Evidence Profile

Recommendation Question 2: Should practical education for the insertion and management of vascular access devices for nurses and the inter-professional team be recommended?

Recommendation 2.1: The guideline panel recommends that health service organizations implement practical education on the insertion and/or management of vascular access devices for health providers.

Population: Nurses and the interprofessional team

Intervention: Practical education for the insertion and management of vascular access devices (e.g. simulation labs, deliberate practice, supervised insertions, hands-on, one-on-one training)
Comparison: Standard education (e.g. lectures, reading material)
Outcomes: complications (e.g. phlebitis, infiltration, extravasation, infection, bleeding, embolism) insertion-related complications, number of successful observed attempts, provider attitude/confidence
Setting: All practice settings where patients with vascular access devices are cared for (e.g., primary care, long-term care, acute care, community care)

Bibliography: 5861, 458, 4302, 5040, 2215, 4322, 12935, 1650, 2181, 3729, 12878, 2818, 13101, 4905, 6138, 1226, 4886, 86, 4021, 2113, 1718, 560, 818, 893, 2193, 2426, 2438, 3383, 4261, 5555, 5745, 7179, 6685, 6168, 6915

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
Number of successful observed attempts[a] (Assessed with: overall success rate on real patients, psychomotor skills checklist, PIVC insertion skills checklist, first attempt success rate, mean global assessment score, time to first cannulation, performance skills assessment, global rating score, learning mastery, Arterial Puncture Skills Assessment Tool (APSAT))													
1[b]	Systematic Review and Meta-analysis of RCTs and non-RCTs	Not serious[c]	Not serious	Not serious	Not serious	None	**5861:** Multiple				The systematic review demonstrated the overall success rate was higher in the simulation group than in the non-simulation group. 8 additional RCTs were identified, and successful attempts were higher in the majority of studies however two studies had no difference between groups. 15 additional non-RCTs were identified, and results supported the findings of the SR.	⊕⊕⊕⊕ HIGH	**5861:** Madenci,

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								5861: Simulation training for CVAD insertion for medical residents or fellows. Control: apprenticeship or lecture training for CVAD insertion. **Additional RCTs identified:**	**5861:** N= 231 participants Overall proportion of successful CVAD insertion: 89.8%	**5861:** N= 176 participants Overall proportion of successful CVAD insertion: 81.2%	**5861:** The overall success rate was higher in the simulation group than in the non-simulation group. RR 1.10 [1.01-1.20]. For every 100 people who receive intervention, 8 more people will have successful CVAD insertion (ranges from 1 more to 16 more).		Solis & de Moya, 2014
							458: Canada	**458**: PVAD insertion education through access to an e-learning module through the learning management system used for teacher–student communication and sharing of course material, in addition to traditional in-class training. The e-learning module consisted of six main sections: Venipuncture Site, Equipment, Preparation, Procedure, Complications, and Continuing Care. Control: The control group was educated using traditional in-class training, consisting of readings, lectures, and lab demonstrations.	**458:** N=28 Mean psychomotor skill score (SD): 17 (3.0)	**458:** N=36 Mean psychomotor skill score (SD): 17 (3.4)	**458:** There were no differences observed between the study and control group scores when testing psychomotor skills.		**458:** Lindenmaier et al. (2018)
							4302: USA	**4302:** Online learning course with live simulation of PVAD insertion. Control: waitlist served as the control.	**4302:** First attempt success n (%)	**4302** First attempt success: period 1: 19 (59%)	**4302:** First attempt success and mean skills checklist were higher in the intervention groups		**4302:** Keleekai et al., 2016

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
									period 1: 14 (47%) Period 2: 18 (60%) Skills mean (SD) range Period 1 62.2 (18.1) 15-50 Period 2 77.0 (21.0) 35-100	Period 2: 15 (52%) Skills mean (SD) range Period 1 67.7 (16.4) 35-89 Period 2 67.3 (16.4) 33-93	than the control; the intervention group improved their skills by 24%.		
							5040: USA	**5040:** Standard training plus simulation-based training: In addition to standard training, intervention group subjects received 1 to 2 hours of individualized instruction and supervised practice on a venous access simulator with an experienced pulmonary and critical care or emergency medicine attending physician. Control: Standard training: 5- to 60-minute didactic lecture, an interactive online module structured around an 18-minute video, familiarization with our hospital's CVAD placement checklist, and instruction by an upper-level resident, fellow or attending during all actual procedures.	**5040** First-attempt cannulation: 29 (59.2) RR (95% CI) 1.00 (0.75-1.34) Overall cannulation success: 45 (91.8) RR (95% CI) 1.02 (0.88-1.18) Mean (SD) global assessment score 3.1 (1.1) MD 0.20 (-0.29-0.69)	**5040** First-attempt cannulation 23 (60.5) Overall cannulation success 34 (89.5) Mean (SD) global assessment score 2.9 (1.1)	**5040:** There was no difference in first attempt cannulation, overall cannulation success or global assessment score RR 0.98 [0.69-1.38] For every 100 people who receive intervention, 1 less people will have cannulation success (ranges from 19 less to 23 more).		**5040:** Peltan, Shiga, Gordon, et al., 2015
							4322: Japan	**4322:** A novel training program that aimed to improve the accuracy of locating the radial artery by palpation. Our program included three features: (1) training with a reduced pulse pressure, (2) training with a deeper artery, and (3)	**4322:** Total catheterization success rates:	**4322** Total catheterization success rates: n =	**4322:** Catheterization success rate was higher in the		**4322:** Nakayama et al., 2016

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								sufficient repetition to solidify the experience. Control: trainees who had not participated in the training program.	n = 83 of 100; 83%; Odds ratio, 3.68; 95% CI, 2.66 to 5.10;.	57 of 100; 57%;	intervention group than the control group. RR 1.46 [1.20-1.76] For every 100 people who receive intervention, 26 more people will have catheterization success (ranges from 11 more to 43 more).		
							2215: USA	**2215**: The intervention group performed a central line dressing change with CVAD standard prepackaged dressing change kits on a low fidelity mannequin with a subclavian central catheter in place. The mannequin was placed on a cart and taken to the bedside as the nurses worked in the PICU. Control: standard training, with a demonstration, self-study poster and test.	**2215:** N=39 Mean CVAD score: Baseline: 10.4 ± 2.2 12 months: 15.8 ± 1.1	**2215:** N=40 Mean CVAD score: Baseline: 10.9 ± 2.2 12 months: 13.2 ± 2.1	**2215:** The mean CVAD score from the intervention group was higher than that of the control group. The difference in mean scores at 12 months was 2.6 higher in the intervention group.		**2215:** Hebbar, Cunningham, McCracken, et al., 2015
							560: Japan	**560:** The simulation group participated in two simulation training sets with a one-month interval between the sets. Each set consisted of ten simulation training sessions for ability to operate an ultrasound machine, manipulate an ultrasound transducer, and dynamic needle-tip positioning technique on a two millimeter vessel branch in the Blue phantom ultrasound training block. Control: Control ground received background knowledge via lecture and video clip.	**560:** First attempt success rate 36/44 (81.8%)	**560:** First attempt success rate 20/40 (50.0%)	**560:** The first attempt success rate in real patients was significantly higher in the simulation group compared to the control.		**560:** Oh et al. 2020

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							5745: Turkey	**5745:** Prior to the implementation, the researcher gave all the students who participated in the study a 30-minute theoretical didactic lecture on PVAD catheter intervention at the same time. Virtual Intravenous Simulation (VIS) group: Following the traditional method, first, the VIS system was introduced to the students by the instructor and information on the present scenarios was given. Video group: Following the traditional method, the students were first shown a training video on the PVAD catheterization skill in a classroom setting.	**5745**: n=30 Psychomotor skill score Mean: 35.13 SD: 2.9	**5745**: n=30 Psycohomotor skill score Mean: 32.50 SD: 7.4	**5745:** The psychomotor skill score of the simluation group was higher than that of the video group.		**5745:** Ismailoglu et al., 2020
							6915: Iran	6915: Participants in the simulation group were provided with pediatric PVAD insertion training through role play simulation. In the demonstration group, the same instructor initially provided students with information about learning objectives and necessary equipment and then, demonstrated the pediatric PVAD insertion technique for them on the same child mannequin in the skill lab within 20 min. Students in the control group solely received routine theoretical training about pediatric PVAD insertion through a lecture.	**6915**: PVAD Insertion Skill Simulation group n=16 Mean ± SD pre 14.93 ± 6.64 post 33.81 ± 6.86 Demonstration group n=14 Means pre 16.92 ± 10.38 post 41.14 ± 7.67	6915: n=15 PVAD Insertion Skill Mean ± SD pre 17.66 ± 7.46 post 20.66 ± 5.65	6915: Both demonstration and simulation groups had higher insertion scores than in the control group. There was no difference between demonstration and simulation groups.		**6915:** Valizadeh et al, 2021
								Additional non-RCTs identified:					
							1650: USA	**1650** The training included a 30-minute didactic session, access to an online video lecture and a 90 minutes hands-on session where the learners traced veins on each other's arms and practiced PVAD placement with US on gel	**1650:** N= 26 The overall success rate for physicians was 79.4%,	**1650:** N/A	**1650:** There is an increase in successful attempts with more		**1650**: Oliveira & Lawrence, 2016

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								phantoms (Blue Phantom, Kirkland, Washington). The participants had the additional option to place US-guided PIV lines on each other.	nurses 63.2%, and corpsmen 50.0%.		experience and a decrease in number of attempts [only overall success rate percentages reported].		
							2181: USA	**2181** US PVAD placement training program: Training consisted of 3 major phases. Phase 1 consisted of 1:1 mentoring sessions led by a nurse practitioner. The second phase of training required another 2-hour, 1:1 hands-on training session using a validated nonhuman tissue model for practice Phase 3 involved live patients. Patients were selected for the study based on the following criteria: The presence of a physician's order to place an ultrasound-guided IV line and either a lack of palpable or visible peripheral vessels or having a history of requiring ultrasound-guided peripheral or central venous access on prior encounters.	**2181:** n=7 trainees	**2181:** N/A	**2181:** Time to successful attempt improved over study period. The average time required for successful vessel cannulation was 19.57 minutes (range = 5-62 minutes), whereas the average time at the first attempt only (score = 5) was 10.88 minutes.		**2181:** Ault, Tanabe & Rosen, 2015
							3729: USA	**3729** A standard curriculum for the placement of an internal jugular CVAD was developed, designed to be taught during one 3-hour session. Each class	**3729:** Scores on the posttest increased significantly	**3729:** N/A	**3729:** Post course performance scores were higher		**3729:** Grudziak et al., 2016

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								began and ended with tests and questionnaires, assessing intern comfort with ultrasound, their knowledge of anatomy, ultrasound basics, indications for CVAD placement, technique, and potential complications. Participants viewed The New England Journal of Medicine central line insertion video. They were then divided into four hands-on stations, as follows: Ultrasound session, Kit familiarization and sterile technique station, Demonstration of central line insertion, Trainee placement of an ultrasound-guided internal jugular central line.	from a pre course score mean of 13.7 [95% confidence interval (CI): 13.1–14.3], out of a possible score of 18, to a post course score mean of 16.1 (95% CI: 15.7–16.6)		than pre course. The difference in mean scores was 2.4 higher in the post-test.		
							12878: USA	**12878:** Residents attended a formal didactic training during which they watched a video presentation on ultrasound-guided central venous access. They subsequently underwent 90- minute skills sessions on Blue Phantom trainer models that were designed to simulate ultrasound-guided central venous access.	**12878** pretraining mean score: 11.8 (11.3–12.4) posttraining mean score:14.2 (13.9–14.6) of a maximum of 16 points.	**12878**: N/A	**12878:** Mean scores increased from pre-training to post-training, with a mean difference of 2.4 higher in the posttraining group, indicating improvement. There was also an overall reduction in skin-to-vein time from 51.9 (34.3–69.5) to 21.3 (11.8–30.7) seconds.		**12878:** Jagneaux et al., 2017
							2818: USA	**2818:** A single, 60- to 90-minute US-guided CVAD training session conducted at the Saint Louis University Clinical Simulation Center. Training was conducted in a small-group format with one to three residents per session. At each session, residents were shown a 10-minute instructional video on US	**2818:** checklist score: baseline: 54.2% [IQR, 40.8–68.8%] post-	**2818:** N/A	**2818:** Checklist score, global rating score, and successful insertion rate increased from baseline to post		**2818:** Thomas et al., 2013

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								guided CVAD insertion from the Videos in Clinical Medicine series from the New England Journal of Medicine (14). One of the investigators (S.M.T.) then led a hands-on training session using a SonoSite 180 Plus portable US with L38/10–5 megahertz linear transducer (SonoSite, Bothell, WA) and a VascularAccessChild task trainer (Simulab, Seattle, WA).	intervention: 83.3% [IQR, 70.0–91.7%]) Global rating score: baseline: 8.0 mm [IQR, 0.0–64.3 mm] post-intervention: 79.5 mm [IQR, 16.3–91.7 mm] Successful CVAD insertion rate: baseline: 38.5% post-intervention: 80.8%		simulation training. There was a mean difference in scores of 29.1% from baseline to post-intervention, indicating improvement.		
							13101: USA	**13101:** simulation training which included 4 procedural skills: intubation, arterial line placement, lumbar puncture, and central line insertion. Each student spent on average 40 minutes at each of the 4 stations: intubation, arterial line placement, lumbar puncture, and central line insertion. There were 2 residents present at each station to train 1 medical student at a time. One resident explained the critical steps, whereas another demonstrated how to perform the procedure. Then, students were given, on average, 25 minutes to practice each procedure while they received feedback from residents. Each	**13101:** Mean procedural checklist scores: Pretest arterial: 2.40 (1.70) N= 24 Posttest arterial 10.19 (1.28) N= 24 Central pre test: 3.79 (2.63) N= 24,	**13101:** N/A	**13101:** There was an increase in performance score for both arterial line placement and central line placement. The mean difference in scores were 7.79 for arterial line placement, and 9.36 for central line placement, indicating improvement.		**13101:** Toy et al., 2016

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								medical student rotated through all 4 stations.	posttest: 13.15 (2.59) N= 24				
							4905: USA	**4905:** Central line maintenance simulation-based mastery learning (SBML) intervention to evaluate and train nurses in 5 different aspects of central line maintenance tasks including (a) medication administration, (b) injection cap (needleless connector) changes, (c) tubing changes, (d) blood drawing, and (e) dressing changes.	**4905** N= 49	**4905**: N/A	**4905:** Performance on skills assessed improved for all tasks on the post-test. At posttest, individual scores for each task improved from a median of 30.4% to 70.3% for the tasks on the pretest to 100% on the post-test. (median differences of 69.6 to 29.7 improvement).		**4905:** Barsuk et al., 2015
							6138: USA	**6138:** CVAD dress rehearsal program - The nurse was instructed to assume that the mannequin was a patient waiting for a dressing change and perform a simulated CVAD dressing change on the CVAD skills trainer. The clinical educator directly observed and assessed psychomotor skill performance. Upon completion of the simulated dressing change, the clinical educators provided a structured debriefing (Plus-Delta approach).	**6138:** The proportion of the nurses who were able to complete the dress rehearsal without any prompts was significantly larger after mastery learning strategy was implemented. Observed dressing	**6138:** Of the 587 (24%) dressing changes performed by nurses who did not complete a CVAD dress rehearsal, 122 (21%) required a corrective prompt to	**6138** The proportion of nurses who were able to complete the dress rehearsal without any prompts was higher after mastery learning. Of 2469 real-patient CVAD dressing changes observed, dress rehearsal trainees required fewer corrective prompts (9% vs. 21%,		**6138:** Scholtz, Monachino, Nishisaki, et al., 2013

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								changes: 1882 (76%) were performed by nurses who indicated that they had completed a CVAD dress rehearsal; 165 (9%) required a corrective prompt to complete the dressing change.	complete the dressing change	difference of 12%). During observed dressing changes, nurses who had completed the mastery training program required less prompts than those that had completed the program .		**1226:** Hernández-Padilla et al., 2016
							1226: Spain	**1226**: A 5-hour simulation-based workshop in arterial puncture for arterial blood gas (ABG) analysis. The educational intervention started with a 5-minute introduction on the session's aims, learning outcomes and structure. Then, all attendees were shown a 10-minute video lecture on arterial puncture for ABG analysis, which was followed by two flawless modelling examples performed by the facilitator. Finally, students were paired up in dyads and the last 50 minutes of the workshop were dedicated to self-directed simulated practice.	**1226** Skills in arterial puncture: ≥70% achieved in Total APSAT n(%): pretest: 4(4.7) posttest: 74(86)	**1226:** N/A	**1226**: Participation in a 1.5-hour simulation-based workshop resulted in a higher proportion of students achieving and demonstrating adequate levels of knowledge, skills, self-efficacy and overall competence. Pretest to posttest scores improved by 70 points.		
							2193: USA	**2193**: Participants completed a 2-hour curriculum consisting of watching video on the indications, contraindications, complications of ultrasound-guided intravenous catheter insertion and how to perform the procedure. This was followed	**2193**: n=76 The overall median pretest score was 21 checklist items	**2193**: N/A	**2193:** Post-test scores were higher than pre-test scores after implementing a		**2193:** Ballard et al., 2020

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								by deliberate practice using live models (their peers) for ultrasound scanning and simulator for ultrasound-guided intravenous catheter insertion. Finally, all participants were required to meet or exceed a minimum passing standard on a simulated skills post-test using the same skills checklist.	correct (IQR 19-22) and 24 (IQR 24-25) on the post-test.		simulation program.		
							2438: India	**2438:** The intervention was simulation training for PVAD insertion for all nurses and doctors. This activity was done as part of the infection control activity of the unit. All staff nurses and junior resident doctors posted in the NICU at the point of training were included in the study.	**2438:** n (first training)=29 n (second training)=10 Pre-test score first training mean score 29.9 ± 10.39 second training 395 ± 4.503 MD -9.5 Post-test score first training 42.66 ± 2.72 second training 44.70 ± 1.16, MD -2.045	**2438:** N/A	**2438:** There was an increase from pre-test to posttest scores in the first training. The mean scores between the first and second training also improved.		**2438:** Balachander et al, 2020
							3383: Austria	**3383:** Skills Training Program Session Prior to the skills training session, participants were required to complete a questionnaire assessing their level of training (i.e., resident, fellow, or consultant) and proficiency with ultrasound (e.g., performance of ultrasound at the bedside) and CVAD. Afterwards, the instructor briefly demonstrated the inplane (IP) and out-of-plane (OOP) approaches of CVAD placement for the 4-mm tube without	**3383:** All participants (n = 39) Mean failed attempts In-Plane 2 mm Pre 2.1 (0–3) Post 1.1 (0–3) In-Plane 4 mm	**3383:** NA	**3383:** The number of successful cannulations on the first attempt for all four methods was higher after than before the teaching course.		**3383:** Wagner et al., 2018

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							4261: Argentina	providing explanations. During the practical pre- and postteaching sessions, each participant attempted ultrasound-guided CVAD placement and insertion of the guide-wire into the small (ID 2 mm) and large (ID 4 mm) tubes using both the IP and OOP approaches. The duration of the teaching course was approximately 30 minutes. **4261:** The course consisted of three training phases: an e-learning phase, a simulation-based hands on workshop phase, and an observational learning phase. These were combined with sequential assessments to evaluate whether and to what extent trainees achieved learning goals and how they progressed throughout the course. Simulation-based hands on workshops consisted of deliberate trainee practice with direct supervision and constant feedback. For peripheral intravenous cannulation, male multi-venous PVAD training arm kits were used. Cannulation techniques were demonstrated once and then 2 h deliberate practice with feedback followed.	Pre 0.8 (0–3) Post 0.4 (0–3) Out-of-Plane 2 mm Pre 1.8 (0–3) Post 1.2 (0–3) Out-of-Plane 4 mm Pre 0.6 (0–3) Post 0.3 (0–3) **4261**: Scores mean (SD) PVAD insertion Checklist scores: stage 1: 62.2 ± 10.3 stage 2: 71.7 ± 7.8 stage 3: 93.9 ± 3.9 GRS Scores: stage 1: 56.1 ± 10.4 stage 2: 77.4 ± 13.4 stage 3: 89.4 ± 9.7	**4261:** N/A	**4261:** Checklists and GRS scores improved between stage 1 and 2 as well as stage 2 and 3.		**4261:** Sanchez Novas et al., 2020

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							6168: Egypt	**6168:** The knowledge and simulation training were divided into 4-sessions, 40–50 min each. Two sessions were theoretical background: anatomy of blood vessels, and peripheral intravenous cannula insertion and maintenance care. The teaching methods were lectures, handouts, charts, and a printed Arabic illustrated guidebook. Two structured simulation-based learning sessions on PVAD insertion and care skills were conducted. A mannequin training arm venipuncture model was used for training.	**6168**: n=150 Baseline Insertion of peripheral cannula Competent n (%): 30 (20%) Care of peripheral cannula: 36 (24%) total practice score: 23 (15.3%) Post-training Insertion of peripheral cannula: 109 (72.7%) Care of peripheral cannula: 112 (74.7%) Total practice score: 104 (69.3%) Reassessment after 2-months Insertion of peripheral cannula: 105 (70%) Care of peripheral cannula: 116 (77.3%)	**6168:** NA	**6168:** Post-training assessment, knowledge, attitudes, and skill competency were improved for the 150 nurses.		**6168:** Hassanein et al., 2021

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							6685: USA	**6685:** The course focused on US guided PVAD insertion. Nurses watched a step-by-step instructional video, followed by a recorded didactic lecture including a discussion of the current evidence-based guidelines. Next, nurses participated in deliberate practice on the simulator with feedback from an instructor.	total practice score: 107 (71.3%) **6685:** n=238 Median checklist scores: pre: 6.0 [IQR = 4.0–9.0 post: 29.0, IQR = 28–30	**6685:** NA	**6685:** US guided PVAD insertion checklist scores increased from pre to post intervention.		**6685:** Amick et al, 2021
Provider attitude/confidence (Assessed using: confidence likert scales, Confidence C-scale, self-reported comfort survey, Arterial Puncture Self-Efficacy Scale (APSES))													
4	RCT	Very serious[d]	Serious[e]	Not serious	Serious[f]	None	**458:** Canada	**458**: PVAD insertion education through access to our e-learning module through the learning management system used for teacher–student communication and	**458** N=34 Mean pre-confidence	**458** N= 50 Mean preconfiden	Overall, results for provider confidence and attitude were mixed. There was an improvement reported in two studies and no difference reported in one study. Another study reported an improvement when compared pre to post but not when compared to a control group. **458** There was no differences observed	⊕○○○ VERY LOW	**458:** Lindenmaie

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								sharing of course material, in addition to traditional in-class training. The e-learning module consisted of six main sections: Venipuncture Site, Equipment, Preparation, Procedure, Complications, and Continuing Care. Control: The control group was educated using traditional in-class training, consisting of readings, lectures, and lab demonstrations.	score (SD):47.1 (16.4) Mean post-confidence score (SD): N=9, 63.1 (5.0)	ce score (SD): 50.1 (13.6) Mean postconfidence score (SD): N=13, 61.8 (8.5)	between the control and study groups for pre- or postconfidence level scores). The difference in mean scores was 16 for the intervention group and 11.7 in the control group, indicating greater improvement in the intervention group .		r et al., 2018
							4302: USA	**4302:** Online learning course with live simulation of PVAD insertion. Control: waitlist served as the control.	**4302:** Confidence mean (SD) range Period 1 40.7 (8.0) 15-50 Period 2 40.5 (11.1) 10-50	**4302:** Confidence mean (SD) range Period 1 38.0 (9.1) 10-50 Period 2 37.1 (9.2) 10-50	**4302:** Confidence improved in the intervention group from pre to post but not in the control group. Difference in mean scores was 2.7 higher in the intervention group during period 1, and 3.4 higher during period 2 compared to the control group.		**4302:** Keleekai et al., 2016
							12935: Spain	**12935:** Simulation group: In the simulation method of teaching students practiced the PVAD insertion procedure in a clinical laboratory (practice room) on infant mannequins under supervision of the researcher. Demonstration group: In the demonstration group, the researcher first discussed the aim and requirements of	**12935:** Simulation N=16 Before mean (SD) 0.51 (0.81) 2.07, 2.93 After mean (SD) 3.43 (0.64) 3.09, 3.78	**12935:** N=15 Before mean (SD) 3.01 (1.07) 2.41, 3.60 After mean (SD) 3.18 (0.84) 2.71, 3.65	**12935:** Confidence was higher in the demonstration and simulation groups than in the control group. The mean difference in the intervention group was 2.92 higher		**12935:** Valizadeh, Amini, Fathi-Azar, et al., 2013

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№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
								the procedure with the students and then displayed the procedure on a mannequin for 20 minutes. Then, each student practiced the procedure for 25 minutes on the mannequin. Control: traditional lecture and theory-based method.	Demonstration N= 14 Before mean (SD) 2.60 (0.77) 2.15, 3.04 After mean (SD) 3.18 (0.62) 2.82, 3.54		from before to after, vs. 0.18 higher in the control group, indicating greater improved confidence in the intervention group.		
							5745: Turkey	5745: Prior to the implementation, the researcher gave all the students who participated in the study a 30-minute theoretical didactic lecture on PVAD catheter intervention at the same time. Virtual intravenous simulation (VIS) group: Following the traditional method, first, the VIS system was introduced to the students by the instructor and information on the present scenarios was given. Video group: Following the traditional method, the students were first shown a training video on the PVAD catheterization skill in a classroom setting.	5745: n=30 Mean score: 7.2 SD: 2.82	5745 n=30 Mean score: 6.83 SD: 2.21	5745: Confidence scores were marginally higherin the simulation group compared to the video group.		5745: Ismailoglu et al., 2020
19	Non-RCT, pre/post studies	Very serious[g]	Serious[h]	Not serious	Not serious	None	**3729:** USA	**3729** A standard curriculum for the placement of an internal jugular CVAD was developed, designed to be taught	**3729:** Comfort with ultrasound	**3729:** N/A	Provider attitude and confidence was improved in all studies but one, when compared from pre to post intervention. **3729:** Three different measures of comfort	⊕○○○ VERY LOW	**3729:** Grudziak et al., 2016

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
								during one 3-hour session. Each class began and ended with tests and questionnaires, assessing intern comfort with ultrasound, their knowledge of anatomy, ultrasound basics, indications for CVAD placement, technique, and potential complications. Participants viewed The New England Journal of Medicine central line insertion video. They were then divided into four hands-on stations, as follows: Ultrasound session, Kit familiarization and sterile technique station, Demonstration of central line insertion, Trainee placement of an ultrasound-guided internal jugular CVAD. **4886:** Providers participated in a tiered educational module designed to teach safe US-guided subclavian vein (SCV) CVAD insertion. The education consisted of a multimedia didactic presentation and a hands-on simulation session, including US anatomy on live subjects and anatomical model-based SCV CVAD insertion.	basics: 2.70 ± 1.13 to 4.10 ± 0.6, P < 0.001 Interpretation of ultrasound findings: 2.51 ± 0.8 to 4.14 ± 0.5, comfort for central line placement with ultrasound: 2.29 ± 1.18 to 3.61 ± 0.79 **4886:** Post module confidence survey: SCV CVAD insertion in general: 60% participants more confident, SCV CVAD insertion using the landmark approach: 38% participant more confident, SCV CVAD insertion using US-guided approach: 86% participants	**4886:** N/A	increased significantly from pre to post intervention. **4886:** Participants were more confident post module in 4 measures of confidence.		**4886:** Bayci, Mangla, Jenkins, et al., 2015

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
							12878: USA **2818:** USA	**12878:** Residents attended a formal didactic training during which they watched a video presentation on ultrasound-guided central venous access. They subsequently underwent 90- minute skills sessions on Blue Phantom trainer models that were designed to simulate ultrasound-guided central venous access. **2818:** A single, 60- to 90-minute US-guided CVAD training session conducted at the Saint Louis University Clinical Simulation Center. Training was conducted in a small-group format with one to three residents per session. At each session, residents were shown a 10-minute instructional video on US guided CVAD insertion from the Videos in Clinical Medicine series from the New England Journal of Medicine (14). One of the investigators (S.M.T.) then led a hands-on training session using a SonoSite 180 Plus portable US with	more confident, use of US to image the SCV: 74% participants more confident, **12878:** pre/post scores (N(%)): Q1: 30 (44.8), 64 (95.5), Q2: 37 (55.2), 65 (97.0), Q3: 42 (62.7) 63 (94.0), Q4: 45 (67.2) 62 (92.5), Q5: 55 (82.1) 66 (98.5), Q6: 59 (88.1) 66 (98.5), Q7: 31 (46.3) 58 (86.6), **2818:** Self-confidence, mm Median Baseline: 8.0 Post Training: 52.0 3 months: 61.0	**12878**: NA **2818:** NA	**12878:** Residents confidence scores increased across all questions. **2818:** Provider confidence increased immediately post intervention as well as at 3 months follow-up (median difference of 44 higher post-training,).		**12878:** Jagneaux et al., 2017 **2818:** Thomas et al., 2013

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
								L38/10–5 megahertz linear transducer (SonoSite, Bothell, WA) and a VascularAccessChild task trainer (Simulab, Seattle, WA).					
							13101: USA	**13101:** Simulation training which included 4 procedural skills: intubation, arterial line placement, lumbar puncture, and CVAD insertion. Each student spent on average 40 minutes at each of the 4 stations: intubation, arterial line placement, lumbar puncture, and central line insertion. There were 2 residents present at each station to train 1 medical student at a time. One resident explained the critical steps, whereas another demonstrated how to perform the procedure. Then, students were given, on average, 25 minutes to practice each procedure while they received feedback from residents. Each medical student rotated through all 4 stations.	**13101** n=24 confidence on simulator (mean (SD)) Arterial line placement: pre-test: 1.83 (0.96) post-test: 4.29 (0.86) Central line: pre: 1.79 (0.93) post: 4.13 (0.99) confidence on real patient (mean (SD)) Arterial line: pre: 1.13 (0.34) post: 3.08 (1.02) Central line: pre: 1.17 (0.38) post: 2.92 (1.02)	**13101:** NA	**13101:** Medical students reported higher confidence scores after training, in performing all 4 procedures on a task trainer/ simulator as well as on a real patient.		**13101:** Toy et al., 2016
							6138: USA	**6138**: CVAD dress rehearsal program - The nurse was instructed to assume that the mannequin was a patient waiting for a dressing change and perform a simulated CVAD dressing change on the CVAD skills trainer. The clinical educator directly observed and assessed psychomotor skill performance. Upon	**6138** Provider self-confidence to perform CVAD dressing change skills increased	**6138:** N/A	**6138:** Provider confidence increased from pre to post-intervention (mean difference of 0.5).		**6138**: Scholtz, Monachino, Nishisaki, et al., 2013

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
								completion of the simulated dressing change, the clinical educators provided a structured debriefing (Plus-Delta approach).	after dress rehearsal (before, 4.1 [0.8] vs. after, 4.6 [0.6])				
							1226: Spain	**1226**: A 5-hour simulation-based workshop in arterial puncture for ABG analysis. The educational intervention started with a 5-minute introduction on the session's aims, learning outcomes and structure. Then, all attendees were shown a 10-minute video lecture on arterial puncture for ABG analysis, which was followed by two flawless modeling examples performed by the facilitator. Finally, students were paired up in dyads and the last 50 minutes of the workshop were dedicated to self-directed simulated practice.	**1226:** Self-efficacy in arterial puncture: ≥70% achieved in Total APSES: pretest (n(%)): 18(20.9) posttest: 81(94.2) p=<0.05	**1226:** N/A	**1226:** participation in a 1.5-hour simulation-based workshop resulted in a higher proportion of students achieving and demonstrating adequate level of self-efficacy. There was a 73.3% improvement.		**1226**: Hernández-Padilla et al., 2016
							86: Jordan	**86:** Educational program: The program was implemented over a 2-week period by trained and expert clinical educators under the supervision of the primary investigator. The program consisted of 25 actual hours (15 theoretical hours and 10 clinical training hours). Participants also had hands-on experience. They practiced caring of CVADs on mannequins under the supervision of the research team. Control: did not receive education	**86:** Self-confidence M = 61.50, SD = 14.20	**86:** Self-confidence M = 35.50, SD = 7.20	**86:** The intervention group had high self-confidence than the control group that did not receive the intervention (mean difference of 26 higher in the intervention group).		**86:** Sharour et al., 2018
							4021: USA	**4021:** Residents completed four simulated clinical procedures: urinary	**4021** Confidence	**4021:** N/A	**4021:** There was no difference in confidence		**4021:** Jones et al., 2017

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
								catheterization, subclavian central line insertion, bowel anastomosis, and laparoscopic ventral hernia (LVH) repair. Residents were provided with clinical scenarios and the necessary equipment to complete each procedure successfully.	(estimated from Figure 2) Successfully perform the entire task New Pre 3.0 Post: 3.5 Repeat Pre 3.0 Post 3.5 p=NS		between pre and post intervention for new or repeat students.		
							2113: Scotland	**2113:** The format of the training consisted of a didactic theory based session followed by a hands-on practical workshop using part-task simulation. As the main aspects of catheter maintenance are dressing changes and catheter clearance (flushing), these elements formed the main focus of the practical training. Techniques used included videos, case scenarios and audio response systems. A chest phantom and arm phantom with CVADs present were used to allow the nurses to perform the key elements of dressing and flushing.	**2113** Following the didactic element of the workshop and the hands-on practice with the devices, all nurses stated that both elements of the workshop were useful and had improved their confidence in working with CVADs.	**2113:** N/A	**2113:** Nurses self-confidence increased following the education program [no clear numerical results given].		**2113:** Kelly, Green & Hainey, 2015
							818: Australia	**818:** The USG PVAD training program was delivered in a clinical simulation bay over two hours and consisted of three sections:1 A 30-min didactic session, covering how to identify a vein on ultrasound, and common techniques for inserting PVAD under ultrasound guidance. Both short axis and long axis methods were taught. We educated staff	**818:** Following course attendance, participant's perceived confidence to insert PVADs using USG	**818:** N/A	**818:** Participants confidence increased after participation in the course.		**818:** Archer-Jones et al., 2020

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
								of the evidence-based patient characteristics that make PVAD insertion more difficult, and encouraged early use of ultrasound for these patients. There was no formal difficulty assessment tool or escalation pathway used. A 30-min session of practical vein mapping, where participants were oriented to the machines, identified landmarks, and assessed suitable veins with USS on their fellow trainees. A 60-min practical session where ultrasound was used to place PVADs in tissue models made from chicken breasts and fluid-filled balloons.	increased significantly from a median of 1 (interquartile range [IQR] 1–2) to 3 (IQR 3–4; p < .001)), with 43 (38%) respondents, indicating their confidence in USG cannulation was 4 or higher.				
							893: USA	**893:** Cohort A received Vascular Access Experience Training Program Class Topics 1. Overview of our institution's vascular access policy 2. Vascular access device selection 3. Didactic presentation on short PVAD insertion 4. Review of short PVAD algorithm 5. Review of extravasation 6. Hands-on experience with model arm Control: cohort B did not receive education.	**893:** There was a trend toward a higher comfort level in placing short PVADs after participation in the training from baseline to after training to 6 months.	**893:** N/A	**893:** There was an increasing trend of comfort after participating in training.		**893:** Goodfriend et al, 2020
							2193: USA	**2193:** Participants completed a 2-hour curriculum consisting of watching video on the indications, contraindications, complications of ultrasound-guided intravenous catheter insertion and how to perform the procedure. This was followed by deliberate practice using live models (their peers) for ultrasound scanning and simulator for ultrasound-guided intravenous catheter insertion. Finally, all	**2193:** N = 76 precourse self-confidence mean (SD) 3.2 (1.2) postcouse self-confidence	**2193:** NA	**2193:** Confidence scores were higher after completing the simulation course.		**2193:** Ballard et al., 2020

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
								participants were required to meet or exceed a minimum passing standard on a simulated skills post-test using the same skills checklist.	mean (SD) 3.9 (0.7)				
							2426: USA	**2426:** Delivery of the course was performed through two modules—an online eBook 4-h self-paced didactic component, followed by four 1-h stations with mixed fidelity simulation equipment which was performed at the 100 participating facilities. All attendees completed a total of 8 h of learning. The 4 h of clinical practice components were separated into readily achievable skill stations and practiced to the point of individual mastery deemed by the instructors. Mixed fidelity simulation equipment was available at each station.	**2426:** Total N=1238 Physician N= 688 pre-confidence 5.2 post-confidence 8.1 Non-physician N= 550 pre-confidence 3.2 post-confidence 7.7	**2426:** NA	**2426:** Confidence improved in both physician and non-physician groups after practical education.		**2426:** Spencer and Bardin-Spencer, 2020
							5555: Saudi Arabia	**5555:** The course was conducted in two sessions, scheduled one week apart, offering a total of eight skills as given below. During the first session, the residents were trained in four techniques, namely: 1) lumbar puncture and cerebrospinal fluid (CSF) interpretation, 2) oral intubation, 3) bone marrow aspiration, and 4) critical airway management. During the second session, conducted a week later, they were trained for the remaining 4 techniques: 1) chest tube insertion, 2) pleural tap, 3) insertion of central venous pressure line, and 4) arthrocentesis. The residents were divided into 4 groups. The skills were set in a series of 4 stations.	**5555**: Median confidence score pre-course central line insertion (median=3.00, IQR [1-3]) post-course central line insertion (median=4.00, [4-4])	**5555:** NA	**5555:** Confidence scores improved after course compared with before.		**5555:** AlShammari et al., 2018
							7179: USA	7179: The course included multiple two-hour sessions that were conducted over two separate days with each session including three of six procedural skills:	7179: n=49 (pre questionnaire)	7179: NA	7179: confidence scores improved from pre to post intervention for		7179: Sattler et al, 2020

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
								lumbar puncture, arterial line, central line, thoracentesis, paracentesis and arthrocentesis. Skills education and training were performed on a combination of high-fidelity SimMan3G mannequins (Laerdal), CentraLineMan system (Simulab), and Ultrasound ArteriaLine Trainer (Simulab).	n=36 (post questionnaire) Confidence score central line: pre simulation 2.86±1.08 vs. post simulation 3.5±1.02 arterial line: pre 2.48 ± 1.06 post 3.39 ± 1.04		both central line and arterial line insertion.		
							6685: USA	6685: The course focused on US guided PVAD insertion. Nurses watched a step-by-step instructional video, followed by a recorded didactic lecture including a discussion of the current evidence-based guidelines. Next, nurses participated in deliberate practice on the simulator with feedback from an instructor.	6685: n=238 Pre mean self-confidence 2.32 (1.17) Post mean self-confidence: 3.85 (0.73)	6685: NA	6685: Self-confidence increased from pre to post education.		6685: Amick et al, 2021
							6168: Egypt	6168: The knowledge and simulation training were divided into 4-sessions, 40–50 min each. Two sessions were theoretical background: anatomy of blood vessels, and peripheral intravenous cannula insertion and maintenance care. The teaching methods were lectures, handouts, charts, and a printed Arabic illustrated guidebook. Two structured simulation-based learning sessions on PVAD insertion and care skills	6168: n=150 Baseline Positive: 29 (19.3%) Negative: 121 (80.7%) Post-training Positive: 72 (48%) Negative: 78 (52%)	6168: NA	6168: The total attitude score improved in the reassessment after 2-months and post training assessment, compared to baseline.		6168: Hassanein et al., 2021

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
								were conducted. A mannequin training arm venipuncture model was used for training.	2 months post: Positive: 85 (56.7%) Negative: 65 (43.3%)				
Complications (Assessed with: adverse events (including pneumothorax, transient arrhythmia, arterial puncture, blood stream infection, and improper line position on radiograph), catheter-associated bloodstream infection, catheter malposition, arterial puncture, or hematoma, PICC complications, hospital wide CLABSI data)													
1 [i]	Systematic Review and Meta-analysis of randomized controlled trials and prospective 2-group cohort studies	Not serious[j]	Not serious	Not serious	Serious[k]	None					The systematic review demonstrated there were less adverse events reported in the intervention group than the control group. 2 additional RCTs were identified, and complications (blood stream infection) was reduced in one study in the group that received education and was not different between groups in another study. 4 additional non-RCTs were identified, and complications decreased from pre to post	⊕⊕⊕○ MODERATE	

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
							5861: Multiple **5040:** USA	**5861:** Simulation training for CVAD insertion for medical residents or fellows. Control: apprenticeship or lecture training for CVAD insertion. **Additional RCTs identified:** **5040**: Standard training plus simulation-based training: In addition to standard training, intervention group subjects received 1 to 2 hours of individualized instruction and supervised practice on a venous access simulator with an experienced pulmonary and critical care or emergency medicine attending physician. Control: Standard training: 5- to 60-minute didactic lecture, an interactive online module structured around an 18-minute video, familiarization with our hospital's CVAD placement checklist, and instruction by an upper-level resident, fellow or attending during all actual procedures.	**5861:** 513 CVAD insertions procedures (performed by 267 residents) Adverse events: 3.8% **5040** n= 49 insertions Catheter malposition 5 (11.4) Catheter-associated infection 1 (2.6) Pneumothorax 0 (0) Death 0 (0) 0 Total CVC attempts with Q1 complication 11 (22.9)	**5861:** 429 CVAD insertion procedures (performed by 220 residents). Adverse events: 4.9% **5040** n=38 insertions Catheter malposition 2 (6.1) Catheter-associated infection 1 (3.2) Pneumothorax 0 (0) Death 0 (0) Total CVC attempts with Q1 complication 5 (13.9)	implementation of practical education. **5861:** There were less adverse events reported in the intervention group than the control group RR 0.76 [0.41-1.39]. For every 100 people who receive intervention, 1 less people will have adverse events (ranges from 3 less to 2 more). . **5040** There were no differences in individual complications (catheter-associated bloodstream infection, catheter malposition, arterial puncture, or hematoma) or overall complication rates between study groups. RR 1.71 [0.65-4.49]. For every 100 people who receive		**5861:** Madenci, Solis & de Moya, 2014 **5040**: Peltan, Shiga, Gordon, et al., 2015

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
											intervention, 9 more people will have complications (ranges from 45 more to 5 less).		
							2215: USA	**2215**: The intervention group performed a central line dressing change with CVAD standard prepackaged dressing change kits on a low fidelity mannequin with a subclavian central catheter in place. The mannequin was placed on a cart and taken to the bedside as the nurses worked in the PICU. Control: standard training, with a demonstration, self-study poster and test	**2215**: mean of 0.6 ± 1.6 BSIs per 1000/CVAD days for the last six months and immediately following the study (p = 0.034)	**2215:** mean of 1.9 ± 2.2 BSIs per 1000/CVAD days for the six months pre-study	**2215:** The mean number of BSI was lower in the 6 months immediately following the study compared to the six months prior to the study (mean difference of 1.3 lower in the intervention group)		**2215**: Hebbar, Cunningham, McCracken, et al., 2015
								Additional non-RCTs identified:					
							6138: USA	**6138:** CVAD dress rehearsal program - The nurse was instructed to assume that the mannequin was a patient waiting for a dressing change and perform a simulated CVAD dressing change on the CVAD skills trainer. The clinical educator directly observed and assessed psychomotor skill performance. Upon completion of the simulated dressing change, the clinical educators provided a structured debriefing (Plus-Delta approach).	**6138:** Pre-implementation: 5.3/1000 CVC line days (January 2007 to October 2008) Post-implementation: 2.9/1000 line days (November 2008 to July 2010)	**6138:** NA	**6138:** The overall CLABSI rate decreased by 2.4/1000 line days after program implementation .		**6138**: Scholtz, Monachino, Nishisaki, et al., 2013
							1718: UK	**1718**: The programme was designed in three parts, with each session lasting around 90 minutes. The first part of the	**1718:** Complications pre-	**1718:** NA	**1718:** Rates of complication (occlusion)		**1718:** Purran, Weller & Kerr, 2014

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
								training included a 20-minute presentation covering the theoretical aspects of PICC care and management. The second part of the training was a practical demonstration on a life-sized anatomical human arm model. The final part of the training was the assessment process; once the attendees had observed the practical procedure, they were divided into two groups to demonstrate what they had learned on the human arm model.	implementation:14/67 patients (april 2011 to June 2012) Post-implementation: 11/228 patients (July 2012 to December 2014)		decreased post-implementation.		
							2438: India	**2438:** The intervention was a simulation training for PVAD insertion for all nurses and doctors. This activity was done as part of the infection control activity of the unit. All staff nurses and junior resident doctors posted in the NICU at the point of training were included in the study.	**2438:** BSI/1000 patient days pre 5.5 ± 4.13 post 1.65 ± 2.16 PLABSI/1000 peripheral line days pre 10.8 ± 8.4 post 2.37 ± 3.33 CLABSI/1000 central line days pre 9.11 ± 8.9 post 18.34 ± 27.31	**2438:** NA	**2438:** There was a significant reduction in BSI rate. The PLABSI per 1000 peripheral line days were significantly lower 6 months after the training. However, there was no difference in CLABSI rates.		**2438:** Balachander et al, 2020
							6959: Brazil	6959: The training was outlined based on current evidence regarding the insertion of central venous access devices, and provided for the new residents (first-year residents). It was divided into three steps during the first month of residence: a 60-min lecture, practical training in mannequins via anatomical landmarks (location of jugular, subclavian, and femoral veins)	6959: n=748 CVAD insertions in 2016 (year with training) Any complication 2016: 40 (5.3%)	6959: n=754 CVAD insertions in 2015 (year without training)	6959: The rate of all complications decreased after implementing training. The largest improvement was in infection rate.		6959: Hanauer et al., 2020

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
								plus ultrasound handling, and a 10-question theoretical test.	OR 0.732 (0.480–1.117) Mechanical complication 2016: 20 (2.7%) OR 0.996 (0.727–1.363) Infection 2016: 22 (2%) OR 0.784 (0.642–0.957)	Any complication 2015: 54 (7.2%) Mechanical complication 2015: 20 (2.7%) Infection 2015: 38 (5%)			
Insertion related complications (Assessed with: immediate complications (hematoma, arterial puncture))													
1	RCT	Not serious[l]	Not serious	Not serious	Very serious[m]	None	**5040:** USA	**5040** Standard training plus simulation-based training: In addition to standard training, intervention group subjects received 1 to 2 hours of individualized instruction and supervised practice on a venous access simulator with an experienced pulmonary and critical care or emergency medicine attending physician. Control: Standard training: 5- to 60-minute didactic lecture, an interactive online module structured around an 18-minute video, familiarization with our hospital's CVAD placement checklist, and instruction by an upper-level resident, fellow or attending during all actual procedures.	**5040**: n= 49 insertions Arterial puncture: 2 (4.1) Hematoma: 5 (10.2)	**5040**: n= 38 insertions Arterial puncture: 2 (5.4) Hematoma: 2 (5.3)	**5040:** No difference in arterial puncture was observed between groups. There were more cases of hematoma in the intervention group than the control group. Arterial puncture: RR 0.78 [0.11-5.26] For every 100 people who receive intervention, 1 less people will have arterial puncture	⊕⊕○○ LOW	**5040** Peltan, Shiga, Gordon, et al., 2015

Quality assessment							Summary of Findings		No. of Participants		Reported Effects/Outcomes	Certainty	Reference
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Country	Intervention	Intervention	Control			
											(ranges from 4 less to 21 more). Hematoma: RR 1.94 [0.40-9.45] For every 100 people who receive intervention, 5 more people will have hematoma (ranges from 3 less to 42 more).		

Acronyms & Explanations

CVAD = central venous access device

CI = confidence interval

PICU = pediatric intensive care unit

ABG = arterial blood gas

US = ultrasound

SCV = subclavian vein

PVAD: peripheral vascular access device

CLABSI: central line associated bloodstream infection

PLABSI: peripheral line associated blood stream infection

USGPIV: Ultrasound-Guided Peripheral Intravenous

N/A = not applicable

[a] Surrogate outcomes of global competency scales or checklists were also included for this outcome to capture both VAD insertion and management.

[b] One systematic review was included comprised of 3 randomized controlled trials and 2 prospective 2-group cohort studies. An additional 8 RCTs and 15 non-RCTs were identified to support the body of evidence, however they were not GRADEd separately.

[c] No serious risk of bias reported in the review. The review assessed the 3 included RCTs to be high quality based on the Critical Appraisal Skills Program checklist for RCTs. The review scored both non-randomized studies 8 out of a possible 9 using the Newcastle-Ottawa Scale. Additionally, the review was rated a high quality using the ROBIS tool.

[d] Studies were assessed for risk of bias using the Cochrane risk of bias 2.0 tool. All studies were rated as *high* risk of bias due to unblinded measurement of outcomes and no details about allocation concealment. We downgraded by 2.

[e] There was inconsistency in the measurement of provider attitude or confidence (likert scale, checklist). There was also inconsistency in the results as the results were mixed between null and positive results. We downgraded by 0.5 for each issue for a total of 1.

[f] The sample size was less than the optimal 400. We downgraded by 1.

[g] Studies were assessed for risk of bias using the ROBINS-I tool. All studies were single arm quasi-experimental studies that rated as critical or serious due to lack of controlling for confounding and unblinded outcome assessment or missing data. We downgraded by 2.

[h] There was inconsistency in the measurement of provider attitude or confidence (likert scale, checklist). We downgraded by 0.5.

[i] One systematic review and meta-analysis of 3 randomized controlled trials and 2 prospective 2-group cohort studies was included for this outcome. An additional 2 RCTs and 4 non-RCTs were identified to support the body of evidence, however they were not GRADEd separately.

[j] No serious risk of bias reported in the review. The review assessed the 3 included RCTs to be high quality based on the Critical Appraisal Skills Program checklist for RCTs. The review scored both non-randomized studies 8 out of a possible 9 using the Newcastle-Ottawa Scale. Additionally, the review was rated a high quality using the ROBIS tool.

[k] The sample size was less than the optimal 400. We downgraded by 1.

[l] Study was assessed for risk of bias using the Cochrane risk of bias 2.0 tool. There were some concerns of risk of bias due to no information on allocation concealment in the study. As this was the only concern we downgraded by 0.5.

[m] The total number of events was less than the optimal 300 and the confidence interval was wide. We downgraded by 2.