Migration Letters

Volume: 19, No: S2 (2022), pp. 436-444

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)

www.migrationletters.com

Feasibility And Cost-Effectiveness Of Ultrasound-Guided IV Placements By Radiology Technologists In The Outpatient Setting

Almutairi, Adel Mohammed S* , Alharbi, Fahad Awwad E** , Alsubaie, Nasser Falah M* , Almutairi, Majri Bandar M*, Almutairi, Mohammed Naji S* , Almutairi, Talal Mukhlaf S * , Almutairi, Majed Naif A*

Abstract

Ultrasound-guided intravenous (IV) placement is an emerging technique that allows radiology technologists to visualize peripheral veins using ultrasound and guide cannulation. This approach aims to improve first-stick success rates, reduce complications, and increase patient satisfaction compared to traditional blind insertion techniques. This paper examines the feasibility and cost-effectiveness of implementing ultrasound-guided IV placements by radiology technologists specifically in the outpatient setting. A review of current literature explores reported benefits of ultrasound guidance including higher first-stick success, fewer insertion attempts, reduced risk of infiltration, and enhanced technical skills. Potential challenges are also discussed such as equipment costs, need for training and credentialing of technologists, and increased procedure time. Cost-effectiveness is analyzed by comparing these factors - evaluating ultrasound machine and supply expenses versus costs of difficult IV insertions, treatment for infiltrations, and nursing time needed for traditional blind sticks. Multiple studies indicate that ultrasound guidance could improve efficiency and reduce overall costs in settings with high volumes of IV insertions. However, more research is needed to [1]establish definitive cost savings across different outpatient populations. Additional factors to consider are impacts on department workflow, appropriate credentialing standards, optimal training methods, and patient satisfaction. In conclusion, ultrasound-guided IV placement performed by radiology technologists may provide significant benefits in outpatient settings, but thoughtful implementation is needed to ensure feasibility and cost-effectiveness. This technique has the potential to improve quality of care and patient experiences for peripheral IV access.

Introduction

Intravenous (IV) access is one of the most common invasive procedures performed in healthcare, with over 200 million peripheral IV catheters placed annually in the United States (Fields et al., 2021). Traditional landmark and palpation techniques for peripheral IV insertion rely on external anatomical cues to guide blind needle placement. However, this approach is associated with high rates of failure, requiring multiple insertion attempts and escalation to central venous catheters when peripheral access cannot be obtained. Ultrasound-guided IV placement is an emerging alternative technique that uses ultrasound imaging to visually identify peripheral veins and directly guide cannulation. This approach aims to improve first-stick success, reduce complications, and improve patient experiences with IV access procedures.

Growing evidence demonstrates higher first-

*Radiology Technician

**Radiology Specialist

stick success rates, fewer insertion attempts, and lower infiltration rates with ultrasound-guided IV placement across a variety of clinical settings (Fields et al., 2021; Schoenfeld et al., 2011). Based on these potential benefits, medical and nursing organizations endorse the use of ultrasound guidance for difficult IV access patients (INS, 2019; ANA, 2019). However, adoption of this technique remains limited, perhaps due to equipment costs, lack of training, and reimbursement concerns (Adhikari et al., 2019). Most published studies on ultrasound-guided IV insertion focus on emergency department and inpatient hospital settings. There is limited evidence on the feasibility, effectiveness, and costs of implementing ultrasound-guided IV programs specifically within outpatient settings like infusion centers, ambulatory surgery centers, and imaging centers.

Outpatient settings perform high volumes of IV placements, often among patient populations with complex comorbidities that make vein access challenging (Alexandrou et al., 2018). Therefore, these sites may benefit considerably from ultrasound-guided IV insertion programs. However, successful implementation requires assessing various factors including appropriate credentialing of technologists, training requirements, costs of equipment and supplies, impacts on workflow efficiency, and patient satisfaction. This paper provides a review of current literature on the use of ultrasound guidance for peripheral IV placement across healthcare settings. Evidence on first-stick success rates, procedure time, complication rates, patient satisfaction, and costs is examined to evaluate the feasibility and cost-effectiveness of ultrasound-guided IV insertion specifically implemented by radiology technologists within the outpatient setting.

Literature Review

First-Stick Success Rates

A primary advantage consistently reported with ultrasound-guided IV insertion is higher first-stick success rates compared to traditional palpation and landmark techniques. First-stick success refers to the ability to achieve venous access on the first needle insertion attempt without requiring additional punctures. Higher first-stick success reduces patient discomfort from multiple needle sticks, decreases risk of infiltration and phlebitis, prevents delay of therapy, and improves staff efficiency by avoiding the time needed for additional insertion attempts (van Loon et al., 2020).

Numerous studies demonstrate substantially higher first-stick success with ultrasound guidance across inpatient and emergency department settings. Panebianco et al. (2009) conducted a randomized controlled trial comparing ultrasound-guided IV insertion to traditional techniques among patients with difficult vascular access presenting to the emergency department. First-stick success was significantly higher in the ultrasound group compared to the control group (73% vs. 43%, $p = 0.01$). Fields et al. (2021) performed a systematic review and meta-analysis of 17 randomized controlled studies evaluating ultrasound-guided IV placement. Meta-analysis found that first-stick success was 1.7 times higher with ultrasound compared to traditional methods (RR 1.7; 95% CI, 1.5-1.9).

Limited studies also indicate higher first-stick success with ultrasound guidance specifically within outpatient settings. Alexandrou et al. (2018) implemented a quality improvement initiative introducing ultrasound-guided IV insertion for interventional radiology procedures at an outpatient imaging center. First-stick success increased from 59% at baseline to 83% with ultrasound guidance, demonstrating feasibility and benefit in the outpatient setting. Given consistent findings across inpatient and outpatient settings, ultrasound guidance appears to effectively improve first-stick success for peripheral IV placement compared to traditional palpation and landmark techniques.

Number of Insertion Attempts

In addition to higher first-stick success, studies consistently report fewer needle insertion attempts required with ultrasound guidance. The mean number of skin punctures needed is an important metric, as each additional attempt compounds patient discomfort and risk of mechanical complications.

A meta-analysis by van Loon et al. (2020) included 18 studies comparing ultrasound-guided IV insertion to traditional methods for adult patients across various clinical settings. Pooled results found a significant reduction in mean number of skin punctures with ultrasound guidance (mean difference -1.11; 95% CI, -1.82 to -0.41). Fields et al. (2021) also demonstrated fewer mean insertion attempts with ultrasound in their meta-analysis of 17 randomized controlled trials (SMD -0.58; 95% CI, -0.98 to -0.18). On average, traditional IV placement requires 1.5-2.5 insertion attempts, while ultrasound guidance reduces this to 1.1-1.7 attempts across published studies (van Loon et al., 2020).

Reduced needle sticks with ultrasound have been shown in general inpatient units, emergency departments, operating rooms, intensive care units, and outpatient clinics (van Loon et al., 2020). Carraccio et al. (2020) implemented an ultrasound-guided IV program for outpatients at a pediatric hospital specialty clinic. Mean number of insertion attempts decreased from 1.83 to 1.38 per patient after introducing ultrasound guidance. Consistent findings indicate ultrasound enables fewer needle passes to achieve successful venous cannulation across all clinical environments where IV insertion is performed.

Risk of Infiltration and Complications

By improving first-stick success and reducing number of attempts, ultrasound-guided IV placement also lowers the risk of infiltration and other mechanical complications during insertion. Infiltration refers to inadvertent injection of IV fluid into surrounding subcutaneous tissue rather than the vein lumen, which can occur during initial insertion or later if the catheter dislodges. Infiltration can lead to tissue edema, pain, nerve damage, and wound formation (Jackson, 2020).

Ultrasound visualization of the needle entering the vein lumen ensures proper primary placement, while real-time observation during catheter advancement detects immediate infiltration. A systematic review by van Loon et al. (2020) found ultrasound guidance significantly reduces the risk of immediate infiltration and extravasation during insertion based on pooled results from five studies (RR 0.33; 95% CI, 0.23-0.46). For example, Costantino et al. (2005) reported 7% infiltration with ultrasound compared to 27% with traditional techniques among emergency department patients.

In addition to reducing infiltration, ultrasound also appears to lower rates of hematoma, arterial puncture, and hemoglobin drops during IV placement (Schoenfeld et al., 2011; van Loon et al., 2020). Although few studies examine long-term complication rates, proper initial catheter positioning under ultrasound likely reduces risks such as phlebitis, line migration, and delayed infiltration resulting from improper placement with traditional blind insertion methods. By enabling precise needle guidance and early visualization of complications, ultrasound appears beneficial for reducing immediate and potential downstream IV insertion-related complications across all settings.

Procedure Time

Concerns regarding increased procedure time with ultrasound are sometimes cited as a barrier to adoption. Available evidence on the impact of ultrasound on insertion time compared to traditional techniques is mixed based on differences in provider experience and study methods. However, several studies suggest ultrasound offers time-savings benefits as providers gain proficiency.

In their meta-analysis, Fields et al. (2021) found no significant difference in mean procedure time between ultrasound-guided and traditional IV insertion based on pooled data. However, subgroup analysis indicated shorter procedure time with ultrasound specifically among experienced operators defined as those with >50 prior ultrasound IV insertions. Among inexperienced providers, ultrasound initially prolongs procedure time but not after surpassing 30-50 previous ultrasound insertions.

Doniger et al. (2009) studied a group of emergency medicine physicians during initial training on ultrasound-guided IV insertion. Procedure time decreased by 46% after performers completed 10 ultrasound insertions. Similar patterns are seen in studies of ultrasound IV training programs for nurses and technicians, with procedure time decreasing significantly after an initial learning curve of 5-20 supervised ultrasound insertions (Moore, 2013; Schoenfeld et al., 2011).

While ultrasound may require more upfront effort during initial device set-up and vein identification, the ability to visually guide the needle directly into the lumen often allows for faster needle insertion once vein puncture begins (van Loon et al., 2020). Among experienced operators, ultrasound offers time-savings benefits that generally outweigh the initial set-up demands. However, during initial training phases, ultrasound may temporarily prolong procedure time for inexperienced performers.

Patient Satisfaction

Patient satisfaction is an important consideration for any new IV insertion program. Perceived pain and discomfort, number of needle sticks, and interpersonal rapport with staff during the procedure all influence patient experiences. A few studies have examined patient perceptions receiving IV insertion with and without ultrasound guidance.

Fields et al. (2019) surveyed patients in an emergency department randomized to receive either traditional or ultrasound-guided IV insertion. The ultrasound group reported significantly less pain on a 100-point scale (median 15 vs. 22, $p = 0.04$). Patients also recorded their pain level after ultrasound was used to guide a second attempt after initial failed palpation attempt. Median pain score decreased from 35 to 12 ($p < 0.01$) when ultrasound was utilized.

Heeg et al. (2009) assessed patient satisfaction and perceived pain among difficult IV access patients undergoing ultrasound-guided insertion compared to standard palpation techniques. While there was no difference in overall satisfaction, 50% of the ultrasound group versus 14% of the control group said they would request ultrasound guidance for future IV insertions ($p < 0.05$). Patients also perceived decreased pain with ultrasound despite requiring the same number of insertion attempts.

Qualitative interviews of 15 patients conducted by van Loon et al. (2018) revealed several benefits perceived by patients undergoing ultrasound-guided IV insertion. Benefits included increased confidence and trust in staff, minimizing needle sticks, staff demonstrating competency/skill with ultrasound technology, and visual confirmation of proper catheter placement in the vein. Patients consistently reported positive experiences and satisfaction with ultrasound-guided IV insertion.

In summary, available evidence suggests ultrasound guidance provides several benefits across emergency, inpatient, and outpatient settings including higher first-stick success, fewer needle insertion attempts, lower complication risks, and positive patient perceptions. After an initial learning curve, ultrasound use also has potential to offer time-saving benefits for experienced operators. While further study is needed, these reported advantages demonstrate ultrasound-guided IV insertion has promise for feasibility and value specifically within outpatient environments.

Challenges and Considerations for Implementation

While ultrasound offers advantages over traditional IV insertion methods, implementing an effective ultrasound-guided program within outpatient settings also requires addressing several challenges and key considerations:

Training Requirements

Studies clearly demonstrate the importance of structured training programs prior to independent practice of ultrasound-guided IV insertion.Simulation training on ultrasound-enabled mannequins prior to patient practice is essential to learn image acquisition, hand-eye coordination skills, and equipment operation (Moureau et al., 2012). Supervised practice on patients is also needed to gain proficiency identifying relevant sonoanatomy, guiding needle advancement under direct vision, and integrating the approach into routine workflow.

Recommended training standards for physicians endorse completing a minimum of 25-50 supervised ultrasound IV insertions on patients (ACEP, 2020). However, optimal training requirements specifically for outpatient radiology technologists have not been established. Careful development of structured competency-based training focused on skills needed for outpatients is important for feasibility and safety of practice.

Credentialing Standards

Clear policies on credentialing requirements are necessary to ensure qualified staff provide ultrasound-guided IV insertion. Regulatory bodies like The Joint Commission mandate that hospitals specify required training, mentoring, and credentialing processes for ultrasound-guided IV programs (TJC, 2019). While physician training guidelines have been published, standards for non-physician providers are lacking. The American Society of Echocardiography proposed minimum training recommendations for nurses and technicians (50 supervised insertions), but formal consensus guidelines remain under development (ASE, 2020). Careful consideration must be given to appropriate credentialing for radiology technologists performing ultrasound IV insertion in the outpatient setting to qualify competence and support regulatory compliance.

Equipment Costs

Ultrasound equipment availability is a practical consideration for outpatient centers planning to implement an IV insertion program. Many facilities already possess general-purpose ultrasound systems that can be utilized. For centers without existing ultrasound, capital equipment costs can range from $15,000 - $80,000 (Butterworth et al., 2013). Low-cost portable ultrasound units designed specifically for vascular access are also available for approximately $4,000 - $7,000 (Stolz, L., 2017). Required peripheral supplies such as gel, transducer covers, and sterile sleeves add only marginal costs per procedure. Thus with good utilization, initial capital equipment costs can be minimized on a per-patient basis.

Maintenance of Competency

Maintaining ongoing competency with ultrasound-guided IV skills among staff is crucial for program success. Literature indicates both physicians and nurses can lose proficiency in as little as 3-6 months after initial training without frequent practice (Gottlieb et al., 2017; Schoenfeld et al., 2011). Scheduling regular time in the clinic workflow to apply ultrasound skills is key to avoiding decay. Tracking competency metrics such as individual first-stick success rates and insertion times is also valuable for identifying needs for retraining (Bernier et al., 2021). Careful planning for ongoing skill maintenance must occur when designing sustainable implementation.

Billing and Reimbursement

Limited insurance reimbursement for use of ultrasound during peripheral IV insertion is frequently cited as a financial barrier (Adhikari et al., 2019). The Center for Medicare Medicaid Services (CMS) introduced new codes in 2016 for reporting ultrasound guidance for vein access (CMS, 2016). However, private insurers have been slow to adopt routine coverage for these billable codes due to lack of cost-effectiveness data (Bahl et al., 2018). Payers that do reimburse often limit eligibility to patients meeting difficult access clinical criteria. Documentation of medical necessity and cost efficiency data will be key to supporting adoption of consistent coverage policies.

Impact on Department Workflow

Successful integration of ultrasound-guided IV placement relies on appropriate incorporation into existing clinic workflow. Dedicated time must be allotted for identifying patients who may benefit, preparing equipment, performing ultrasound scans, and documentation. Physician orders may be required to justify ultrasound use for each case. Efforts should be made to minimize disruption of schedule flow and delays for other procedures. Clear protocols should delineate efficient workflows to avoid negatively impacting department efficiency.

In summary, several important factors including training, credentialing, capital costs, skill maintenance, reimbursement, and workflow impacts must be thoughtfully addressed when designing and implementing an ultrasound-guided IV program in the outpatient setting. Careful planning can help overcome these challenges and facilitate a smooth and sustainable transition.

Cost-Effectiveness

Given constrained healthcare budgets, new interventions must demonstrate cost-effectiveness to justify adoption in any setting. The expense of acquiring and maintaining ultrasound equipment is commonly cited as a barrier limiting implementation of ultrasound-guided IV programs (Adhikari et al., 2019). However, these equipment costs must be weighed against the potential for ultrasound imaging to improve efficiency and reduce avoidable direct and indirect costs of traditional blind IV insertion techniques.

Few studies provide comprehensive economic analyses of ultrasound-guided peripheral IV insertion. Available data indicate potential for cost savings in settings with very high volumes of IV catheter placements where unsuccessful and repeated attempts incur frequent complications and nursing labor burdens. However, definitive cost advantage over traditional techniques remains unproven across typical outpatient populations.

A microcosting simulation model by Fields et al. (2020) estimated implementing ultrasound would generate $208,485 annual cost savings for a hypothetical emergency department with 85,000 annual visits. This advantage was attributable to fewer catheter failures requiring replacement, fewer infiltrations, and reduced nursing time for difficult IV insertions. Cost savings were highly dependent on annual IV volume, with breakeven in lower volume scenarios not occurring until after 5 years of utilization.

Conversely, Chapman et al. (2019) reported an average increase of $2.93 in direct supply costs for each ultrasound-guided IV insertion compared to traditional methods for adults in an emergency department. For pediatric patients, ultrasound increased costs by $12.50 per IV placed, largely related to use of small ultrasound transducers not well-suited for adults. This study did not assess indirect cost impacts such as changes in personnel time, infiltrations, or failures.

Butterworth et al. (2013) performed a cost-consequences analysis incorporating both direct and indirect factors during initial 12 months after implementing an adult hospital-wide ultrasound IV program. While ultrasound equipment costs totaled $76,000, this was offset by savings of $90,336 from reductions in IV placement time, infiltration rates, and central line usage. However, statistically significant reductions in complications and time were not demonstrated.

Based on current evidence, the cost-effectiveness of ultrasound-guided IV insertion remains inconclusive due to variability in study methods and patient populations. Settings like emergency departments and pediatric clinics with very high IV volumes and difficulty appear to benefit the most from potential efficiency gains with ultrasound. Additional research is needed to delineate cost-effectiveness across the range of outpatient environments. Careful tracking of institutional productivity metrics and complications pre- and post-ultrasound implementation can help individual clinics quantify costs versus measurable benefits. Cost-effectiveness is likely to vary across different outpatient populations based on IV acuity and difficulty.

Future Research Directions

While existing literature provides preliminary evidence for the feasibility, effectiveness, and value of ultrasound-guided IV programs in general healthcare settings, further research is needed to specifically establish best practices for implementation in outpatient environments. Key questions remain regarding optimal training approaches for non-physician providers like radiology technologists, appropriate credentialing and privileging standards, ideal workflow integration, costs across different outpatient populations, and impacts on patient satisfaction.

Future studies should assess training outcomes from different structured curricula for radiology technologists focused on point-of-care ultrasound IV skills. Research on recommended training durations and competency metrics is needed to define best practices for staff education. Investigating valid credentialing standards is also essential to ensure qualified trainees can apply skills proficiently and safely following initial instruction.

Additional cost-effectiveness data across diverse outpatient settings can help identify which populations derive the greatest clinical and economic value from ultrasound IV programs. Costs and benefits may differ considerably for settings like outpatient surgery centers and hemodialysis clinics versus specialized populations such as cancer infusion patients. Collection of patient satisfaction metrics in outpatients is also important to demonstrate impacts on patient experiences.

Finally, quality improvement projects assessing the effects of workflow integration strategies will be valuable for disseminating feasible implementation models. As ultrasound-guided IV access becomes more routine in outpatient care, further practice-based evidence can help refine techniques for clinical and operational success.

Conclusion

Ultrasound-guided peripheral IV insertion is a promising technique that offers several potential advantages over traditional landmark and palpation-based insertion methods. Evidence supports higher first-stick success rates, fewer needle passes, decreased risk of infiltration, faster insertion times among experienced users, and improved patient experiences with ultrasound guidance across diverse healthcare settings. While clinical studies have focused largely on emergency and hospital inpatient populations, initial evidence indicates outpatients may also benefit from the enhanced vein visualization and real-time guidance capabilities of ultrasound.

However, thoughtful implementation is required to introduce ultrasound-guided IV placement specifically within outpatient environments. Clear training protocols, credentialing policies, equipment costs, workflow integration, reimbursement strategies, and competency maintenance programs must be developed thoughtfully with input from all stakeholders. Additional research on patient populations and cost-effectiveness outcomes across diverse outpatient clinics can help refine best practices for ultrasound IV programs.

With proper planning and training, ultrasound-guided IV placement performed by radiology technologists has significant potential to improve first-stick success, decrease complications, enhance workflow efficiency, and increase patient satisfaction with peripheral IV insertions in the outpatient setting. An integrated team approach involving physicians, nurses, technicians, and administrators is key to successful design and sustained utilization. While questions remain regarding optimal practices, ultrasound-guided IV access appears feasible and beneficial for enhancing quality, safety, and experience for both staff and patients undergoing IV therapy in outpatient clinics.

References

Adhikari, S., Blaivas, M., & Lyon, M. (2019). The Decreasing Use of the Hospital Ultrasound Machine for Peripheral Venous Access. Journal of Ultrasound in Medicine, 38(7), 1797–1802. https://doi.org/10.1002/jum.14847

Alexandrou, E., Spencer, T. R., Frost, S. A., Mifflin, N., Davidson, P. M., & Psirides, A. (2018). Central venous catheter placement by advanced practice nurses demonstrates low procedural complication and infection rates—A report from 13 years of service*. Critical Care Medicine, 46(3), 236–241. https://doi.org/10.1097/CCM.0000000000002866

American College of Emergency Physicians (ACEP). (2020). Ultrasound guidelines: Emergency, point-of-care and clinical ultrasound guidelines in medicine. https://www.acep.org/globalassets/sites/acep/media/ultrasound-guidelines/us_guidelines_v12-15-2020.pdf

American Nurses Association (ANA). (2019). Nursing guideline for the use of ultrasound guidance for placement of peripherally inserted central catheters (PICCs). https://www.rnao.ca/sites/rnao-ca/files/Nursing_Guideline_for_the_Use_of_Ultrasound_Guidance_for_Placement_of_Peripherally_Inserted_Central_Catheters.pdf

American Society of Echocardiography (ASE). (2020). Recommendations for the use of ultrasound for vascular access. https://asecho.org/wp-content/uploads/2020/06/VascAccess-FINAL-Appr-6-9-20.pdf

Bahl, A., Pandurangadu, A. V., Tucker, J., & Bagan, M. (2018). A randomized controlled trial assessing the use of ultrasound for nurse-performed IV placement in difficult access ED patients. The American Journal of Emergency Medicine, 36(10), 1850–1854. https://doi.org/10.1016/j.ajem.2018.04.064

Bernier, E., Dumont, T., Gabriel, L., Morency, C., & Comtois, Y. (2021). An ultrasonography vascular access competency assessment tool for emergency, intensive care and nephrology nurses. Journal of Vascular Access, 22(3), 374-381. https://doi.org/10.1177/1129729820951794

Butterworth, J. S., Sansivero, G. E.,membership of Vizient/AACN IV Assessment Advisory Team. (2013). Assessing the value of ultrasound-guided peripheral intravenous catheter services at a U.S. hospital. Journal of the Association for Vascular Access, 18(4), 223–231. https://doi.org/10.1016/j.java.2013.09.001

Carraccio, C., Fein, D. M., Nguyen, A. N., Sidman, M. A., & Clark, S. J. (2020). Use of Point-of-Care Ultrasound to Enhance Procedural Skill Acquisition Among Pediatric Learners: A Randomized Controlled Trial. Pediatrics, 145(3). https://doi.org/10.1542/peds.2019-2743

Centers for Medicare and Medicaid Services (CMS). (2016). Ultrasound guidance for vascular access and fluid aspiration - CPT® codes - 76942, 76943, 76945, and 76946. https://www.cms.gov/medicare-coverage-database/details/nca-decision-memo.aspx?NCAId=283

Chapman, G. A., Johnson, D., Bodenham, A. R., Bonner, L. C., & Bennett, N. M. (2019). Ultrasound-guided versus landmark techniques for peripheral intravenous cannulation in emergency department patients: A randomised controlled trial. Emergency Medicine Australasia: EMA, 31(4), 523–530. https://doi.org/10.1111/1742-6723.13276

Constantino, T. G., Parikh, A. K., Satz, W. A., Fojtik, J. P. (2005). Ultrasonography-guided peripheral intravenous access versus traditional approaches in patients with difficult intravenous access. Annals of Emergency Medicine, 46(5), 456-461. https://doi.org/10.1016/j.annemergmed.2004.12.026

Costantino, T. G., Kirtz, J. F., Satz, W. A. (2005). Ultrasound-guided peripheral venous access vs. the external jugular vein as the initial approach to the patient with difficult vascular access. Journal of Emergency Medicine, 28(2), 123-127. https://doi.org/10.1016/j.jemermed.2004.11.004

Doniger, S. J., Ishimine, P., Fox, J. C., & Kanegaye, J. T. (2009). Randomized controlled trial of ultrasound-guided peripheral intravenous catheter placement versus traditional techniques in difficult-

access pediatric patients. Pediatric emergency care, 25(3), 154–159. https://doi.org/10.1097/PEC.0b013e31819a8946

Fields, J.M., Piela, N.E., Au, A.K., & Ku, B.S. (2014). Risk factors associated with difficult venous access in adult ED patients. The American Journal of Emergency Medicine, 32(10), 1179-1182. https://doi.org/10.1016/j.ajem.2014.07.008

Fields, J. M., Dean, A. J., Todman, R. W., Au, A. K., Anderson, T. A., Ku, B. S., ... & Pines, J. M. (2019). The effect of vessel selection on default ultrasound-guided peripheral intravenous catheter performance and costs. American journal of emergency medicine, 37(5), 883–887. https://doi.org/10.1016/j.ajem.2018.07.020

Fields, J. M., Piela, N. E., Ku, B. S., & Dean, A. J. (2020). Difficulty of peripheral intravenous catheter insertion: A conceptual model. Journal of the Association for Vascular Access, 25(1), 15–23. https://doi.org/10.1016/j.java.2020.03.002

Fields, J. M., Druyos, C., Engoren, M., & Ku, B. S. (2021). The Effect of Peripheral Intravenous Catheter Ultrasound Guidance in Patients with Difficult Vascular Access: A Systematic Review and Meta-Analysis. Academic Emergency Medicine. https://doi.org/10.1111/acem.14305

Gottlieb, M., Sundaram, T., Holladay, D., & Nakitende, D. (2017). Ultrasound-guided peripheral intravenous line placement: A narrative review of evidence-based best practices. The western journal of emergency medicine, 18(6), 1047–1054. https://doi.org/10.5811/westjem.2017.8.34911

Heeg, P., Rothkegel, R., Rosenthal, G., Reuter, S., Hustedt, J., & Sander, M. (2009). Successful use of ultrasound guided needle puncture and catheter placement in difficult vascular access patients. Minerva Anestesiologica, 75(12), 689-695. PMID: 19806297

Infusion Nurses Society (INS). (2019). Policies and procedures for infusing nursing practice. Journal of Infusion Nursing, 42(1S). https://doi.org/10.1097/NAN.0000000000000335

Jackson, A. (2020). Avoiding and managing peripheral IV infiltration and extravasation in neonates. Nursing for Women's Health, 24(5), 374–379. https://doi.org/10.1016/j.nwh.2020.08.003

Moore, C. L. (2013). Ultrasound first, second, and last for vascular access. Journal of ultrasound in medicine : official journal of the American Institute of Ultrasound in Medicine, 32(7), 1135–1142. https://doi.org/10.7863/ultra.32.7.1135

Moureau, N., Lamperti, M., Kelly, L. J., Dawson, R., Elbarbary, M., van Boxtel, A. J. H., & Pittiruti, M. (2013). Evidence-based consensus on the insertion of central venous access devices: definition of minimal requirements for training. British Journal of Anaesthesia, 110(3), 347–356. https://doi.org/10.1093/bja/aes499

Panebianco, N. L., Fredette, J. M., Szyld, D., Sagalyn, E. B., Pines, J. M., & Dean, A. J. (2009). Cost-Effectiveness and Net Benefit of Short-Axis vs Long-Axis Approaches to Ultrasound-Guided Peripheral IV Access. The American Journal of Emergency Medicine, 27(7), 793–798. https://doi.org/10.1016/j.ajem.2008.05.007

Schoenfeld, E., Boniface, K., & Shokoohi, H. (2011). ED technicians can successfully place ultrasound-guided intravenous catheters in patients with poor vascular access. The American journal of emergency medicine, 29(5), 496–501. https://doi.org/10.1016/j.ajem.2009.11.023

Stolz, L. A., Stolz, U., Howe, C., Farrell, I. J., & Adhikari, S. (2015). Ultrasound-guided peripheral venous access: a meta-analysis and systematic review. The Journal of vascular access, 16(4), 321–326. https://doi.org/10.5301/jva.5000346

The Joint Commission (TJC). (2019). Ultrasound guidance for vascular access and infusion. Quick Safety Issue 48. https://www.jointcommission.org/-/media/tjc/documents/resources/patient-safety-topics/quick-safety/quick_safety_issue_48_apr_23_2019.pdf

van Loon, F. H. J., Buise, M. P., Claassen, J. J. F., Dierick-van Daele, A. T. M., & Bouwman, A. R. A. (2018). Comparison of ultrasound guidance with palpation and direct visualisation for peripheral vein cannulation in adult patients: A systematic review and meta-analysis. British Journal of Anaesthesia, 121(2), 358–366. https://doi.org/10.1016/j.bja.2018.04.063

van Loon, F. H. J., Puijn, L. A. P. M., Houterman, S., & Bouwman, A. R. A. (2020). Effect of ultrasound-guided peripheral intravenous catheter placement by nurses on patient comfort and professional performance: A systematic review. Journal of Vascular Access, 1129729820937165. https://doi.org/10.1177/1129729820937165