Implementation of an Ultrasound-Guided Algorithm for Difficult Intravenous Access

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Abstract

Problem & Purpose: Obtaining peripheral intravenous (PIV) access is a frequent, but challenging procedure in difficult access patients (DIVA). Emergency medical care frequently requires PIV access to administer medications and perform diagnostic testing. Traditional methods for obtaining PIV access have resulted in repeated painful attempts and treatment delays in this tertiary care emergency department. The purpose of this quality improvement project was to implement and evaluate a nursing-initiated clinical pathway directing the use of ultrasound-guided intravenous techniques for DIVA patients to increase first attempt success rates and reduce treatment delays.

Methods: A departmental policy was created to support the practice change. The policy provided an illustration of the DIVA clinical algorithm and specified training and competency validation expectations. Training included 30-minutes of didactic instruction followed by 60-minutes of hands-on training. Competency validated operators documented DIVA screening, ultrasound utilization rates, pain scores, number of venous attempts, and treatment delays. Project compliance and outcome measures were collected over 14-weeks and converted into run charts for weekly unit dissemination. Chi-squared and independent samples t-tests were used to compare pre-and post-implementation results.

Results: Sixteen operators completed the education and training program which included nurses (n=8) and technicians (n=8). Operator compliance to DIVA screening and ultrasound-guided intravenous algorithm utilization suggested early adoption ($M = 89.25$, $SD = 7.45$). First-attempt success rates for DIVA patients increased from 57% to 87% ($p = 0.03$) and treatment delays decreased from 20% to 0% ($p = 0.01$). There was a significant reduction in pain scores ($M = 2.2$, $SD = 1.17$) compared to baseline ($M = 5.3$, $SD = 1.65$) data; $t(58) = 8.08$, $p < 0.001$.

Conclusions: The use of a nurse-initiated clinical pathway to identify difficult access patients requiring ultrasound-guided intravenous cannulation increases the likelihood of first attempt access success and ensures timely medication administration, laboratory analysis, and diagnostic testing in the emergency department. The reduction in cannulation attempts optimizes patient outcomes by decreasing pain experienced by the patient, and treatment delays.

Introduction

Peripheral intravenous (PIV) cannulation is a common, yet challenging procedure performed in the emergency department (ED) (Weiner et al., 2012). In the United States, approximately 35 million ED visits in 2017 resulted in PIV placement for intravenous fluids (Centers for Disease Control and Prevention [CDC], 2017). Timely PIV access is essential for medication administration, diagnostic testing, and laboratory analysis (Witting, 2012). Obtaining PIV access in difficult intravenous access (DIVA) patients is challenging despite the high frequency of PIV procedure requirements in the ED (Bahl et al., 2016). Defining DIVA is difficult, although notable predictors include a history of DIVA, technician expectation for DIVA, absence of palpable and visible veins, and selecting cannulation veins less than three millimeters (VanLoon et al., 2019). The current practice for obtaining PIV access involves a restricting band, vein visualization, palpation, and use of landmarks (RVPL). However, RVPL practices are associated with a 65 % first attempt failure rate in DIVA patients (McCarthy et al., 2016). Failed cannulations result in treatment delays and increased venipuncture attempts, pain, and central venous catheter placements (Bahl et al., 2016). A novel technique designed to assist with obtaining PIV access in DIVA patients includes employing ultrasound-guided intravenous (USGIV) techniques. USGIV technique is defined as utilizing an ultrasound machine and transducer to create a real-time, two-dimensional image to visualize catheter insertion into the vein (Liu et al., 2014; Oliveira & Lawrence, 2016).

A tertiary medical center was experiencing treatment delays in the ED secondary to high PIV access failure rates for DIVA patients. Treatment delays related to failed PIV access were estimated to be between 45 to 100 minutes and comprised approximately 16 % of ED encounters requiring PIV access. Four weeks of data collection from August to September 2020 verified that

first attempt PIV success rates were approximately 50 % in DIVA patients. The purpose of this QI project was to implement and evaluate a nursing-initiated clinical pathway directing the use of USGIV techniques for DIVA access to increase first attempt PIV success rates and reduce treatment delays in the ED.

Literature Review

A comprehensive literature review provided sufficient evidence supporting the use of USGIV techniques for DIVA patients in the ED setting. This review provides a brief summation of the major findings in the six main studies that supported USGIV techniques to improve PIV cannulation first attempt success rates, reduce venipuncture rates, and prevent treatment delays in all ED patients (Bahl et al., 2016; Benkhadra et al. 2012; Constantino et al., 2010; McCarthy et al., 2016; Van Loon et al., 2019; Weiner et al., 2012). The review concludes with a condensed summary of the level and quality of the presented evidence (See Tables 1 & 2).

The use of USGIV techniques in DIVA patients improved first attempt success rates when compared to traditional RVPL techniques (Bahl et al., 2016; Benkhadra et al., 2012; Constantino et al., 2010; McCarthy et al., 2016; Van Loon et al., 2019). Five studies showed that first attempt PIV success rates increased with statistical significance in the USGIV groups compared to RVPL groups ($p<0.05$; risk ratio: 2.32 [CI] 95%) (Bahl et al., 2016; Benkhadra et al. 2012; Constantino et al., 2010; McCarthy et al., 2016; Van Loon et al., 2019). Similarly, the use of USGIV techniques in DIVA patients reduced the total number of venipunctures necessary to successfully cannulate a vessel (Bahl et al., 2016; Benkhadra et al., 2012; Van Loon et al., 2019). Benkhadra et al. (2012) found the number of venipunctures was significantly lower in the USGIV group compared to the blind group ($p<0.05$). Three of the studies found that the USGIV groups required less venipunctures to obtain PIV access compared to the RVPL groups, although

the studies failed to reach statistical significance (Bahl et al., 2016; Van Loon et al., 2019; Weiner et al., 2012).

The utilization of USGIV techniques in DIVA patients reduced the time to PIV cannulation and prevented treatment delays. Witting et al. (2012) found that DIVA patients were subjected to treatment delays ranging between 15 to 120 minutes. The evidence surrounding treatment delays requires careful analysis owing to the concept that using USGIV techniques in patients considered not to have difficult access might increase cannulation times. Stratifying only DIVA patients to USGIV techniques is essential to reduce cannulation times to prevent treatment delays. Benkhadra et al. (2012) found the median times to cannulation were significantly shorter in the USGIV group than in the blind group ($p<0.001$), and ultimately terminated enrollment at 50 percent. Alternatively, one study found that the mean time to cannulation for the USGIV group took an average of 79 to 97 seconds longer than the RVPL group reinforcing prior claims that using the ultrasound to obtain PIV access in patients not classified as DIVA is likely to produce paradoxical results (McCarthy et al., 2016).

The evidence provided in this review was critically appraised using Melnyk and Fineout-Overholt's (2019) level of evidence rating scale and Newhouse's (2006) quality of evidence rating scale (Tables 1 & 2). The studies included one systematic review and meta-analysis (level I), and five randomized controlled trials (level II) (Bahl et al., 2016; Benkhadra et al. 2012, Constantino et al., 2010; McCarthy et al., 2016; Van Loon et al., 2019; Weiner et al., 2012). The population in all six studies aligned well with the intended population in the ED and strengthened generalizability. Recommendations for practice change advocated for the use of USGIV techniques for DIVA patients. Based on the United States Preventative Services Task

Force (USPSTF) guidelines, a level B grading is appropriate, suggesting that there is moderate to substantial certainty that USGIV techniques are beneficial (USPSTF, 2018).

Theoretical Framework

Locsin's Technological Competency as Caring in Nursing (TCCN) theoretical framework was used to frame the implementation of this practice change (Locsin, 2005; Locsin & Purnell, 2015). TCCN is a middle-range theory grounded in Boykin and Schoenhofer's grand theory of *nursing as caring* and seeks to conceptualize the inherent existence and utility of technology in caring and nursing (Locsin & Purnell, 2015). Locsin's theory proposes the technological competence of a nurse is an expression of caring (Locsin & Purnell, 2015). Locsin describes the elements of technological knowing, mutual designing, and participative engaging as the main tenets of TCCN emphasizing the importance of practicing nursing within the realm of a universal technological domain (UTD) to improve the delivery of care (Locsin & Purnell, 2015).

Technological advancements have fundamentally transformed and complicated the way nurses interact within the health care domain. However, Locsin's TCCN theory can be used to leverage nursing support for the practice change (Locsin & Purnell, 2007). Facing technological advancements while conserving the core values of caring in nursing is attractive; however, many nurses in the ED expressed fears that technology creates inevitable nurse-patient detachment (Locsin & Purnell, 2015). Nurses maintain that inherent to technology, is that the reliance, replacement, and overutilization of technology can obstruct the caring process. Locsin's TCCN theory addresses this concern, contending that accepting and seeking technological competency equips nurses to better understand the complexities of patients as persons and therefore, improve the delivery of patient care (Locsin & Purnell, 2015). Leveraging Locsin's theoretical concepts empowered nurses to adopt ultrasound technology to obtain PIV access in DIVA patients.

Sharing the conceptual underpinnings of TCCN helped the nursing team accept new technology to maximize the nature of caring for their patients (Locsin & Purnell, 2015).

Methods

This QI project was conducted in a 28-bed ED of a tertiary military medical center in the U.S. The target population included all difficult access patients requiring PIV access. Patients were classified as DIVA if they presented with two or more of the following predictors: history of DIVA; expected DIVA by the person performing the procedure; non-visible veins; non-palpable veins; and/or vein diameter less than three millimeters (VanLoon et al., 2019). The project was implemented from August 1st to December 7th, 2020. After project completion, a total of 423 patients were categorized as DIVA after exposure to the intervention.

Two nurses volunteered to serve as project champions. Champions provided insight during program development and were trained by the project leader. The current process for obtaining PIV access was not standardized; therefore, a policy was developed to support the practice change. The policy provided a DIVA algorithm illustration and specified training and competency requirements. The algorithm was triggered by a nurse or technician tasked to obtain PIV access. DIVA screening was the initial step; DIVA positive patients were directed to USGIV techniques, whereas non-DIVA patients underwent traditional PIV access techniques. Patients that were subjected to two failed attempts in the traditional pathway were directed to USGIV techniques for subsequent cannulation attempts.

The training program included 30-minutes of didactic instruction followed by 60-minutes of hands-on training. Didactic training was provided as a PowerPoint presentation and included disseminating baseline data, supporting evidence, DIVA screening, and the USGIV algorithm (See Appendix A). Hands-on training included practicing single-operator techniques using short-

axis views for vein tracing on the lead trainer's arm and insertions on two artificial gel training arms. Training was conducted in groups of two participants to reduce staffing burdens. Participants were required to attend both training sessions and complete three successful USGIV cannulations to obtain competency validation.

Project compliance and outcome measures were monitored for six weeks and converted into weekly run charts. The project lead monitored structure outcomes categorically (yes/no) which included policy publication, education, and training. Process measure were monitored by the project lead and champions categorically (yes/no) for DIVA screening and USGIV employment. Outcome measures were collected as interval level data (0 to 10) for patient pain scores, and categorically (yes/no) for first attempt success rates and treatment delays.

Implementation strategies and tactics included policy publication, PowerPoint aids, hands-on training, competency checklists and outcome data sharing on the unit communication board (see Appendix A). The PowerPoint presentation and skills station provided baseline education and skills validation and was captured using competency checklists (See Appendix B). Training a large staff (n=79) amid a pandemic challenged staffing availability and led to project modifications to reduce the total number of trained operators (n=16). Training tools were maintained on the unit shared drive and the departmental level "Lens Board" served as the primary communication vessel for disseminating weekly run charts (See Appendix A).

A sampling technique indicated that five patients each week would generate a sufficient sample size (n=60). There was a concern for outcome variable over-capture and modifications were made to reduce data collection to two primary outcomes: First attempt cannulation success rates and number of treatment delays. Data points were extracted weekly and Chi-squared and independent samples t-tests were used to compare pre-and post-implementation results.

The project was reviewed by the academic institution and hospital organization's Institutional Review Board and received dual Non-Human Subjects Research determinations. The DNP student and the project champions performed all data collection in the Clinical Nurse Specialist's office and tracking tools were maintained on a password-protected computer assigned exclusively to the DNP student (See Appendix C).

Results

The results of this project indicated that implementing an USGIV training program and incorporating a DIVA screening tool into the process of obtaining PIV access in the ED was necessary and effective. The targeted process, structure, and outcome measures for this project resulted in significant improvements and was comparable to similar projects in the literature. A total of sixteen operators completed the education and training program which included an equal representation of nurses (n=8) and technicians (n=8). Trained operator ages ranged from 20 to 53 years old, and operator clinical experience varied in years and specialty between two and twenty-four years in ED settings. In total, 423 patients received the intervention, and postimplementation data analyses indicated improvements in all outcome measures from baseline.

The primary process measures comprised of operator directed DIVA screening and USGIV algorithm utilization compliance remained consistent (90%) throughout the project. The primary short-term outcome measure of first-attempt success for DIVA patients increased from 50% to 86% (p =.03) and the targeted long-term outcome measure of treatment delays decreased from 20% to 0% (p = .01). Additionally, there was a significant reduction in patient pain scores (M=2.2, SD=1.17) compared to baseline (M=5.3, SD=1.65) data; $t(58) = 8.08$, $p < 0.001$.

Two important associations were observed between the intervention and the targeted outcome measures. First, the relationship between the intervention and first attempt success rates

was directly proportional suggesting training ED operators to screen patients for DIVA and utilize USGIV techniques for DIVA classified patients effectively increased first attempt PIV success rates. Second, was the association seen between first attempt success rates and treatment delays; this relationship was inversely proportional indicating that increasing PIV success rates were associated with decreasing numbers of treatment delays. Additionally, there was also a negative, unintended consequence noted with project implementation despite several positive effects of the intervention on the targeted outcome measures. The inability to incorporate USGIV documentation into the electronic health record resulted in increased documentation workload burdens which challenged operators, project leaders, champions, and departmental leaders.

Discussion

Project findings at this site were consistent with the current literature and suggest that the use of USGIV techniques for difficult access was beneficial in this ED. Operator feedback obtained from verbal interviews indicated nurses and corpsman technicians maintained a perception of improved confidence and independence when evaluating patients for DIVA and obtaining PIV access. Operators with higher levels of clinical experience in years and specialty reported that individual discomfort with technology and prior ultrasound inexperience were major contributors to previously avoiding USGIV techniques for DIVA. The same operators reported a perception of increased confidence levels after participating in the training program which they attributed to increased USGIV utilization. It is important to note that participating operators were volunteers, which may have created unintended operator selection bias toward self-motivated staff members. It is also notable to mention that this ED was unique in that it maintained four ultrasound machines on the unit. The consistent ultrasound availability likely prevented operator competition for simultaneous ultrasound technology requirements.

The employment of both an active unit and student clinical nurse specialist (CNS) in this project was unique and should be considered a critical factor responsible for achieving successful training and project sustainment. The CNS involvement positively influenced the motivation and readiness of the staff to learn a new skill. The CNS provided critical, unit specific, contextual knowledge to the working group tasked to develop the customized operator training plan. An important design limitation was the inability to incorporate the USGIV documentation into the electronic health record which inadvertently increased documentation workload burdens. The unit CNS and nurse manager were both instrumental in helping overcome these barriers by reviewing and reducing operator workload redundancy. Perhaps the two most notable limitations to the generalizability of these findings were that the project included a specialized population comprised of Army and Navy Nurses and Army Medics and Navy Corpsman operators which enabled distinct customization of the USGIV algorithm. Military servicemember skill sets are unique to the systems and processes of their organization and therefore, the results of this project should not be used to create generalizable knowledge or be disseminated beyond this ED.

Conclusion

This QI project demonstrated that the use of a nurse-initiated clinical pathway to identify DIVA patients requiring USGIV cannulation increased the likelihood of first attempt access successes and reduced the incidence of medical treatment delays. This project targeted an operator specific skill set but resulted in improvements in several downstream patient care treatments including the provision of medication administration, laboratory analysis, and diagnostic testing in the ED. Incorporating the DIVA screening tool prior to employing USGIV techniques ensured the ultrasound was reserved for patients with DIVA scores greater than two (difficult access), while permitting operators to use standard RVPL techniques for patients with

DIVA scores less than two (easy access). Failing to incorporate DIVA screening into the PIV access process prior to progressing to USGIV techniques might have resulted in delayed patient care in the ED. The DIVA screening tool is relatively new and includes five measurable items. Future research should target identifying a modified DIVA scale with fewer items to enhance rapid screening while also maintaining the high sensitivity and specificity of the current tool.

Long-term sustainability was critical to maintaining and spreading project gains in this organization. Unfortunately, high staffing turnover rates challenged long-term project sustainability, particularly when facing continuous non-critical training allocations constraints amid the coronavirus pandemic. The incorporation of an organizational policy supporting the practice change and integrating the process into the departmental onboarding process has helped improve long-term sustainability. Sharing reports of department level policies, processes, and outcomes with QI representatives, managers, and other organizational leaders has resulted in organizational level discussions surrounding implementing the process in other hospital departments. This project suggests that nurses and corpsman technicians retain the clinical and technical acumen to incorporate the use of USGIV techniques into the provision of care for DIVA patients in the ED.

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Table 1

Evidence Review Table Comparing Purpose, Design, Sample, Interventions, Outcomes and Results of (n=5) Studies

Citation: Bahl, Amit., Pandurangadu, A., Tucker, J., Bagan, M. (2016). A randomized controlled trial assessing the use of ultrasound for nurse-performed IV placement in difficult access ED patients. *American Journal of Emergency Medicine 34*, 1950-1954. http://doi.org/f9dtx7					Level: II
Purpose/Hypothesis	Design	Sample	Intervention	Outcomes	Results
The purpose of the study was to "assess if emergency department (ED) nurses trained in ultrasound guided peripheral intravenous (USGIV) insertion could have better success in placing peripheral intravenous (PIV) in difficult access patients using ultrasound guidance as compared to nurses placing PIV's in these patients using the standard of care palpation technique."	Prospective, non-blinded, randomized controlled trial at a single-site, tertiary, level I trauma center Phase I: Nurses were randomized to either the USGPIV or standard of care (SOC) control arm using the statistical analysis software (SAS) program and a research biostatistical team. Phase II: A randomized prospective cohort study was conducted and consisted of randomizing the sample patients into either the USGIV or SOC groups.	**Sampling technique:** Convenience **Eligible participants:** Patients presenting to the ED with difficult access. Phase I: A total of (n=20) nurses were randomized into two groups. (n=10) in the USGIV intervention group and (n=10) in the SOC control group Phase II: A total of (n=124) patients were placed into either the USGIV group (n=63), or the SOC control group (n=61), however, two participants were excluded due to lack of availability of the SOC nurse leaving (n=59) patients in the SOC control group. **Inclusion criteria:** Phase I: Nurses in good clinical standing and with at least two years of experience. Phase II: patients 18 years or older; identified themselves as a "difficult stick," experienced at least one previous episode requiring two or more PIV access attempts, at least one of the following: prior history of rescue catheter due to inability to obtain peripheral access, history of end stage renal disease, dialysis, or sickle cell disease. **Exclusion criteria:** Did not meet inclusion criteria, participated in prior	**Intervention Group:** USGIV technique when obtaining peripheral access. **Protocol:** Nurses received training on USGIV techniques for obtaining PIV access in difficult access patients, including didactic and hands-on training. Nurses used the Sonosite M-turbo ultrasound machine with a high frequency linear transducer. **Control Group:** Use of restricting band, visualization and palpation technique (RVPL) to obtain peripheral access. **Protocol:** The SOC group received training on techniques for obtaining intravenous access	**Dependent variables:** Primary DV: Intravenous success rate and time to cannulation placement. Measurements: Intravenous success was defined as cannulation placement by a nurse that was confirmed by extracting 5ml of non-pulsatile blood, or infusion of a 5ml saline flush without evidence of extravasation. (dichotomous) Secondary DV: Time to cannulation Measured: Defined as continuous variables as the total time to obtain functional PIV access which began after the supplies for PIV insertion were gathered and	There was a statistically significant difference in success rates between the groups with the USGIV group being 76% (48/63) and 56% (33/59) in the SOC group (p=0.02). Odds ratio for success for the USGIV group was 2.52 (95% confidence interval, 1.09-5.92). There was no statistically significant difference between the groups time to cannulation. USGIV group times ranged from 3 to 125 minutes, with a mean of 20.7 minutes, while the control group times ranged from

		study, already underwent a PIV attempt either by emergency services, or the enrollment process had potential to delay their care **Power analysis:** A Wilcoxon-Mann-Whitney test was used to calculate the sample size needed to obtain 80% power at a significance level of 0.05. **Homogeneity:** The two groups were demographically homogenous in terms of age (p=0.96), gender (p=0.83), medical history (BMI, p=0.49; dialysis, p=0.62; renal disease, p=0.37; sickle cell, p=1.0), heart rate (p=0.46), and MAP (p=0.28)	in difficult access patients, which also included didactic and hands-on training, however, the control group was unable to use the ultrasound and was forced to rely on RVPL technique.	stopped when successful cannulation was obtained.	1.5 to 86 minutes, with a mean of 15.8 minutes (p=0.75). The USGIV group mean number of attempts per subject was 1.52 and the SOC group mean attempts was 1.71 (p=0.63)
Citation: Benkhadra, M., Collignon, M., Fournel, I., Oeuvrard, C., Rollin, P., Perrin, M., Volot, F., Girard, C. (2012). Ultrasound guidance allows faster peripheral IV cannulation in children under 3 years of age with difficult venous access: a prospective randomized study. *Pediatric Anesthesia (22)*, 449-454. https://doi.org/10.1111/j.1460-9592.2012.03830.x					Level: II
Purpose/Hypothesis	Design	Sample	Intervention	Outcomes	Results
The purpose of this study was to "compare to compare USGIV with the blind technique in children less than 3 years of age undergoing general anesthesia"	Prospective, randomized, controlled study in a pediatric anesthesia unit of a teaching hospital in Dijon, France. Patients were randomized into either the USGIV group or the "blind stick" control group with the EpiInfo V6 software, with study numbers corresponding to a sealed envelope pulled sequentially to determine assigned grouping.	**Sampling technique:** Convenience **Eligible participants (target population):** Patients under 3 years of age with difficult access who were scheduled to undergo general anesthesia for imaging were eligible for participation in the study. The ultrasound group included (n=20), and the "blind stick" control group contained (n=20). **Inclusion criteria:** Parental consent, and at least one limb where no vein was visible or palpable. **Exclusion criteria:** Visible and palpable veins in each limb, and age 3 or greater. **Power analysis:** Researchers compared study with similar study populations and determined sampling based on the primary outcome as the endpoint with a beta risk of 10% and	**Intervention Group:** USGIV technique when obtaining peripheral venous access. **Protocol:** Operators were selected if they already maintained competency skills in ultrasound techniques or in blind venous cannulation techniques. The upper or lower limb could be accessed with the M-turbo sonosite device using a 22-gauge	**Dependent variables DV:** Primary DV: Time to cannulation Measurements: Time to cannulation, evaluated in seconds (continuous) Secondary DV's: Overall success rate, first puncture success rates, types of catheters used, total number of punctures Measurements: Time to cannulation: expressed in seconds (continuous)	Study was stopped at 50% enrollment when researchers observed the time to cannulation was significantly shorter than the blind stick group (p=<0.025) and final analysis was conducted from the first 40 patients. The number of venipunctures was significantly lower in the USGIV group (1 puncture) compared to the blind group (2.5

		two-sided alpha risk of 0.025, which required (n=48), (n=24 per group). To adjust for potential attrition researcher sought (n=40) per group; set the significance threshold to p<0.025 based off Bonferoni's correction. **Homogeneity:** The demographics were homogenous between the two groups in terms of age (p=0.71), weight (p=0.28), height (p=0.48), and ability to walk (p=0.74)	catheter. If unsuccessful after 15 minutes the procedure was classified as failed. **Control Group:** "Blind" approach access using only RVPL techniques. **Protocol:** Operators were restricted to the lower limb where there were no visible or palpable veins, forcing reliance on RVPL. Operators were allowed to choose between 22 and 24-gauge catheters. The same time limits applied.	First puncture success rates were defined as successful when the catheter was in the intravenous position with reflux of blood into the catheter combined with the absence of swelling after a 5ml flush of saline solution (categorical) Types of catheters used were either 22 or 24-gauge. (categorical) Number of total venipunctures was a variable count (continuous)	punctures) (p=0.004) Success rate was at first puncture was significantly higher in the USGIV group (85%) compared to the blind group (35%) (p=0.0012) Median times to cannulation was significantly shorter in the USGIV group than the blind group (p=0.001)
Citation: Costantino, T. G., Kirtz, J. F., & Satz, W. A. (2010). Ultrasound-guided peripheral venous access vs. the external jugular (EJ) vein as the initial approach to the patient with difficult vascular access. *Journal of Emergency Medicine 39*(4), 462–467. http://doi.org/cb2p62					Level: II
Purpose/Hypothesis	Design	Sample	Intervention	Outcomes	Results
"This study seeks to determine which initial approach by emergency physicians would lead to greater peripheral intravenous (PIV) access success" between ultrasound guided techniques and EJ cannulation techniques.	This was a prospective, non-blinded, randomized, controlled trial conducted at an urban, tertiary-care, university hospital ED.	**Sampling technique:** Purposive **Eligible participants (target population):** All patients presenting to the ED who failed at least three nursing attempts at PIV access. Total of (n=60) patients were enrolled, (n=32) in the USGIV, and (n=28) in the EJ control group. Ultimately, (n=1) patient required central venous access after unsuccessful cannulation. **Inclusion criteria:** All patients presenting to the ED with greater than or equal to 18 years of age, who	**Intervention Group:** USGIV technique when obtaining peripheral access. **Protocol:** Ultrasound guidance was performed by a single operator with a SonoSite linear transducer. The probe was held in	**Dependent variables (DV):** Primary DV: PIV access success rates. Measurements: PIV access success was defined as cannulation that was confirmed by extracting 5ml of blood, and infusion of an intravenous flush without	Success rate for the ultrasound guided group was found to be significantly greater (p=0.006) with success rates for the ultrasound group at 27/32 or 84% (95% CI 68–93%) versus 14/28 or 50% for the EJ vein group (95% CI 33–67%).

		experienced at least three failed PIV attempts by the ED nurse. **Exclusion criteria:** Exclusion criteria were those in need of central venous access as determined by the treating physician, and those unable to consent. **Power analysis:** Based upon previous studies, a sample size (n=25) was needed to detect a 40% difference in primary endpoints with a power of .80 using a two-sided *t*-tests with a type I error of 0.05. **Homogeneity:** Time, data, and age were assessed for normality, and then compared with Mann-Whitney *U* or Student's *t*-test; the two groups were demographically homogenous.	the transverse plane. Veins were identified in their suspected anatomic locations. Cannulation was attempted using a 1.75-inch and 18-gauge catheter. **Control Group:** EJ vein control group **Protocol:** EJ veins were identified by visual inspection and palpation by the physician performing the procedure. Cannulation was attempted with a 1.25-inch catheter. Both techniques were performed by 2nd- and 3rd- year ED residents who successfully performed five successful EJ vein cannulations and five USGIV cannulations. The residents had all completed a 1-month rotation in ED ultrasound, including 16 hours of didactic training.	producing extravasation. (dichotomously) Secondary DV 1: Total number of successfully placed intravenous lines. Measured: As a continuous variable count for both groups. Secondary DV 2: Time to successful cannulation. Measured: This was measured by an assistant with a digital clock from first puncture to the time of successful cannulation. Secondary DV 3: The percent of functioning lines upon completion of ED treatment. Measured: The line was assessed for patency, observed complications, pain, nerve irritation, hematomas, or arterial punctures upon transfer or discharge.	A total of 41/46 (89%) lines were successfully placed by USGIV when compared to 18/33 (55%) for external jugular techniques (p=0.001). Mean times to cannulation did not reach statistical significance at 8.9 minutes for the USGIV group and 8.1 minutes in the EJ group. 24/27 (89%) of the USGIVs were functional upon disposition when compared to 13/14 (93%) of the successfully placed EJ lines.

Citation: McCarthy, M., Shokoohi, H., Boniface, K., Eggelton, R., Lowley, A., Lim, K., Shesser, R., Li, X., Zeger, S. (2016). Ultrasonography versus landmark for peripheral intravenous cannulation: a randomized controlled trial. *Annals of Emergency Medicine (68)*1, 10-18. http://dx.doi.org/10.1016/j.annemergmed.2015.09.009					Level: II
Purpose/Hypothesis	Design	Sample	Intervention	Outcomes	Results
Alternate Hypothesis (H_1): "The initial success rate would be at least 5% higher when USGIV was used among patients with difficult or moderately difficult peripheral intravenous access but no difference (<5%) among patients with easy access."	Randomized controlled trial, with 2-group parallel design in a single center academic ED. Patients were randomized using SAS software to either landmark or USGIV groups. If the first attempt failed, the patient was again randomized, to better compare the two interventions by ensuring the patients had similar baseline characteristics at each attempt.	**Sampling technique:** Convenience **Eligible participants (target population):** Patients presenting to the ED requiring PIV access. (n=1,662) screened, (n=1,617) eligible, (n=217) refused to participate, (n=181) too easy access, leaving sample size of (n=1,189) with (n=192) difficult access, (n=401) moderate difficult access, (n=596) easy access. **Inclusion criteria:** Patients that were deemed capable of providing informed consent, requiring a PIV line in their upper extremity **Exclusion criteria:** High acuity patients (triage level I and II deemed unsafe to delay care for inclusion), or PIV access to be placed in the hand. **Power analysis:** Calculations used to determine sample size for 80% power were based off prior studies. To detect a 5% difference, researchers over-estimated (n=6,314). Revisions changed the detection from 5% to 10% for the easy to moderately easy access group and 20% for difficult access. The revised sample was (n=948). For each subgroup, risk ratio and 95% confidence intervals were calculated. Post hoc analysis tested for a significant interaction between the technician's skill and technique. **Homogeneity:** The two groups were demographically homogenous.	**Intervention Group:** USGIV access group. **Protocol:** Technicians were used because they received training on USGIV techniques for PIV access, including didactic and hands-on. Technicians used the Sonosite M-turbo or Zonare ultra ultrasound machines during the procedure. After insertion, the site was checked for function with a 10 ml saline flush. **Control Group:** Landmark group technique to obtain peripheral access. **Protocol:** Technicians used restricting bands, visualization and palpation technique to obtain peripheral access. The same definition of success was used for the control.	**Dependent variables:** <u>Primary DV:</u> Cannulation success or failure on the initial and second attempts. <u>Measurements:</u> Successful cannulation was achieved when the technician was able to infuse fluid without infiltration. (dichotomous) An "attempt" was defined as one percutaneous needle puncture, regardless of the degree of exploration. (continuous) <u>Secondary DV's:</u> Patient pain <u>Measurement:</u> Pain was reported by the patient on a scale 0 (no pain at all) to 10 (extremely painful). (ordinal)	Success rates of techniques depends on the level of difficulty. When veins are easily visible, landmark procedures are better; however, when unable to visualize veins, USGIV proved more successful. First attempt success rate for USGIV group ranged from 82%-86% regardless of difficulty level, whereas landmark groups varied from 35% to 97%. The USGIV group took an average of 79-97 seconds longer than control group. Pain rating was similar between the two groups.

Citation: Van Loon, F., Buise, M., Claassen, A., Daele, D., Bouwman, A. (2018). Comparison of ultrasound guidance with palpation and direct visualization 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.2018.04.047					Level: I
Purpose/Hypothesis	Design	Sample	Intervention	Outcomes	Results
"The objective of this study was to systematically review the results of studies comparing ultrasound (US) with the traditional technique of RVPL, with successful PIV cannulation as the outcome of interest." "The meta-analysis aimed to prove the utility of the USGIV guidance during PIV cannulation-in terms of efficacy and efficiency in clinical practice."	Systematic review and meta-analysis utilizing (five RCT's, two prospective non-blinded, and one descriptive, non-blinded studies). Randomization and blinding were used in five of eight studies.	**Sampling technique:** Systematic review and meta-analysis **Eligible participants (target population):** (8) studies describing USGIV success rates in adult humans, greater than 18-years-old. Pooled sample (n=1660) were split into two groups, (n=855) in the USGIV group and (n=805) in the RVPL control groups. Five of eight studies incorporated randomization and blinding, and seven of the eight studies used the same intervention and comparator in the PICOT question. Six studies were conducted in the ED, one on a medical floor, and one in the intensive care unit (ICU). **Inclusion criteria:** Study inclusion selection was conducted independently by two reviewers following PRISMA guidelines, where discrepancies were resolved by an independent reviewer for relevance to PICOT and in full text. **Exclusion criteria:** Studies were excluded if PIV was attempted on any site other than the upper extremity; USGIV was compared to another technique than RVPL. **Power analysis:** All samples met the required power (80%). **Homogeneity:** The heterogeneity was determined using the I2 statistic, with I2>50% indicating significant heterogeneity. Between-study variance also indicated statistical heterogeneity.	**Intervention Group:** USGIV technique when obtaining PIV access (n=855). **Protocol:** All studies used similar US machines increasing internal validity, however, variance existed among operator training, decreasing interrater reliability, which threatened internal validity. **Control Group:** "Blind" approach access using only landmarks. (n=805 in control group) **Protocol:** Operators were restricted to using lower limbs where with no visible or palpable veins, forcing reliance on landmarks alone. Operators choose between 22 and 24-gauge catheters. The same time limits applied for each group.	**Dependent variables (DV):** Primary DV: Success rates of PIV cannulation. Measurement: First attempt success rates defined as successful when the catheter was in the position with reflux of blood into the catheter combined with the absence of swelling after a 5ml flush of saline (dichotomous) Secondary DV 1: Total number of venipunctures needed to cannulate. Measurement: Count (continuous) Secondary DV 2: Time to cannulation: Measurement: Seconds (continuous) Secondary DV 3: Patient pain scores Measurement: Pain was scaled (0-10), where 0 = no pain, and 10 = severe pain (ratio level)	The use of USGIV consistently increases PIV access success rates when compared to traditional techniques in patients with difficult access. First attempt success rates were significantly higher in the USGIV group (USGIV 81%, RVPL 70%; p=0.003). USGIV groups had a lesser number of total venipunctures attempts when compared to the RVPL control groups, although the number failed to reach statistical significance (p=0.08).

Citation: Weiner, S., Sarff, A., Esner, D., Shroff, S., Budhram, G., Switkowski, K., Mosofi, M., Barus, R., Coute, R., darvish, A. (2013). Single-operator ultrasound-guided intravenous line placement by emergency nurses reduces the need for physician intervention in patients with difficult-to-establish intravenous access. The *Journal of Emergency Medicine (44)*3, 653-660. http://doi.org/f4r6zz					Level: II
Purpose/Hypothesis	Design	Sample	Intervention	Outcomes	Results
Alternate hypothesis (H_1): Researchers hypothesized that "adequately trained ED nurses (EN) can effectively perform single-operator USGIV placement with less physician intervention than is required with blind techniques." The purpose was to determine if placement of USGIV by emergency nurses who undergo training can be performed with less physician intervention than standard intravenous line placement.	Prospective, non-blinded, study conducted at two large teaching hospitals within 90 miles of each other. <u>Hospital A:</u> 42,000 patients per year <u>Hospital B:</u> 106,000 patients per year <u>Phase I:</u> Nurses volunteered to receive training in emergency ultrasonography techniques and to participate in the USGPIV or standard of care (SOC) "blind stick" group <u>Phase II:</u> Patients were assigned to study groups using a website (www.random.org/coins) to replicate a "coin flip" which later changed to choosing from shuffled and sealed envelopes mixed at 1:1 ratio	**Sampling technique:** Purposive **Eligible participants (target population):** ED patients requiring PIV cannulation with difficult access. Hospital A enrolled (n=29) patients (n=16) to USGIV group and (n=13) to the "blind stick" control group. Hospital B enrolled (n=24) patients, (n=14) assigned to USGIV group and (n=10) to the "blind stick" control. (n=1) withdrew from the USGIV group and (n=2) from the "blind stick" control group. Final sample size was (n=29) in the USGIV group and (n=21) in the "blind stick" control group. **Inclusion criteria:** Patients were identified for inclusion by the primary nurse as being greater than 18 years old, requiring PIV therapy, having a known history of difficult access, or experienced two prior unsuccessful PIV attempts. **Exclusion criteria:** Intoxication, acute psychiatric illness with exacerbation, prisoners, could not provide consent, and non-English speaking. **Power analysis:** Researchers sought (n=50) but did not specifically mention a power analysis, but based the study sample on other similar studies. **Homogeneity:** The groups were homogenous in terms of race (p=0.44), gender (p=0.26), age (p=0.10), reason for study inclusion (p=0.96).	**Intervention Group:** USGIV technique when obtaining PIV access (n=29). **Protocol:** ED nurses were used because they were the most experienced in placing PIV lines. Nurses received a two-hour training course from an ED physician skilled in USGIV techniques which included combined didactic and hands-on training on a mannequin. Nurses at Hospital A used the Zonare US and Hospital B used the Sonosite M-turbo US for procedures. **Control Group:** "Blind stick" approach for PIV access (n=21). **Protocol:** Location and technique were left to the nurse to determine using standard practice of restricting band,	**Dependent variables:** <u>Primary DV:</u> Physician involvement in obtaining IV access <u>Measurements:</u> Physician involvement was dichotomous (yes/no) and each study group that requested a physician were compared using the chi-squared test. <u>Secondary DV's:</u> Time to cannulation, number of total venipunctures, level of patient satisfaction, and patient pain. <u>Measurements:</u> Time to cannulation (continuous); Number of total venipunctures (continuous); Level of patient satisfaction: (satisfied/not satisfied) (dichotomous); Patient pain	The two groups showed statistically significant differences with physicians being asked to help 11/21 times in the "blind stick" group and 7/29 in the USGIV group (p=0.04). Mean cannulation times were not statistically significant between the groups; USGIV (27.6 minutes) and "blind stick" group (26.4 minutes) (p=0.88) There was no statistically significant difference in number of venipunctures between USGIV (2.0) and "blind stick" group (2.1) (p=0.57) Patient satisfaction tended to be higher in the USGIV group (86.2% satisfied),

			palpation, and visualization combined with their preferred selection of catheter size (ranged from 18-20 gauge in diameter).	perception: scale 0-10 (ordinal)	compared to the (63.2%) for the "blind stick" group, however, results did not reach significance, p=0.06. Pain was similar between groups (p=0.50).

Note. Evidence was appraised using Melnyk and Fineout-Overholt's (2019) level of evidence rating scale and Newhouse's (2006) quality of evidence rating scale.

Table 2

Synthesis Table for Evidence Table (n=5) studies

Evidence Based Practice Question (PICO): In all ED patients presenting with difficult intravenous access (P), does the use of USGIV techniques (I) increase cannulation success rates (O) during the length of stay in the ED (T) when compared to the current practice of manually palpated cannulation techniques (C)?			
Level of Evidence	Number of Studies	Summary of Findings	Overall Quality
I	1	Van Loon et al. (2018) found that the use of ultrasound guidance consistently increases PIV access success rates when compared to traditional techniques using palpation and landmarks in the patients with difficult PIV access. First attempt success rates between the groups were found to be significantly different (USGIV group 81%, RVPL group 70%; p=0.003). The pooled odds ratio for USGIV success rates was 2.49 (95% confidence interval 1.37-4.52). Van Loon et al. (2018) also found that the USGIV groups had a lesser number of total venipunctures attempts when compared to the RVPL control groups, although the number failed to reach statistical significance (p=0.08).	A, this systematic review and meta-analysis incorporated a total of eight studies, polling a total of (n=1660) patients which were split into two groups, (n=855) in the USGIV group and (n=805) in the RVPL groups. Five of the eight studies incorporated both randomization and blinding, and seven of the eight studies used the exact same intervention and comparator in the PICOT question strengthening generalizability. Although the largest portion of the sample came from the McCarthy and colleagues' study (n=1189), this study proved to be a high quality randomized controlled trial, with results that showed reliability with other studies with lesser sample sizes. Although other samples were not as large, all samples met the required power (80%). The results among the studies consistently demonstrated similar results reflecting high reliability.
II	5	Four of the five studies showed first attempt PIV success rates increased with statistical significance with the use of ultrasound guided techniques when compared to traditional RVPL techniques (Bahl et al., p=0.02; Benkhadra et al., p=0.0012; Constantino et al., p=0.006; McCarthy et al., pooled odds=2.32, CI=95%;). The fifth study sought a different endpoint which was the need for ultrasound guided assistance from a physician (Weiner et al., 2013). Although Weiner et al (2013), did not find a statistically significant difference between the number of venipunctures between the two groups, they did find that the USGIV groups received less venipunctures to obtain PIV access. Furthermore, Weiner et al (2013) found a statistically significant difference in the need	B, all five studies were adequately powered (Bahl et al., 2016; Benkhadra et al., 2012; Constantino et al., 2010; McCarthy et al., 2016; Weiner et al., 2012). Four of the five studies were randomized controlled trials (Bahl et al., 2016; Benkhadra et al., 2012; Constantino et al. 2010; McCarthy et al., 2016) and the fifth study was a prospective non-blinded study (Weiner et al., 2012). Additionally, the study conducted by Bahl et al. (2016), was non-blinded. Sampling techniques amongst studies varied between a combination of purposive (Benkhadra et al., 2012; Constantino et al., 2010; Mccarthy et al, 2016) and convenience (Weiner et al, 2012; Bahl et al., 2016) sampling which may have threatened the external validity; however, the strict enrollment criteria supported the PICOT population well which suggests generalizability to other emergency departments. One study addressed only pediatrics under the age of three in the anesthesia department which

		for ultrasound guided physician intervention for difficult access patients (p=0.04). This data from this study suggests that USGIV can successfully be performed by nurses in the ED as a rescue option for difficult PIV patients. Four of the five studies included the same population (emergency room patients) as the PICOT question (Bahl et al., 2016; Constantino et al., 2010; McCarthy et al., 2016; Weiner et al., 2012). The fifth study conducted by Benkhadra et al. (2012), was performed in the anesthesia unit of a hospital in France, however, included a very specific and relevant demographic subset of the PICOT population (pediatrics under the age of three).	compromised generalizability to the entire target population in the PICOT (Benkhadra et al., 2012). All five studies utilized the same intervention and comparator as the PICOT question (USGIV versus RVPL) techniques (Bahl et al., 2016; Benkhadra et al., 2012; Constantino et al., 2010; McCarthy et al., 2016; Weiner et al., 2012). The results of four out of five studies showed statistically significant and consistent results (Benkhadra et al., 2012; McCarthy et al., 2016; Bahl et al., 2016). The fifth study by Weiner et al. (2012), did not reach statistical significance, but demonstrated that the USGIV group received less skin punctures to achieve successful cannulation. Therefore, all five studies produced consistently similar trends in their data outputs, indicating reliability amongst findings.

Note. Evidence was appraised using Melnyk and Fineout-Overholt's (2019) level of evidence rating scale and Newhouse's (2006) quality of evidence rating scale

Appendix A

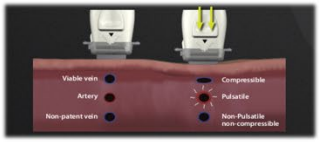
Implementation Aids for Project Training and Competencies, Documentation, and Data Sharing

UNIVERSITY of MARYLAND
SCHOOL OF NURSING

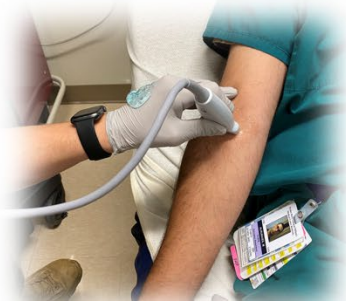
DIVA Screening and USGIV Technique Training in the ED

PowerPoint Training Aid

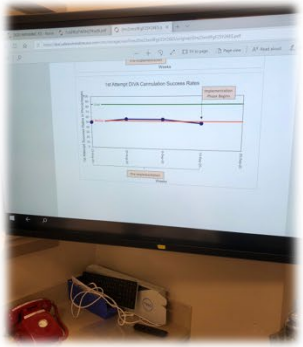
Vessel Identification



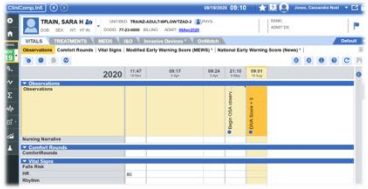
Hands-on Skills Training



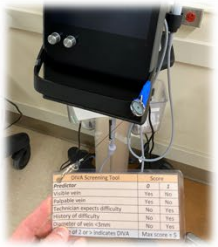
Unit "Lens" Tracking Board



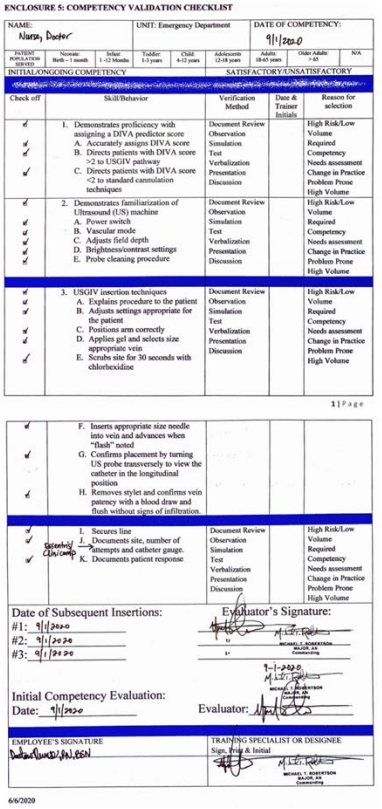
Documentation Training



DIVA Screening Tool on US Machine



Competency Validation Tool



ENCLOSURE 5: COMPETENCY VALIDATION CHECKLIST

NAME: Nursey Doctor | UNIT: Emergency Department | DATE OF COMPETENCY: 9/1/2020

PATIENT POPULATION SERVED: Neonate: Birth – 1 month | Infant: 1 -12 Months | Toddler: 1-3 years | Child: 4-12 years | Adolescents: 12-18 years | Adults: 18-65 years | Older Adults: >65 | N/A

INITIAL/ONGOING COMPETENCY | SATISFACTORY/UNSATISFACTORY

Check off	Skill/Behavior	Verification Method	Date & Trainer Initials	Reason for selection
✓	1. Demonstrates proficiency with assigning a DIVA predictor score	Document Review, Observation, Simulation, Test, Verbalization, Presentation, Discussion		High Risk/Low Volume, Required, Competency, Needs assessment, Change in Practice, Problem Prone, High Volume
✓	A. Accurately assigns DIVA score			
✓	B. Directs patients with DIVA score >2 to USGIV pathway			
✓	C. Directs patients with DIVA score <2 to standard cannulation techniques			
✓	2. Demonstrates familiarization of Ultrasound (US) machine	Document Review, Observation, Simulation, Test, Verbalization, Presentation, Discussion		High Risk/Low Volume, Required, Competency, Needs assessment, Change in Practice, Problem Prone, High Volume
✓	A. Power switch			
✓	B. Vascular mode			
✓	C. Adjusts field depth			
✓	D. Brightness/contrast settings			
✓	E. Probe cleaning procedure			
✓	3. USGIV insertion techniques	Document Review, Observation, Simulation, Test, Verbalization, Presentation, Discussion		High Risk/Low Volume, Required, Competency, Needs assessment, Change in Practice, Problem Prone, High Volume
✓	A. Explains procedure to the patient			
✓	B. Adjusts settings appropriate for the patient			
✓	C. Positions arm correctly			
✓	D. Applies gel and selects size appropriate vein			
✓	E. Scrubs site for 30 seconds with chlorhexidine			

1 | Page

✓	F. Inserts appropriate size needle into vein and advances when "flash" noted			
✓	G. Confirms placement by turning US probe transversely to view the catheter in the longitudinal position			
✓	H. Removes stylet and confirms vein patency with a blood draw and flush without signs of infiltration.			
✓	I. Secures line	Document Review, Observation, Simulation, Test, Verbalization, Presentation, Discussion		High Risk/Low Volume, Required, Competency, Needs assessment, Change in Practice, Problem Prone, High Volume
✓	J. Documents site, number of attempts and catheter gauge. Successfully cannulated			
✓	K. Documents patient response			

Date of Subsequent Insertions:
#1: 9/1/2020
#2: 9/1/2020
#3: 9/1/2020

Evaluator's Signature:

Initial Competency Evaluation:
Date: 9/1/2020

Evaluator: 9-1-2020

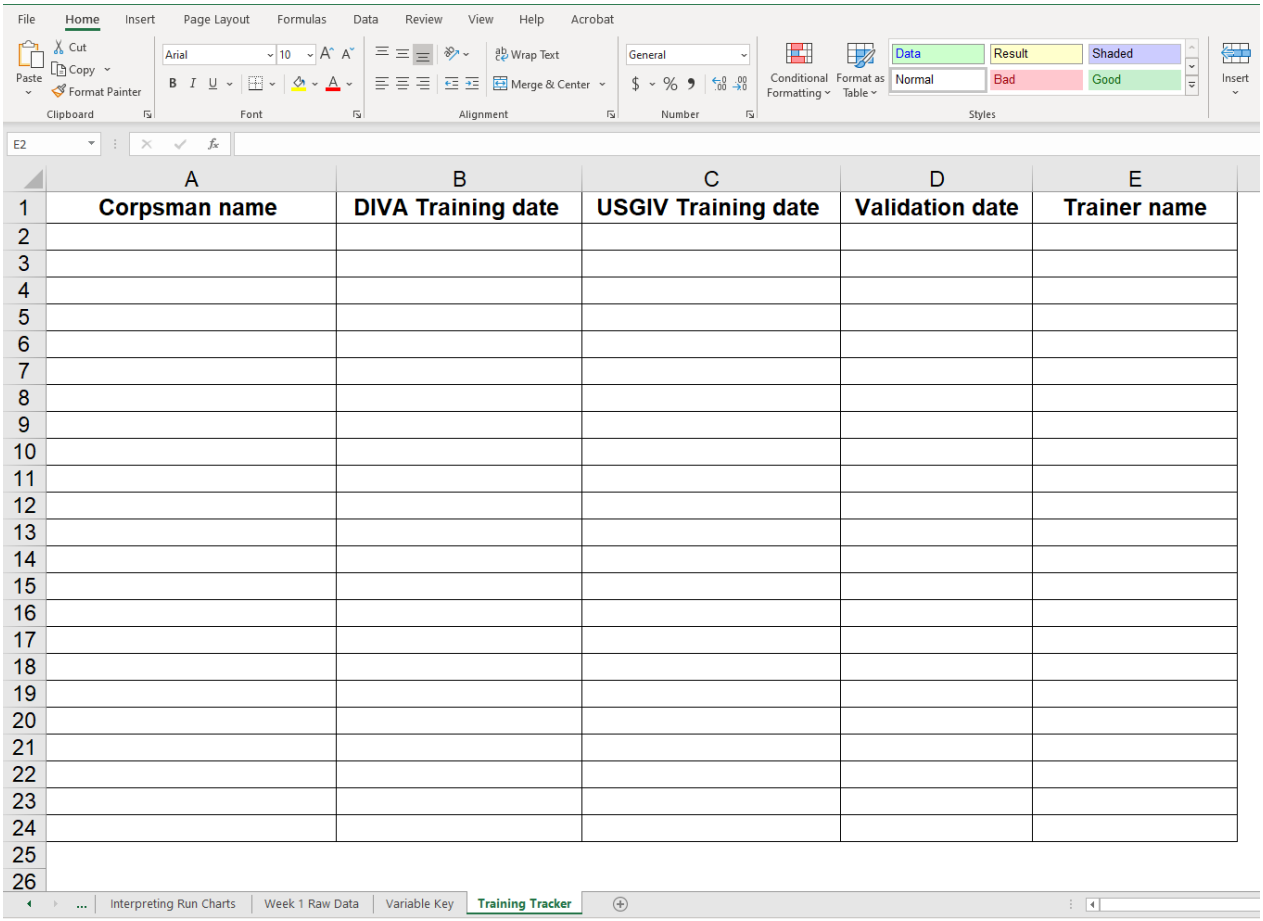
EMPLOYEE'S SIGNATURE

TRAINING SPECIALIST OR DESIGNEE Sign, Print & Initial

6/6/2020

Appendix B

Data Tracking Tool for Competency Training



	A	B	C	D	E
1	**Corpsman name**	**DIVA Training date**	**USGIV Training date**	**Validation date**	**Trainer name**
2					
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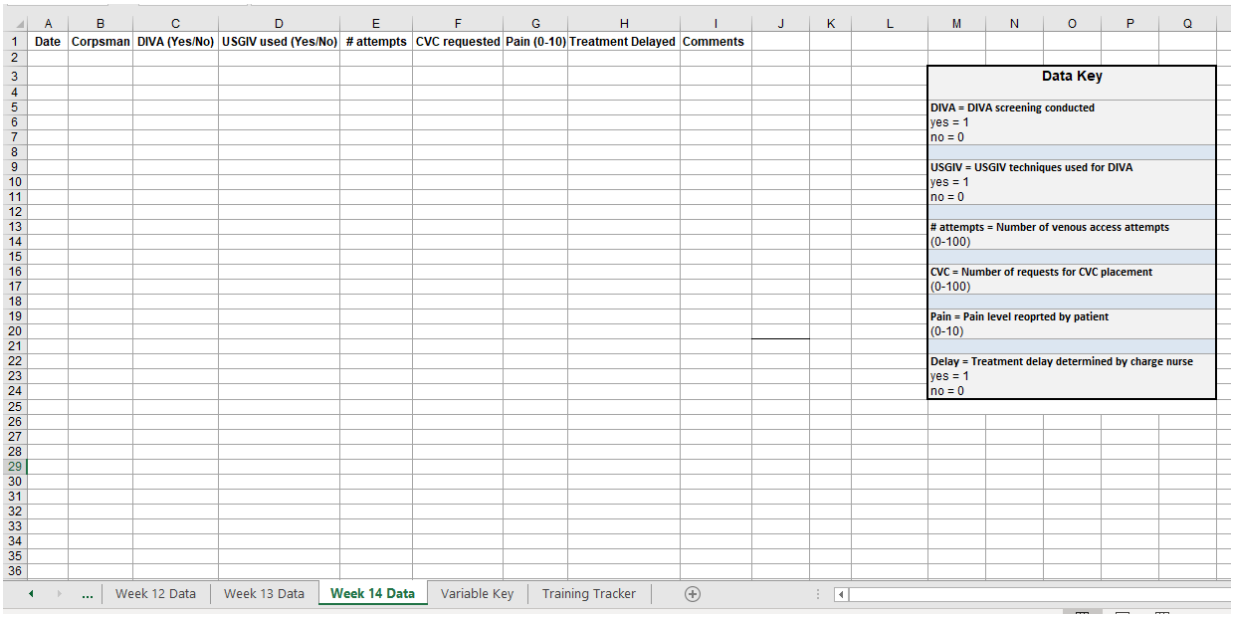
Appendix C

Data Collection Tool with Data Variable Coding Key



Date	Corpsman	DIVA (Yes/No)	USGIV used (Yes/No)	# attempts	CVC requested	Pain (0-10)	Treatment Delayed	Comments

Data Key

DIVA = DIVA screening conducted
yes = 1
no = 0

USGIV = USGIV techniques used for DIVA
yes = 1
no = 0

 # attempts = Number of venous access attempts
(0-100)

CVC = Number of requests for CVC placement
(0-100)

Pain = Pain level reoprted by patient
(0-10)

Delay = Treatment delay determined by charge nurse
yes = 1
no = 0

Week 12 Data | Week 13 Data | Week 14 Data | Variable Key | Training Tracker