mentor | Dexterity | Novice endoscopists training EndoBubble on the simulator | Pre- and posttraining assessment using Colonoscopy case module I outcome parameters and GAGES assessment form | Performance on the simulator, as measured by the simulator parameters, improved significantly after performing EndoBubble tasks ranging 13 +/-10 for EndoBubble level 1 and 23 +/- 16 for level 2 | ⊕⊕⊕o |
| Ende (2012) | Multicenter, randomized, 28 novices, EGD | Various | EGD | 3 groups; clinical+simulator training, clinical training only, simulator training only. Different simulators used. | Assessment by simulator and blinded experts using standardized forms | Clinical trained groups outperformed the simulator trained group significantly. Results in the combination group were better than clinical training alone | ⊕⊕⊕⊕ |
| Ahad (2013) | Single center, randomized, 32 novice endoscopists | AccuTouch | Colonoscopy | Low versus high-fidelity model simulator training | Pre- and posttraining assessment using colonoscopy tasks on the Immersion AccuTouch simulator | Colonoscopy skills acquisition of basic endoscopy skills on a low-fidelity model is just as effective as on a high-fidelity simulator | ⊕⊕⊕o |