

**Abstract:**

Point-of-care ultrasound is at an early developmental stage in the field of pediatric emergency medicine. Ultrasound-guided vascular access has been identified as a key procedural application by several published educational guidelines and surveys of pediatric emergency medicine directors, fellowship directors, and fellows, and ultrasound-guided peripheral vascular access is well suited for the pediatric population. This article reviews the current literature on pediatric ultrasound-guided peripheral vascular access methods and demonstrates the suitability of point-of-care ultrasound as a safe, effective, patient-centered, timely, efficient, and equitable means of establishing peripheral vascular access in pediatric patients.

**Keywords:**

ultrasound; pediatric ultrasound; point-of-care ultrasound; POCUS; peripheral intravenous access; vascular access

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# A Review of Pediatric Ultrasound- Guided Peripheral Intravenous Access

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**P**oint-of-care ultrasound (POCUS) was first introduced to the field of emergency medicine more than 20 years ago. Since then, the field of pediatric emergency medicine (PEM) has gradually integrated POCUS into training and clinical practice with recent advances and research expanding the scope of pediatric POCUS.<sup>1-4</sup> Point-of-care ultrasound education and training for many PEM fellowships are still at an early developmental stage. Recently, a consensus educational guideline for PEM fellow training in ultrasound was developed by POCUS educators and the American Academy of Pediatrics Section on Emergency Medicine Fellowship Directors Subcommittee. This guideline recommended ultrasound-guided vascular access as a key procedural application.<sup>5</sup> Several published surveys of PEM directors, fellowship directors, and graduating fellows have described the use of ultrasound for vascular access as one of the most popular applications for POCUS, with central venous catheter (CVC) insertion occurring more frequently than peripheral intravenous (PIV) line insertion.<sup>6-8</sup>

A majority of the vascular access research has focused on ultrasound guidance for CVC insertion. However, PEM physicians

encounter the need for PIV access in children much more frequently than CVC insertion. This has led to increased utilization of pediatric ultrasound-guided PIV (USGPIV) access in the emergency setting and clinical research. Ultrasound-guided vascular access relies on static or dynamic ultrasound methods. Static ultrasound uses ultrasound to locate and identify the vein; then, the operator performs vein cannulation without ultrasound use. Dynamic ultrasound uses ultrasound in real time to locate the vein and allow direct visualization to guide vein cannulation. Limited studies on adult and pediatric patients using both methods have demonstrated the suitability of POCUS as a safe, effective, patient-centered, timely, efficient, and equitable means of establishing peripheral vascular access in patients.<sup>9-15</sup> This article reviews the research on USGPIV access and also highlights how POCUS for vascular access can help optimize pediatric patient care by following the 6 domains of health care quality as outlined by the Institute of Medicine.<sup>16</sup>

## ULTRASOUND-GUIDED PERIPHERAL VASCULAR ACCESS IN ADULTS

Several studies have evaluated USGPIV catheter placement in adult difficult access patients. In a prospective, observational study published in 2012, use of dynamic ultrasound guidance for PIV catheter placement prevented the need for CVC placement in 85% of difficult access adult emergency department (ED) patients. These patients had failed 2 prior landmark-based PIV catheter attempts or had difficult to palpate peripheral veins with inability to establish external jugular vein access.<sup>17</sup> One retrospective, cohort study in the intensive care unit setting described a high USGPIV access success rate in critically ill adults that had failed initial efforts for landmark PIV placement due to edema, obesity, and/or intravenous drug abuse history and similarly in those requiring emergency vascular access. The overall success rate for dynamic USGPIV access was 99%, with a 71% first attempt success rate and a minimal procedural complication rate of 6.8% (intravenous infiltration, inadvertent removal, and phlebitis/cellulitis).<sup>9</sup> Another study published in 1999 evaluated a 2-person technique for USGPIV catheter placement in deep brachial or basilic veins in adult ED patients with 2 prior unsuccessful peripheral vascular access attempts.<sup>10</sup> Catheter placement success was reported to be 91% overall with a 73% first attempt success rate. Fairly rapid placement of peripheral catheters was also noted, with a mean time of 77 seconds ( $\pm$ SD 129;

range, 4-600 seconds), and complications were limited to 11% of patients (mainly line infiltration or displacement).<sup>10</sup> In 2005, Costantino et al<sup>11</sup> initially demonstrated successful USGPIV catheter placement using a 2-person technique in adult ED difficult access patients in a prospective, systematically allocated study. Adult patients with 3 unsuccessful PIV catheter attempts were allocated to have further landmark or USGPIV catheter attempts. The success rate for USGPIV catheter placement was 97%, compared to the control landmark success rate of 33%. They also reported less time to cannulation from first percutaneous puncture to catheter placement for USGPIV vs landmark techniques (4 vs 15 minutes; difference of 11 minutes; 95% confidence interval [CI], 8.2-19.4) and overall greater patient satisfaction scores (8.7 vs 5.7; difference of 3.0; 95% CI, 1.82-4.29).<sup>11</sup> A subsequent prospective, randomized study by Costantino et al<sup>12</sup> in 2010 once again showed high success rates for USGPIV catheter placement using a 1-person dynamic technique. Adult ED patients with 3 prior unsuccessful PIV catheter attempts were randomized to USGPIV or external jugular landmark PIV catheter placement, and initial PIV catheter success rate was 84% (95% CI, 68-93%) using USGPIV access methods compared to a 50% (95% CI, 33-67%) initial success rate for external jugular landmark catheterization methods ( $P = .006$ ).<sup>12</sup>

## ULTRASOUND-GUIDED PERIPHERAL VASCULAR ACCESS IN CHILDREN

Once USGPIV access was established as a safe and effective means of vascular access in adult patients, the focus shifted toward optimizing pediatric patient care with this technique. In 2007, a pilot study by Schnadower et al<sup>18</sup> showed that pediatric ED physicians were successful in using ultrasound to identify peripheral veins for vascular access and that a lack of ultrasound visualization was associated with unsuccessful PIV catheter placement by individuals blinded to ultrasound results. One prospective, observational convenience sample study in 2010 compared landmark and USGPIV catheter placement in pediatric ED patients. Pediatric patients requiring peripheral vascular access were evaluated by PEM physicians using a Likert scale to estimate degree of vascular access difficulty. Ultrasound-guided PIV access methods were more successful than landmark methods in patients identified as "difficult" or "very difficult" (35% vs 18%;  $P = .003$ ) while requiring a moderate increase in time to cannulation (2 minutes 15 seconds vs

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