

An Assessment Tool for the Placement of Ultrasound-Guided Peripheral Intravenous Access

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ABSTRACT

Background Ultrasound-guided peripheral intravenous line (USGPV) placement is becoming an important tool in current clinical practice. Many residency programs utilize unstructured clinical observation to evaluate residents in this and other procedural skills. Simulation-based assessment permits educators to make objective, standardized observations, and may be ideal for assessment of important procedural competencies.

Objective We created a simulation-based assessment tool for the skill of USGPV placement.

Methods A checklist tool was developed by a review of relevant literature and an expert review in accordance with established guidelines. Emergency medicine residents were recruited and surveyed on previous experience with USGPV placement. Blinded, independent reviewers then utilized the checklist to assess residents as they made up to 3 attempts at USGPV placement on a simulated pediatric arm.

Results Of the 26 residents enrolled in our study, 26 participated (100%). A best attempt checklist score greater than or equal to 9 out of 10 correlated with expert performance ($P < .001$). Agreement between independent raters on first-attempt USGPV placement score was determined by weighted kappa statistics to be 0.93 (95% CI 0.86–1.00).

Conclusions The checklist assessment tool has acceptable interrater reliability and ability to distinguish performance at differing levels of competence. We propose this tool as a valuable component in the assessment of USGPV access, and we hope this article serves as a roadmap for other educators to create similar assessment tools.

Introduction

Ultrasound guidance has become an important component of peripheral intravenous line placement in difficult-access patients. In adult patients, ultrasound-guided peripheral intravenous line (USGPV) placement significantly reduces the need for central venous access,¹ a procedure associated with increased complications when compared to traditional peripheral access.² In pediatrics patients, USGPV access has been shown to decrease the number of attempts, the time to line placement,^{3,4} and the number of needle redirections during a procedure.⁵ These outcomes are not only important for efficient and effective patient care, but also increase patient satisfaction and patient and parental comfort. As these outcomes are important across specialties, there is a need for training and evaluation methods in this valuable skill.

Simulation-based assessment may provide the key to objective, structured resident assessment for procedure-based skills. The standardization and reproducibility of simulation have resulted in the use of

simulation-based assessment in high-stakes testing in several fields of medicine, including board certification testing in some countries.⁶ Many medical schools also embrace simulation-based testing in end-of-rotation observed structured clinical examinations.⁷ Simulation-based assessments also allow educators to simulate rare or difficult patient encounters or procedural complications without endangering patient safety.⁸

There is a need for more robust and objective methodologies to measure resident procedural skills. With this challenge in mind, we designed a simulation-based assessment tool to determine learner proficiency in the skill of USGPV placement.

Methods

This prospective, observational study validated a novel checklist assessment tool, using observers who were blinded to participants' reported level of experience.

Checklist Development

The checklist tool was developed using the "Guidelines for Developing Evaluation Checklists" created by Western Michigan University (TABLE 1).⁹ A literature search was completed in accordance with the guidelines, which included PubMed, Embase, Web

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Editor's Note: The online version of this article contains the survey instrument used in the study.

of Science, Scopus, and the Cochrane Library on January 8, 2013. Search terms included ultrasound guidance terms, difficult access terms, catheterization terms, and pediatric age terms.

The 40 abstracts resulting from this search were reviewed by the study authors. Duplicate abstracts or abstracts that described central access or arterial access were excluded. The resultant 12 articles were reviewed for comments on technique in the skill of USGPV placement.^{3-5,10-18} Although the literature search yielded information on the benefits of USGPV placement in pediatrics patients, the articles contained limited information on the procedural steps for placement of the line. Relevant sections of *Roberts & Hedges' Clinical Procedures in Emergency Medicine* were reviewed to develop a list of essential tasks for this procedure.¹⁹ Faculty from the adult and pediatrics emergency departments and the pediatrics intensive care unit reviewed the initial checklist and provided commentary. Comments were reviewed, and revisions were made to the checklist by the study group. Definitions for each step were developed as a checklist supplement.

Pediatric Arm Simulator

The simulation used the M50B-B Pediatric IV Hand Simulators (Kyoto Kagaku Co Ltd, Torrance, CA). The simulators are made from realistic tissue and modeled after a 3-year-old pediatric arm. The circulation pump provides circulation to and from the task trainer. The task trainer is not marketed as an ultrasound training product; however, the simulation center attempted this based on flow +2D/color given the presence of the circulation pump.

Checklist Performance

Emergency medicine residents at the study institution were asked to participate by performing

What was known and gap

Most residency programs use unstructured observation of clinical performance to evaluate residents. Use of simulation and assessment checklists improves assessment and feedback to residents on procedural competence.

What is new

A simulation-based assessment tool for ultrasound-guided peripheral intravenous line placement.

Limitations

Single site study; some limitations of the simulated arm.

Bottom line

The checklist assessment tool had interrater reliability and the ability to distinguish performance at differing levels of competence.

placement of a USGPV in the pediatric arm simulator. Baseline information about previous experience with USGPV placement in pediatrics and adult patients and level of training was collected via a survey instrument (provided as online supplemental material). Resident participants were divided into 3 skill levels based on their report of previous experience with the following definitions: novice (0–5 USGPV), intermediate (6–20 USGPV), and expert (> 20 USGPV). There are no published guidelines on the categorization of “expert” versus “non-expert” in the skill of USGPV placement, and we based our categorizations on program standards and expert consensus at our site. Each resident was provided with PIV placement supplies, including a SonoSite Edge ultrasound (SonoSite, Bothell, WA), and was then allowed up to 3 attempts to place a USGPV on the pediatric arm simulator.

Three study authors were used as raters. All 3 were postgraduate year (PGY) 4 emergency medicine residents who had previously achieved proficiency in USGPV placement as determined by faculty observation and expert level of experience (> 20 USGPV). One of the raters was involved in the development of

TABLE 1
Ultrasound-Guided Peripheral Intravenous Access Checklist

Step	Attempt 1	Attempt 2	Attempt 3
Wash hands, apply gloves			
Tourniquet placed			
Turn on ultrasound			
Locate vessel with linear transducer			
Demonstrate vessel is venous			
Disinfect area			
Insert IV and follow needle tip to vessel			
Advance catheter and demonstrate placement with draw back 1 cc			
Flush 3 to 5 cc saline			
Secure IV			
Score			

TABLE 2

Evaluator Instructions for Checklist Use with Pediatric IV Hand Simulator

Procedure Step	Evaluator Instructions
Wash hands, apply gloves	Order of gloves/tourniquet placement does not matter; hand washing either soap or hand sanitizer
Tourniquet placed	Placement proximal to intravenous site
Turn on ultrasound	Must operate ultrasound without assistance
Locate vessel with linear transducer	Curvilinear and cardiac probes unacceptable
Demonstrate vessel is venous	Acceptable methods include demonstrating vessel compressibility or doppler flow color technique
Disinfect area	Can be completed at any time, but no credit given for IV inserted through area contaminated during location and evaluation of vessel
Insert IV and follow needle tip to vessel	Bevel up IV tip must be visualized in short or long axis view; no credit given if operator does not attempt to maintain visualization of tip of needle
Advance catheter and demonstrate placement with draw back	Credit given for any intravascular fluid draw back into syringe chamber
Flush 3 to 5 cc saline	No credit given if simulator shows significant local tissue swelling, which suggests extravascular infiltration
Secure IV	Site lock, transparent dressing acceptable

the assessment instrument. All raters were trained via an instruction sheet, which defined acceptable practice for each procedural step (TABLE 2). Raters observed and evaluated participants live during USGPV placement and were blinded to participants' level of experience. Participants were evaluated by 2 raters who completed independent checklists simultaneously.

This study was approved by the Johns Hopkins Institutional Review Board. Written informed consent was obtained from all participants.

Statistical Analysis

All statistical analyses were performed using SAS version 9.3 (SAS Institute Inc, Cary, NC). Descriptive statistics were performed. Resident participants were evaluated in 3 skill levels based on previous USGPV experience. Skill levels were compared against the checklist initial attempt score, best attempt score, and number of attempts, which were grouped based on distribution of each variable. Initial score was grouped as a score of 8 and under ($n = 16$) or a score of 9 and over ($n = 10$); best score was grouped as a score of 8 and under ($n = 9$) or a score of 9 and over ($n = 17$); number of attempts was grouped as 1 attempt or more than 1 attempt.

Fisher exact test and Cochran-Armitage trend test were performed to determine the association between the USGPV experience category and initial score, best score, and number of attempts. Interrater reliability was determined by weighted kappa statistics for first attempt score.

Results

Checklist Creation

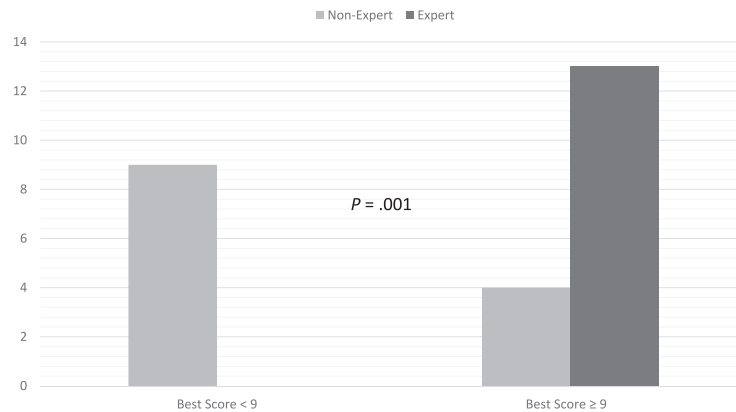
Initial literature and text review yielded 9 essential steps for USGPV placement. After review by experts in pediatrics and emergency medicine, an additional step was added which required that the needle tip was visualized and followed to the vessel. The final checklist was composed of 10 steps, which were deemed essential to correct placement of an USGPV. As each step was considered essential, 1 point was awarded for each completed step for a maximum score of 10 points.

Checklist Performance

Of the 26 emergency medicine residents (PGY 1–4) recruited, 26 (100%) attempted USGPV placement in the pediatric task trainer. Thirteen residents were categorized as non-experts (7 novice, 6 intermediate) and 13 were categorized as experts.

A best checklist score of 3 USGPV placement attempts of ≥ 9 correlated with an expert level of experience (> 20 previous attempts) with 100% of experts scoring a best attempt score ≥ 9 , and only 30% of non-experts (< 20 previous attempts) with any score ≥ 9 ($P < .001$; FIGURE 1). Initial USGPV placement attempt score ≥ 9 was compared to the level of experience, but the results were shown not to be significant ($P = .17$).

Statistical analysis also showed that 69% of participants categorized as experts placed a working intravenous line on the first attempt (FIGURE 2). This was defined as an USGPV that demonstrated

**FIGURE 1**

Non-Expert's Versus Expert's Best Checklist Score Greater Than Or Equal To 9

drawback and the ability to flush easily. Only 23% of non-experts were able to place a line on their first attempt ($P = .04$).

Agreement between 2 independent raters on score grading for the first attempt of USGPV was determined by weighted kappa statistics. The weighted kappa was 0.93 (95% CI 0.86–1.00). Overall rater agreement on all scores was 85%.

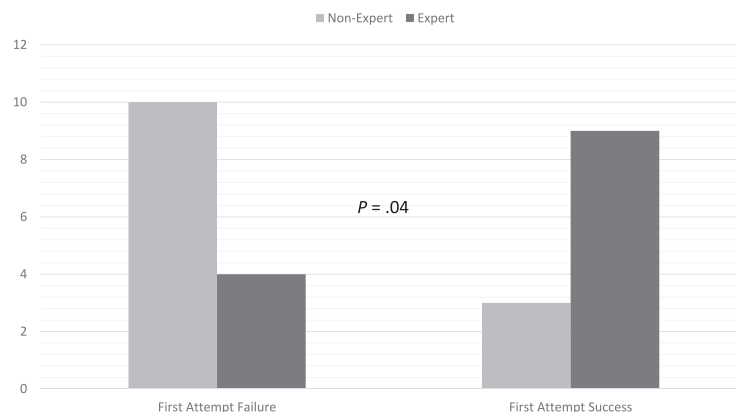
Discussion

Our checklist assessment tool demonstrated the ability to distinguish between experts and non-experts in the skill of USGPV access in this group of participants. We supported the validity of this tool by defining content, response process, and establishing the tool's relationship to other variables, which have been described as important components to this process in the literature.²⁰

Experts were observed to score consistently higher than non-experts on the checklist, which supports its use as an assessment tool. All experts obtained a checklist score of ≥ 9 compared to participants with

less experience who only achieved a score of ≥ 9 one-third of the time. Expert participants also obtained a working USGPV more consistently on first attempt than non-experts.

Ability to secure access on first attempt is important for multiple reasons, including reduction of pain associated with the procedure as well as reduction of the traumatic nature of the experience for young patients. Although gaining access on the first attempt is not factored into our checklist score, this finding suggests a higher level of skill observed in those who obtained an overall higher score on the checklist. Initial attempt checklist score was analyzed to determine if the checklist could be applied to a single attempt at USGPV placement in this simulated patient with significant results. We compared level of expertise (expert versus non-expert) with initial attempt checklist score ≥ 9 , and found no significant correlation ($P = .17$). Therefore, it is important to allow performers up to 3 attempts at USGPV placement for our checklist to be able to distinguish experts from non-experts.

**FIGURE 2**

Non-Expert's Versus Expert's Ability to Successfully Place IV on First Attempt

The study has several limitations. First, the simulated arm failed to simulate many of the challenges inherent in placing an intravenous line on a pediatrics patient, such as patient and parental anxiety and lack of patient cooperation. Although primed with simulated blood in a closed circuit, the trainer demonstrated variable flash when the USGPIV entered the vessel, which may have deterred some participants from attempting placement of an otherwise successful USGPIV.

The assessment tool was used with residents in a single training program. Future attempts to validate the tool, and the creation of future assessment tools, would benefit from testing in multiple training programs.

Conclusion

The checklist's kappa score of 0.93 demonstrates a high degree of interrater agreement in participant score. Reliability between raters suggests the checklist is transferable among emergency medicine educators and thus acceptable for standardized evaluation. We propose this checklist assessment as a useful tool in the assessment of USGPIV access and hope this article serves as a roadmap for other educators to create similar assessment checklists with supporting validity evidence.

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