

Evidence-based consensus on the insertion of central venous access devices: definition of minimal requirements for training

N. Moureau¹, M. Lamperti^{2*}, L. J. Kelly³, R. Dawson⁴, M. Elbarbary⁵, A. J. H. van Boxtel⁶ and M. Pittiruti⁷

¹ PICC Excellence Inc., Greenville Hospital System University Medical Center, Hartwell, GA, USA

² Department of Neuroanaesthesia, Neurological Institute Besta, Via Celoria, 11, 20136 Milan, Italy

³ Department of Health, University of the West of Scotland, Glasgow, UK

⁴ PICC Academy, University of the West of Scotland, Concord Hospital, Nashua, NH, USA

⁵ National and Gulf Center for Evidence Based Health Practice, King Saud University for Health Sciences, Riyadh, Saudi Arabia

⁶ Infusion Innovations, Vascular Access Team Utrecht, Utrecht, The Netherlands

⁷ Department of Surgery, Catholic University, Rome, Italy

* Corresponding author. E-mail: doclampmd@gmail.com

Editor's key points

- This review presents consensus on standard minimal requirements for training on central venous access devices.
- An international task force generated an evidence-based consensus.
- The task force proposed 16 recommendations.
- Standardized education, simulation practice, and supervised insertions are the key to ensuring safe and competent practice.

Summary. There is a lack of standard minimal requirements for the training of insertion techniques and maintenance of central venous access devices (CVADs). An international evidence-based consensus task force was established through the World Congress of Vascular Access (WoCoVA) to provide definitions and recommendations for training and insertion of CVADs. Medical literature published from February 1971 to April 2012 regarding 'central vascular access', 'training', 'competency', 'simulation', and 'ultrasound' was reviewed on Pubmed, BioMed Central, ScienceDirect, and Scopus databases. The GRADE and the GRADE-RAND methods were utilized to develop recommendations. Out of 156 papers initially identified, 83 papers described training for central vascular access placement. Sixteen recommendations are proposed by this task force, each with an evidence level, degree of consensus, and recommendation grade. These recommendations suggest central venous access education include didactic or web-based teaching with insertion procedure, infection prevention, complications, care, and maintenance of devices, along with laboratory models and tools for simulation practice incorporating ultrasound. Clinical competence should be determined by observation during clinical practice using a global rating scale rather than by the number of procedures performed. Ensuring safe insertion and management of central venous devices requires standardized education, simulation practice, and supervised insertions.

Keywords: catheter-related infections, prevention and control; catheterization; central venous access; central venous, standards; clinical competence; competency; complications; computer-assisted instruction; consensus; evidence-based medicine; education; GRADE; guideline; humans; infection; internship and residency; programme development; programme evaluation; RAND; supervision; simulation; subclavian vein; training; ultrasound guidance; ultrasonography; vascular access; vascular surgical procedures

Education surrounding the insertion of central venous access devices (CVADs) remains undefined. Training is defined as the acquisition of knowledge, skills, and competence related to a specific activity or procedure. Understanding and establishing the level of education required for safe insertion procedures and management of CVADs is the focus of this publication. There is variability of knowledge and competency among inserters which is represented quantitatively by the number of complications that occur from patient to patient.¹ It has been demonstrated that a systematic training process, including ultrasound instruction before

patient insertions, reduces mechanical and infectious complications.²⁻⁶

Current CVAD literature related to training, supervision, and competence acquisition does not define a fully standardized programme for trainees; nor does it establish guidelines for supervisors. No standard didactic or simulation training is currently required before the insertion of CVADs by clinicians in training other than supervision of an unspecified number of insertions. The supervision requirements do not specify the role, experience, or competence of the supervisor.

Healthcare workers involved in the placement of CVADs using ultrasound guidance need appropriate education and training to ensure patient safety and avoid major complications with the insertion of CVADs.⁷⁻¹⁰ Basic knowledge of anatomy, ultrasound physics and imaging, and infection prevention strategies have been proposed for the standard didactic education. These recommended topics are necessary for adequate understanding and safety of the insertion procedure.^{11 12}

There are two areas of focus to be addressed in any CVAD educational course; insertion and management. The insertion method and site selected affect the amount of risk involved related to trauma, colonization, and the ability to complete therapy successfully. Even the decision to choose a particular type or size of device contributes to the risk for infection and the development of thrombosis.^{8 13-15} Furthermore, there is a synergistic effect in which risk factors for one event may impact the incidence of other complications. For example, there is a direct association between catheter-related thrombosis and infection; the incidence of thrombosis increases with multiple insertion attempts which then increases the risk of infection.⁸

A growing body of knowledge points to simulation training as a key to safe patient insertions^{3 16} by advocating competency-based education and multidisciplinary practice models.¹⁷ Application of ultrasound guidance with CVAD insertions reduces insertion-related complications, increases success, and establishes a process for vascular access based on safety and vein preservation. The safety afforded with ultrasound-guided insertions dictates that this technique be included in the educational process of any central venous device placement.^{18 19} Educational processes and supervised insertions are needed for healthcare providers to establish credentialing for CVAD procedures in any healthcare facility.^{11 20} In keeping with recommendations and guidelines, standard education on principles of insertion and infection prevention practices should be provided to all CVAD inserters initially and at least annually.⁷⁻⁹

To address the issue of standardization of CVAD training, a task force was formed by the World Congress of Vascular Access (WoCoVA) with a goal to create evidence-based recommendations for minimal education and training for central venous device insertion and management.

Methods

Eight worldwide educational course experts on vascular access device placement, not supported by industry, were identified by WoCoVA in 2010 to create an evidence-based consensus²¹ on minimal requirements in training in central venous device placement. These experts qualified based on a minimum authorship of two peer-reviewed articles published in the past 10 yr related to this topic, and additional activities including teaching and speaking on vascular access. Seven panellists accepted who then created a roadmap to achieve a final document with evidence-based recommendations on CVAD education. A search of medical

literature was performed using two methods to avoid selection bias: the first method entailed a systematic search by all panel experts. Medical subject headings including 'central vascular access', 'training', 'competency', 'simulation', 'infection', 'complications', and 'ultrasound' were searched on Pubmed, BioMed Central, ScienceDirect, and Scopus databases including articles dated from February 1971 to April 2012. A professional medical librarian from the National Neurological Institute Besta in Milan supplemented this first search with a hand search based on selected articles from the expert panel. The second method entailed a systematic search of English language articles from the same period by an epidemiologist (M.E.) assisted by a professional librarian. The two bibliographies were then compared for thoroughness and consistency. Out of 156 papers initially identified, 83 papers were linked with training in vascular access. The GRADE and the GRADE-RAND methods were utilized to develop the 16 recommendations.²²⁻²⁴ The GRADE method utilized two phases in the development of these evidence-based recommendations. This methodology has been previously detailed in the published literature. There are 15 factors that are typically considered in the GRADE process. The level of evidence quality was scored according to nine factors. The final classification of evidence quality was divided into three levels (A, high; B, moderate; C, low). The transformation of evidence into a recommendation was a function of the panel evaluation of five factors. The GRADE system has not standardized this decision-making process of the expert panel. In an effort to standardize this evidence processing, the methodology committee of this working group selected the Rand Appropriateness Method (RAM). The panellists held conference calls in which they discussed the topics of the Consensus and voted separately on all recommendations using a web-based voting system. The voting process required expert decisions utilizing GRADE factors such as outcome importance and evidence-to-recommendation transformers. This process provided a structured and validated method for expert panel activities. In addition, it standardized statistical methodology for determining the degree of agreement to serve as a foundation for deciding about the recommendation grade (weak vs strong).

Results

Eighty-three articles were analysed and voted upon according to the GRADE factors. Sixteen recommendations were proposed, each with an evidence level, degree of consensus, and recommendation grade (Table 1).

Adult learning methods

These teaching methods follow a consistent scientific approach or educational style to engage the student's mind.

The approach to teaching and learning with regard to CVAD insertion should be underpinned by a constructivism or adult learning philosophical framework such as experiential learning.

Table 1 List of evidence-based recommendations on training on the insertion of CVADs

Section code	Recommendation	Level of evidence	Degree of consensus, strength of recommendation
W_R1 Didactic Educational Content	Education on anatomy and physiology is relevant to ultrasound guidance, vein assessment, and selection, and complications that may occur at any possible CVAD insertion site. Specific knowledge of vessel characteristics, skin, peripheral nervous, respiratory, and cardiac systems is included. Insertion sites for central venous access include: upper arm, chest, neck, and inguinal. Anatomy and physiology include both typical and variant presentations	C	Perfect consensus, strong
W_R2 Didactic Education on Ultrasound-guided Technique	Education for using ultrasound for vein access and assessment is a component of any CVAD insertion course. Education includes: physics of ultrasound, image optimization, image analysis, anatomical assessment of both normal and variant anatomy, and simulation skills training. Landmark techniques are also components of CVAD education programmes in case circumstances arise that do not permit the use of ultrasound. Educational programmes emphasize the indisputable benefit of ultrasound for CVAD insertion	B	Perfect consensus, strong
W_R3 Education on Tip Placement	Education on CVAD tip placement is based on three essential features that reduce risk: high blood flow, parallel positioning to the vessel, and pulsatility of blood flow. To achieve these three ideal factors of tip location, the tip of the CVAD is at or near the cavo-atrial junction	C	Very good, strong
W_R4 Infection	Education to prevent catheter-related primary bloodstream infections focus on pre, intra, and post-procedure insertion, care, and maintenance. Three main sources of infection contamination: the catheter-skin junction (extraluminal), the needleless connector and hub (intraluminal), and iatrogenic contamination. Topics to include: site selection, device selection, indications for use, maximal barrier precautions, hand washing, skin antisepsis, and the use of central line checklists are included in CVAD insertion course. Observers, empowered to stop a procedure if contaminated, are part of the implementation of the educational programme	A	Perfect consensus, strong
W_R5 Education on Catheters	Topics in educational programmes include catheter: material composition, size, features, and number of lumen. Focus education on various risks vs benefits of catheter features for both short- and long-term use	C	Perfect consensus, strong
W_R6 Education on Procedure	Any central venous access educational programme includes insertion procedure for respective device placement, with both typical and variant scenarios	B	Perfect consensus, strong
W_R7 Education on Care and Maintenance	CVAD care and maintenance is addressed in CVAD education programme. Complications from CVAD use are related to the insertion procedure or from continued care and maintenance of the device	B	Perfect consensus, strong
W_R8 Instructors	Only providers with demonstrated qualification and competency can provide education on CVAD insertion. The basic tenants of qualification and competency are addressed within the content of a CVAD education programme	C	Perfect consensus, strong
W_R9 Ultrasound Simulation	A simulation practice on ultrasound anatomy is included in the curriculum of CVAD placement training	B	Perfect consensus, strong
W_R10 Anatomical Models	Inanimate models/simulators replace the human anatomy as clinicians follow minimal requirements to allow for the detection of main vessels and surrounding structures	A	Perfect consensus, strong
W_R11 Objective Grading of Proficiency	Levels of performance of theoretical and practical skills are objective and the trainee completes every step of the final assessment in order to obtain the certification of proficiency in ultrasound CVAD positioning	C	Perfect consensus, strong

Continued

Table 1 Continued

Section code	Recommendation	Level of evidence	Degree of consensus, strength of recommendation
W_R12 Examination and Competency	The training process is complete when the trainee fully succeeds in the didactic exam specific to the particular CVAD and demonstrates practical competency in a final assessment/ review	C	Perfect consensus, strong
W_R13 Supervision	Supervision is performed by a practitioner who is in clinical practice, is confident with demonstrated competency and has a thorough current knowledge of best practice demonstrated through participation in performance of education, or with publication activities dealing with CVADs	C	Perfect consensus, strong
W_R14 Didactic or Web-based Training	Standardized training programmes include didactic or web-based teaching, simulation practice and supervised practice. The Web/Internet/online education is a useful alternative educational method for teaching skills in central venous catheter insertion	B	Perfect consensus, strong
W_R15 Objective Competency	Competency is first determined by an objective method of assessment rather than the number of procedures performed. Procedural volume is an important factor in reducing complications and developing and maintaining clinical competence. Global rating scales are used as formal evaluation instruments to determine competence and may be used for annual assessment of competence	B	Perfect consensus, strong
W_R16 Education for Children and Neonates	CVAD education with neonates and children includes: specific aspects of teaching and training with vascular access device insertion, insertion with and without ultrasound, near-infrared technology, and other technology aids for insertion	B	Perfect consensus, strong

Experiential learning is a model of learning, in which learning/meaning is derived from direct experience. According to Bruner,²⁵ professional judgement and higher level skills can be gained from repeated patient care experiences. Experiential learning can be attained in a reflective cycle such as Kolb's learning cycle.²⁶ This cycle applies to patient experiences by observing and reflecting, formulating abstracts and generalizations, and finally testing the implications of concepts in new situations. Theoretical perspective and empirical knowledge are gained from various disciplines including: psychology, sociology, ethics, management, education, and biological sciences.

Experiential education is a methodology where educators/mentors purposefully engage with learners in direct experience and reflection in order to increase knowledge, develop skills, and clarify values.²⁷ The practical application of experiential learning has to take into account the learner's previous experience, knowledge base, and theoretical preparation. Context of learning will vary, but will guide the learner from being dependent to becoming a supervised participant and then, onto supported independence.

Situated learning is a model of learning in a community of practice where learning is derived from active or guided participation. Guided participation involves cognitive (thinking) ability, problem solving, adequate knowledge, personal skills, and appropriate attitudes and values. Students learn best when involved in genuine professional practice, supported by an experienced, capable mentor. The experienced

practitioner (mentor) is the most valuable resource available to the learner. Effective mentor-learner relationships are dynamic and complex and can be achieved through guided participation.²⁸

Educational courses on central venous device placement should include basic anatomy, ultrasound physics and imaging, detection/management of major and minor complications, and maintenance/care of the CVAD.^{7-9 11}

Educational programmes reduce the occurrence of CVAD infections and insertion complications.^{5 8 29 30} The use of ultrasound, checklists, bundle programmes, and simulation labs in conjunction with organized educational programmes improves patient safety related to CVAD insertion.^{8 31} Experience and skill are also associated with reduced complication rates related to insertion.^{1 32 33} Educational programmes that include simulation experience with ultrasound offer the greatest advantage in terms of knowledge and skill acquisition before actual patient interaction.¹⁶

Educational content should be directed at how to perform a CVAD insertion.^{8 23} Clinician knowledge of certain subject areas and competence in device insertion influence the rate of occurrence for CVAD-related complications. This panel of experts recommends the following topics be covered during the didactic section of an educational course on CVADs:^{11 18}

- (1) Anatomy and physiology of relevant body systems
- (2) Ultrasound for insertion and assessment
- (3) Central venous device tip location

- (4) Infection control and sterile technique
- (5) Device selection and indications
- (6) Insertion procedures, complication prevention, evaluation, and management
- (7) Care and maintenance practices along with needleless connectors and securement devices
- (8) Qualification and competency
- (9) Simulation training
- (10) Anatomical models
- (11) Objective grading and proficiency
- (12) Examination and competency
- (13) Supervised instruction
- (14) Didactic or web-based training
- (15) Developing clinical competence
- (16) Education for children and neonates

Anatomy

Knowledge of anatomy affects decision-making and may help to avoid insertion complications (inadvertent nerve, arterial, or lung puncture).¹ Inexperience leads to more attempts, more trauma during insertion procedures, increasing the risk of infections.^{14 15 34 35} This supports the idea that more training and knowledge of relevant anatomy and physiology reduces complications during CVAD insertions.³⁶

In terms of insertion site selection: the vessels, skin, and nerves systems directly impact the ability to insert and maintain a CVAD. Additional body systems include musculoskeletal, cardiac, and respiratory systems. Infection and thrombosis can both be impacted by site selection, skin integrity, and catheter-vein ratio (CVR).^{8 14 37-39}

Anatomy and physiology training content:

- Vessel anatomy, location, size, and path^{19 37}
- Vessel differentiation with ultrasound^{8 19}
- Blood flow dynamics⁸
- Virchow’s triad⁸
- Skin integrity, colonization¹
- Peripheral nerve identification and distribution¹⁹
- Respiratory anatomy^{8 19}
- Upper and lower extremity, axillary, neck, and chest anatomy^{8 19}

Ultrasound vein assessment and access

Ultrasound-guided access should focus not only on vein puncture but also on assessment and selection of veins based on size, patency, and risk reduction (Table 2).³⁹

The use of ultrasound during CVAD insertions increases first-pass success rates and reduces overall complications.⁴⁰ ⁴¹ Anatomy is variable and therefore, blind insertion or landmark methods have limitations.⁴² Ultrasound visualization identifies variant anatomy before the procedure and offers the clinician valuable and potentially lifesaving information. A high-risk procedure can be identified and avoided, and one that would be difficult and traumatic becomes safer for the patient.

It is known that vessel characteristics like size and patency impact vascular access outcomes. A simulation study

Table 2 Recommended curriculum for ultrasound vascular assessment and intravascular placement³⁹

Procedural ultrasound	Skills required
Physics/knobology	Describe the indications and limitations when using ultrasound to assist in bedside procedures
	Define the relevant local anatomy for vascular access—central and peripheral placement
	Understand the standard protocols when using ultrasound to assist in procedures
	Skills required
	Understand the role of physics in ultrasound
	Define necessary terms: piezoelectric effect, frequency, resolution, attenuation, echogenicity, Doppler
	Understand the role of instrumentation in image acquisition
	Image mode, gain, time gain compensation, probe types
	Understand types of ultrasound artifacts and their role in image acquisition: mirroring, reverberation, shadowing, enhancement

demonstrated that a CVR that approaches 1:3 reduces blood flow by 80%, while a CVR of 1:4 may only decrease blood flow by 40–60%.³⁷ At this time, there are no *in vivo* studies^{15 29 43} that provide outcomes of CVR. However, the use of ultrasound assessment facilitates vein selection, diameter measurements, appropriate catheter selection, and subsequently reduces the risk of venous thrombosis.

Tip location

Tip location defines a device as central, peripheral, or non-central. A non-central tip location of a CVAD greatly increases the risk for catheter-related complications. Complications include thrombosis, vascular erosion, cardiac erosion, tamponade, and arrhythmia.⁴⁴ Even within the superior vena cava, the risk associated with catheter-related thrombosis varies greatly depending on how close the tip is to the right atrium. The more cephalad the CVAD tip is from the right atrium, the greater the risk for catheter-related thrombosis.¹³ Defining the exact location of the true cavo-atrial junction (CAJ) has been a subject of much debate. Even varying expert opinions exist on whether a tip should be above or below the CAJ.^{44 45} The tip at or near the CAJ provides the least risk. Some exception for right atrial tip placement may exist for the optimal performance of haemodialysis catheters.^{44 46}

Infection control

Central catheter-related infection remains a high source of morbidity and mortality in the acute and long-term care environment.⁸ Through the use of systematic educational

programmes, compliance tracking, and checklists, strides have been made to reduce the occurrence of infections.^{8 32 40}

Infection control and sterile technique are key principles to include in any CVAD insertion programme. The most serious and costly complication of CVAD insertion and maintenance is the catheter-related bloodstream infection (CRBSI). CRBSI has three main sources of contamination: the catheter–skin junction (extraluminal), the needleless connector and hub (intraluminal), and iatrogenic contamination from another site of infection.⁸ Understanding the mechanisms of CRBSIs is key to making clinical decisions that mitigate risk including: optimal site selection, the use of maximal barrier precautions, hand hygiene, appropriate use of skin antiseptic solutions, and evaluation of device necessity with prompt removal. These five points are the basic elements of the Central Line Bundle Program proven to reduce the risk of CRBSIs.^{8 32 40} The bundle is focused on site selection and the ability of the inserter to maintain a sterile environment during CVAD placement.

Inadequate care and maintenance practices during dressing changes, flushing protocols, access for infusions, and needleless connector disinfection all contribute to the development of complications.^{8 38 47 48}

Device selection and indications

Device characteristics and indications for use affect the selection of a CVAD and contribute to successful completion of the treatment plan. The size of a catheter influences flow which impacts the risk of vessel wall damage.^{15 29 42} There is a debate over whether valved catheters impact device function and decrease overall risk to the patient. Multilumen catheters are considered higher risk for infection-related complications compared with those with fewer lumens.⁸ It is incumbent on any education programme to provide current research information on CVAD design features and how these features influence risk profiles.

Insertion procedure

The provider of CVAD insertion education shall provide updated evidence-based education regarding device placement based on the current accepted standards and manufacturer instructions for use. Professional organization guidelines⁴⁹ and literature⁵⁰ give suggestions for proper device insertion and use.

Care and maintenance

The Centers for Disease Control recommend that clinicians receive insertion procedure and maintenance education in an effort to prevent device complications.⁸ In a study by Davis,⁴⁹ 71% of CVAD bacteraemias occurred after 5 days signifying failure and contamination during maintenance practices. The ability to reduce CVAD infections relies as much on care and maintenance as it does on insertion.

Qualification and competency

Only clinicians competent in CVAD insertion and maintenance should perform these procedures.⁸ Instructors must

also demonstrate continued competency and proficiency in CVAD insertion. Competency extends to periodic assessment and not just an initial evaluation at the time of training.⁵¹ A systematic approach is required to continually measure outcomes and provide feedback relevant to competence as a function of safety. Studies evaluating the relationship between clinical knowledge and experience have concluded that the decline in knowledge after initial training is accompanied by a decrease in quality of care.⁵²

Ultrasound and insertion simulation training

Ultrasound guidance is recognized as the gold standard for CVAD insertion.^{7 18 53} All training labs should include ultrasound skills education. At the end of the learning period (see the Developing clinical competence section), all trainees should be able to detect major vessel abnormalities with the aid of ultrasound.¹²

Anatomical models

There are a variety of inanimate models useful for simulating vessel anatomy visualization with ultrasound. The best simulation models should include vessels and also mimic the normal body anatomy with muscles, soft tissues, and bones. For this reason, inanimate animal models such as turkey breasts may be effective for simulation practice with ultrasound.

In the future, virtual simulators may be available for perfect hand–eye coordination of the trainee.^{53–55}

Objective grading and proficiency

The application of the learning curve concept to CVAD placement means the reduction, by 50%, of major complications during the learning process. With the landmark technique, the suggested minimal CVAD placements required to achieve minimal experience was >50 insertions.⁵⁶ With ultrasound guidance, it has been suggested^{11 12} that CVAD-skilled trainees require less training than novices but have more problems with hand–eye coordination.^{2 3 57–60} There is no common training guideline on ultrasound training.^{11 61} This Consensus Task Force recommends 6–8 h of didactic education, 4 h hands-on training on inanimate models, then 6 h hands-on training on normal human volunteers for detection of normal ultrasound anatomy. This training should be followed by supervised ultrasound cannulations, coaching the trainee during the procedure in order to achieve the required minimal skill competence with the lowest rate of complications.⁶²

Examination and competency

A training log-book should be used by the trainee as a checklist to verify completion of all the steps of the training process. If the trainee fails to pass a step, he/she has to repeat the performance until able to demonstrate competence. The educational competence should be evaluated with a multiple-choice test of at least 100 questions. The trainee must pass with at least 70% (according to similar

educational courses)⁶³ of correct answers before proceeding to the hands-on training exam. In the practical audit, the trainee is examined according to practical skills acquired during the training process.⁶⁴ The final audit should be objective and the trainee must pass all the practical steps required. If the trainee fails in the final audit, he/she should continue in his/her current practice until full achievement of practical goals referenced to the Global Rating Scale (Supplementary Appendix S1).

Supervised instruction

Studies^{65–67} suggest that neither medical students nor residents are completely satisfied with their skills in invasive procedures. The most common form of teaching procedural skills has been the traditional demonstration followed by supervised practice and then the teaching of that skill ('see one, do one, teach one'). It is recognized that often practitioners supervise procedures before they feel confident and competent in their own practice.⁶⁸ This method of teaching procedural skills may have a negative impact on patient safety if the supervision is by an inexperienced practitioner.

There is a growing recognition of the importance of training in invasive procedures and also the requirement of competence before procedure performance that must be validated as part of a credentialing process.^{4 34 68–70} Competency validation requires application of clinical experience, education of the skills to be attained, completion of procedural demonstration, and supervision of a specified number of successful procedures.^{71–73} This panel concludes that supervisors require full and certified competence in central venous device placement and must maintain their skills through their clinical activity. Supervisors should be certified with an educational course for trainers before starting their teaching activity.

Didactic or web-based training program

Some authors⁷⁰ discussed a standardized training process for CVAD insertion to improve clinical knowledge, perception, and attitudes of the residents and decrease the rate of complications.⁷³ Other authors evaluated a comprehensive inpatient procedure service rotation which aimed to improve Internal Medicine residents' knowledge and comfort in performing procedures including central venous catheterization.⁷⁴ The outcomes of this study suggest that a comprehensive programme results in improved knowledge and comfort for residents.

Another issue under debate is where training should take place. Trainees who are taught procedural skills in the medical setting perceive that specific education taught before the insertion procedure is rare.⁷⁵ The Internet provides an alternative to training and is currently being used in medical training centres. It has been proven that this method could provide a useful alternative to face-to-face didactic lectures teaching procedural skills and was at least as effective as traditional teaching methods.^{76–78}

Developing clinical competence

Several studies demonstrate an inverse relationship between healthcare professionals' experience and their rate of complications.^{57 79–81} Substantial evidence relating to clinical competence in central venous device insertion is sparse. From the literature, it appears that there are no standard methods of assessing the competence of the practitioner. According to recommendations of the National Institute for Clinical Excellence (NICE), those involved in placing CVADs using ultrasound guidance should undertake appropriate training to achieve competence.⁷ Defining a competent practitioner in objective terms is a difficult task. Competence is often determined after a pre-determined number of procedures being performed or after a subjective assessment by a proctor who is deemed to be competent.^{67 82} This approach is often criticized however, as it relies on general agreement to determine the number of procedures necessary to gain competence. Other authors suggest an alternative, more objective method of training programme.⁸³ This assessment process includes the completion of a written test assessing the practitioner's cognitive level of the procedure. This written exam should be in conjunction with a visual exam to test the knowledge of normal vs abnormal vessels, and a skills test using simulation to test the practitioner's ability to perform the procedure to a satisfactory standard. The practitioner would then undertake observed procedures under the direct supervision of an experienced practitioner.

The two main approaches to rating technical performance are global rating scales and checklists. The goal of checklists is to guide behaviour by confirming routine. It has been argued that the global rating scales (Likert type scales) do not address procedural shortcomings. Global rating scales of competence have evolved⁸⁴ and a validated 24-item checklist using the Angoff method has been created to assess the competence of residents in CVAD insertion.⁸⁵ Because CVAD insertion is sequential and predictable, assessment of the procedure can be performed using a checklist, as each component of the skill can be assessed. Formal evaluation of competence is performed using instruments such as the Ottawa Global Rating Scale (GRS) and the Ottawa Crisis Resource Management (CRS) checklist which both demonstrate effectiveness in multiple domains.⁸⁶

Teaching CVAD insertion with children and neonates

Central venous catheterization in paediatric patients and neonates is considered a challenging procedure, even when ultrasound guidance is used. Several papers demonstrate a significant reduction in major complications when ultrasound guidance is used instead of the landmark technique.^{87–90} Central venous device placement in children and neonates requires specific training in order to achieve competence in central vein cannulation.

Materials used for CVAD placement in paediatric patients must follow specific requirements:

- (i) The catheter is selected according to the type of therapy to be administered to the child/neonate.

- (ii) Ultrasound probes must be linear with a small footprint and a high frequency (from 10 MHz up).
- (iii) Nitinol soft-tipped guidewires are preferred.

It is necessary to have minimal cannulation of 70 central vein punctures per year in order to maintain the skills and the competence in these patients.⁹¹ Ultrasound guidance enhances first-time success and time to cannulation in small infants, but requires supervised training to gain proficiency. It has been demonstrated to take 15 supervised, ultrasound-guided cannulations to reach proficiency with small infants.⁹¹

Minimal training is also required for peripheral vein cannulation in paediatric patients.⁹² Nurses and physicians should be trained in paediatric-specific i.v. procedures during their academic/employment training period. Even so, additional factors noted in the literature were better indicators of success, such as difficulty and cooperativeness of the child.⁹³ In cases of difficult peripheral vein access, ultrasound guidance may not always be useful because simple compression of the probe over the skin may cause collapse of superficial veins, necessitating the use of a very lightweight probe for these patients. In this case, near-infrared technology has increased success rates of peripheral vein catheterizations.^{94 95}

Conclusion

Evidence supporting and directing the education and training of those who insert and maintain CVADs is limited. This study suggests evidence-based recommendations that provide direction for establishing consistency in the development of training programmes and measuring competency through completion of didactic lessons, simulation, examination and supervised practice. These recommendations should be considered minimal level requirements for all inserting clinicians. Each recommendation was considered necessary by the consensus group in establishing uniform training throughout the world, both with adults and children/neonates. This document is designed to serve as a guideline for those creating education and training programmes and for those undertaking the training. More research is necessary to establish stronger recommendations and clearer directives.

Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

Declaration of interest

None declared.

References

- 1 McGee D, Gould M. Preventing complications of central venous catheterization. *N Engl J Med* 2003; **348**: 1123–33
- 2 Woo MY, Frank J, Lee AC, et al. Effectiveness of a novel training program for emergency medicine residents in ultrasound-guided insertion of central venous catheters. *CJEM* 2009; **11**: 343–8
- 3 Barsuk J, Cohen E, Feinglass J, McGaghie W, Wayne D. Use of simulation-based education to reduce catheter-related bloodstream infections. *Arch Intern Med* 2009; **169**: 1420–3
- 4 McGee W. Central venous catheters: better and worse. *J Intensive Care Med* 2006; **21**: 51–3
- 5 Sherertz R, Ely E, Westbrook D, et al. Education of physicians-in-training can decrease the risk for vascular catheter infection. *Ann Intern Med* 2000; **132**: 641–8
- 6 Warren DK, Zack JE, Mayfield JL, et al. The effect of an education program on the incidence of central venous catheter-associated bloodstream infection in a medical ICU. *Chest* 2004; **126**: 1612–8
- 7 National Institute for Health and Clinical Excellence (NICE). Technology Appraisal No 49: guidance on the use of ultrasound locating devices for placing central venous catheters. 2002; 1–24. Available from <http://www.nice.org.uk/nicemedia/live/11474/32461/32461.pdf> (accessed 9 March 2012)
- 8 O'Grady N, Alexander M, Burns L, et al.; HICPAC. *Guidelines for the Prevention of Intravascular Catheter-Related Infections*. (CDC Guidelines). Centers for Disease Control, 2011; 1–83. Available from <http://www.cdc.gov/hicpac/BSI/BSI-guidelines-2011.html> (accessed 9 March 2012)
- 9 Marschall J, Mermel LA, Classen D, et al. Strategies to prevent central-line associated bloodstream infections in acute care hospitals: Supplement Article SHEA/IDSA Practice Recommendations. *Infect Control Hosp Epidemiol* 2008; **29**(Suppl. 1): S22–30
- 10 Eisen L, Narasimhan M, Berger J, Mayo P, Rosen M, Schneider R. Mechanical complications of central venous catheters. *J Intensive Care Med* 2006; **21**: 40–6
- 11 Feller-Kopman D. Ultrasound guided internal jugular access: a proposed standardized approach and implications for training and practice. *Chest* 2007; **132**: 302–9
- 12 Bodenham A. Ultrasound imaging by anaesthetists: training and accreditation issues. *Br J Anaesth* 2006; **96**: 414–7
- 13 Hostetter R, Nakasawa N, Tompkins K, Hill B. Precision in central venous catheter tip placement: a review of the literature. *JAVA* 2010; **15**: 112–25
- 14 Dawson R. PICC Zone Insertion Method™ (ZIMTM): a systematic approach to determine the ideal site for PICCs in the upper arm. *JAVA* 2011; **16**: 156–65
- 15 Trerotola S, Stavropoulos S, Mondschein J, et al. Triple-lumen peripherally inserted central catheter in patients in critical care unit: prospective evaluation. *Radiology* 2010; **256**: 312–20
- 16 Millington SJ, Wong RY, Kassen BO, Roberts JM, Ma IWY. Improving internal medicine residents' performance, knowledge and confidence in central venous catheterization using simulators. *J Hosp Med* 2009; **4**: 410–6
- 17 Institute of Medicine. *Health Professions Education: A Bridge to Quality*. Washington, DC: National Academy Press, 2003
- 18 Troianos CA, Hartman GS, Glas KE, et al.; Councils on Intraoperative Echocardiography and Vascular Ultrasound of the American Society of Echocardiography; Society of Cardiovascular Anesthesiologists. Special articles: guidelines for performing ultrasound guided vascular cannulation: recommendations of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. *Anesth Analg* 2012; **114**: 46–72
- 19 Lamperti M, Bodenham AR, Pittiruti M, et al. International evidence-based recommendations on ultrasound-guided vascular access. *Intensive Care Med* 2012; **38**: 1105–17
- 20 Duncan J, Henderson K, Street M, et al. Creating and evaluating a data-driven curriculum for central venous catheter placement. *J Grad Med Educ* 2010; **2**: 389–97

- 21 Elbarbary M, Melniker LA, Volpicelli G. Development of evidence-based clinical recommendations and consensus statements in critical ultrasound field: why and how? *Crit Ultrasound J* 2010; **2**: 93–5
- 22 <http://www.gradeworkinggroup.org/society/index.htm> (accessed 16 June 2012)
- 23 GRADE guidelines. *J Clin Epidemiol* 2011; **64**: 380–1316
- 24 http://www.rand.org/health/surveys_tools/appropriateness.html (accessed 16 June 2012)
- 25 Bruner J. *Toward a Theory of Instruction*. New York: W.W. Norton & Company Inc., 1966
- 26 Kolb DA. *Experiential Learning*. Englewood Cliffs, NJ: Prentice Hall, 1984
- 27 Dewey J. The relation of theory to practice in education. *John Dewey on Education: Selected Writings*. Chicago: Chicago University Press, 1974
- 28 Lave J, Wenger E. *Situated Learning: Legitimate Peripheral Participation*. New York: Cambridge University Press, 1988
- 29 Grove J, Pevec W. Venous thrombosis related to peripherally inserted central catheters. *J Vasc Interv Radiol* 2000; **11**: 837–40
- 30 Coopersmith C, Rebmann T, Zack J, et al. Effect of an education program on decreasing catheter-related bloodstream infections in the surgical intensive care unit. *Crit Care Med* 2002; **30**: 59–64
- 31 Eggimann P, Harbath S, Constantin M, Touveneau S, Chevrolet J, Pittet D. Impact of a prevention strategy targeted at vascular access care on incidence of infections acquired in intensive care. *Lancet* 2000; **355**: 1864–8
- 32 Pronovost P, Needham D, Berenholtz S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU: key-stone project. *N Engl J Med* 2006; **355**: 2725–32
- 33 Wigmore T, Smythe J, Hacking M, Raobaikady R, MacCallum N. Effect of the implementation of NICE guidelines for ultrasound guidance on the complication rates associated with central venous catheter placement in patients presenting for routine surgery in a tertiary referral center. *Br J Anaesth* 2007; **9**: 662–5
- 34 Masoorli S. Nerve injuries related to vascular access insertion and assessment. *J Infus Nurs* 2007; **30**: 346–50
- 35 Stokowski G, Steele D, Wilson D. The use of ultrasound to improve practice and reduce complication rates in peripherally inserted central catheters. *J Infus Nurs* 2009; **32**: 145–55
- 36 Sansivero GE. Venous anatomy and physiology. Considerations for vascular access device placement and function. *J Intraven Nurs* 1998; **521**(5 Suppl.): 107–14
- 37 Nifong T, McDevitt T. The effect of catheter to vein ratio on blood flow rates in a simulated model of peripherally inserted central venous catheters. *Chest* 2011; **140**: 140–53
- 38 Dawson R. Nursing beyond the 'Process': collegiality and consultation improves outcomes by protecting the tissue integrity of PICC insertion sites. *JAVA* 2008; **13**: 8–11
- 39 American College of Emergency Physicians. *ACEP Policy Statement: Emergency Ultrasound Guidelines*. ACEP, 2008; 1–38
- 40 Harnage S. Achieving zero catheter related blood stream infections: 15 months success in a community based medical center. *JAVA* 2007; **12**: 218–24
- 41 Blaivas M, Brannam L, Fernandez E. Short-axis versus long-axis approaches for teaching ultrasound-guided vascular access on a new inanimate model. *Acad Emerg Med* 2003; **10**: 1307–11
- 42 Agoustides JG. Evidence-based decision making in ultrasound-guided central venous cannulation: choosing between the eye and the ear. *J Clin Anesth* 2006; **18**: 165–6
- 43 Evans S, Sharp J, Linford L, et al. Risk of symptomatic DVT associated with peripherally inserted central catheters. *Chest* 2010; **138**: 803–10
- 44 Vesely T. Central venous catheter tip position: a continuing controversy. *J Vasc Interv Radiol* 2003; **14**: 527–34
- 45 Verhey P, Gosselin M, Primack S, Blackburn P, Kraemer A. The right mediastinal border and central venous anatomy on frontal chest radiograph—direct CT correlation. *JAVA* 2008; **13**: 32–5
- 46 Galliemi M, Pittiruti M, Biffi R. Vascular access in oncology patients. *Cancer J Clin* 2008; **58**: 323–46
- 47 Moureau N, Dawson R. Keeping needleless connectors clean, part 1. *Nursing* 2011; **40**: 18
- 48 Hadaway L. Needleless connectors: improving practice, reducing risks. *JAVA* 2011; **16**: 20–33
- 49 Davis J. Central-line-associated bloodstream infection: comprehensive, data-driven prevention. *Patient Saf Advis* 2011; **8**: 100–5
- 50 Sansivero GE. The microintroducer technique for peripherally inserted central catheter placement. *J Intraven Nurs* 2000; **23**: 345–51
- 51 Dong Y, Suri H, Cook D, et al. Simulations-based objective assessment discerns clinical proficiency in central line placement: a construct validation. *Chest* 2010; **137**: 1050–6
- 52 Basow D. *Use of Evidence-based Resources by Clinicians Improves Patient Outcomes*. Minneapolis, MN: Wolters Kluwer Health, 2010. Available from www.wolterskluwerhealth.com (accessed 15 January 2012)
- 53 Maecken T, Grau T. Ultrasound imaging in vascular access. *Crit Care Med* 2007; **35**: S178–85
- 54 Zorcolo A, Gobetti E, Massimiliano T. Catheter insertion simulation with combined visual and haptic feedback. PURS'99. Available from <http://www.crs4.it/vic/data/papers/purs99-needle.pdf> (accessed 9 March 2012)
- 55 Pratt RJ, Pellowe C, Loveday HP, Robinson N, Smith GW; the Guideline Development Team. The EPIC project: developing national evidence-based guidelines for preventing healthcare associated Infections. Phase 1: guidelines for preventing hospital-acquired infections. *J Hosp Infect* 2001; **47**: S1–82
- 56 Combs C. Final Technical Report. The National Center for Collaboration in Medical Modeling and Simulation. Arlington, VA: Office of Naval Research Human Systems Department Medical and Biomedical Science & Technology Division, 2006. Available from <http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA457977> (accessed 9 March 2012)
- 57 Sznajder J, Zveibil F, Bitterman H, Weiner P, Bursztein S. Central vein catheterization. Failure and complication rates by three percutaneous approaches. *Arch Intern Med* 1986; **146**: 259–61
- 58 Ma IWY, Brindle ME, Ronksley PE, Lorenzetti DL, Sauve RS, Ghali WA. Use of simulation-based education to improve outcomes of central venous catheterization: a systematic review and meta-analysis. *Acad Med* 2011; **86**: 1137–47
- 59 Gentile D. Applying the novice-to-expert model to infusion nursing. *J Infus Nurs* 2012; **35**: 101–7
- 60 Benner P. *Novice to Expert: Promoting Excellence and Power in Clinical Practice*. Menlo Park: Addison-Wesley, 1984
- 61 Royal College of Radiologists RCR Board of the Faculty of Clinical Radiology. *Ultrasound Training Recommendations for Medical and Surgical Specialties*. RCR, 2004; 1–56. Available from <http://www.rcr.ac.uk/docs/radiology/pdf/ultrasound.pdf> (accessed 9 March 2012)
- 62 Lamperti M, Subert M, Cortellazzi P, et al. Is a neutral head position safer than 45-degree neck rotation during ultrasound-guided internal jugular vein cannulation? Results of a randomized controlled clinical trial. *Anesth Analg* 2012; **114**: 777–84
- 63 <http://www.surgery.hku.hk/atls.php>

- 64 Evans LV, Morse JL, Hamann CJ, Osborne M, Lin Z, D'Onofrio G. The development of an independent rater system to assess residents' competence in invasive procedures. *Acad Med* 2009; **84**: 1135–43
- 65 Huang GC, Smith CC, Gordon CE, et al. Beyond the comfort zone: residents assess their comfort performing inpatient medical procedures. *Am J Med* 2006; **119**: 71.e17–24
- 66 ACGME. ACGME outcome project. Available from <http://www.acgme.org/outcome/> (accessed 5 August 2012)
- 67 Wigton RS, Blank LL, Nicolas JA, Tape TG. Procedural skills training in internal medicine residencies. A survey of program directors. *Ann Intern Med* 1989; **111**: 932–8
- 68 Mourad M, Kohlwes J, Maselli J, Auerbach A. Supervising the supervisors—procedural training and supervision in internal medicine residency. *J Gen Intern Med* 2010; **25**: 351–6
- 69 Martin M, Scalabrini B, Rioux A, Xhiquesse M. Training fourth-year medical students in critical invasive skills improve subsequent patient safety. *Am Surg* 2003; **69**: 437–40
- 70 Nip IL, Haruno MM. A systemic approach to teaching insertion of a central venous line. *Acad Med* 2000; **7**: 5–52
- 71 Rusche J, Besuner P, Partusch S, Berning P. CE test: competency program development across a merged healthcare network. *J Nurses Staff Dev* 2001; **17**: 241–2
- 72 O'Hearne Rebholz M. A review of methods to assess competency. *J Nurses Staff Dev* 2006; **22**: 241–5
- 73 Infusion Nurses Society (INS). Infusion nursing standards of practice. *J Infus Nurs* 2011; **534**: 1S:51–110
- 74 Lenhard A, Moallem M, Marrie R, Becker J, Garland A. An intervention to improve procedure education for internal medicine residents. *J Gen Intern Med* 2008; **23**: 288–93
- 75 Elnicki D, Shumway J, Halbritter K, Morris D. Interpretive and procedural skills of the internal medicine clerkship: performance and supervision. *South Med J* 1996; **89**: 603–8
- 76 Chumley-Jones H, Dobbie A, Alford C. Web-based learning: sound educational method or hype? A review of the evaluation literature. *Acad Med* 2002; **77**: 586–93
- 77 Hammoud M, Gruppen L, Erickson S, et al. To the point: reviews in medical education online computer assisted instruction materials. *Am J Obstet Gynecol* 2006; **194**: 1064–9
- 78 Chenkin J, Lee S, Huynh T, Bandiera G. Procedures can be learned on the web: a randomized study of ultrasound-guided vascular access training. *Acad Emerg Med* 2008; **15**: 949–54
- 79 Fares LG, Block PH, Feldman SD. Improved house staff results with subclavian cannulation. *Am Surg* 1986; **52**: 108–11
- 80 Bo-Linn G, Anderson D, Anderson K, McGoon M. Percutaneous central venous catheterization performed by medical house officers: a prospective study. *Cathet Cardiovasc Diagn* 1982; **8**: 23–9
- 81 Bernard R, Stahl W. Subclavian vein catheterizations: a prospective study. *Ann Surg* 1971; **173**: 184–90
- 82 Freeman M. Training and competence in gastrointestinal endoscopy. *Rev Gastroenterol Disord* 2001; **1**: 73–87
- 83 Norris T, Cullison S, Fihn S. Teaching procedural skills. *J Gen Intern Med* 1997; **12**(Suppl. 2): S64–70
- 84 McKinley R, Strand J, Ward L, Gray T, Alun-Jones T, Miller H. Checklists for assessment and certification of clinical procedural skills omit essential competencies: a systematic review. *Med Educ* 2008; **42**: 338–49
- 85 Huang G, Newman L, Schwartzstein R, Clardy P, Feller-Kopman D, Irish J. Procedural competence in internal medicine residents: validity of a central venous catheter insertion assessment instrument. *Acad Med* 2009; **84**: 1127–34
- 86 Gaba D, Fish K, Howard S. *Crisis Management in Anesthesiology*, 1st Edn. New York: Churchill Livingstone, 1994
- 87 Chuan W, Wei W, Yu L. A randomized controlled study of ultrasound prelocation vs anatomical landmark-guided cannulation of the internal jugular vein in infants and children. *Paediatr Anaesth* 2005; **15**: 733–8
- 88 Verghese S, McGill W, Patel R, Sell J, Midgley F, Ruttiman U. Ultrasound-guided internal jugular venous cannulation in infants: a prospective comparison with the traditional palpation method. *Anesthesiology* 1999; **91**: 71–7
- 89 Verghese ST, McGill WA, Patel RI, Sell JE, Midgley FM, Ruttimann UE. Comparison of three techniques for internal jugular vein cannulation in infants. *Paediatr Anaesth* 2000; **10**: 505–11
- 90 Lamperti M, Caldiroli D, Cortellazzi P, et al. Safety and efficacy of ultrasound assistance during internal jugular vein cannulation in neurosurgical infants. *Intensive Care Med* 2008; **34**: 2100–5
- 91 Breschan C, Platzer M, Jost R, et al. Consecutive, prospective case series of a new method for ultrasound-guided supraclavicular approach to the brachiocephalic vein in children. *Br J Anaesth* 2011; **106**: 732–7
- 92 Blaivas M. Ultrasound-guided peripheral i.v. insertion in the ED. *Am J Nurs* 2005; **105**: 54–7
- 93 Larsen P, Eldridge D, Brinkley J, et al. Pediatric peripheral intravenous access: does nursing experience and competence really make a difference? *J Infus Nurs* 2010; **33**: 226–35
- 94 Yamazaki S, Tomita S, Watanabe M, Kawaai H, Shimamura K. Effects of a transmitted light device for pediatric peripheral venipuncture and intravenous cannulation. *Dove Press J* 2011; **1**: 189–92
- 95 Perry A, Caviness A, Hsu D. Efficacy of a near-infrared light device in pediatric intravenous cannulation: a randomized trial. *Pediatr Emerg Care* 2011; **27**: 5–10

Handling editor: R. P. Mahajan