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Brief Report

# Central venous catheter placement after ultrasound guided peripheral IV placement for difficult vascular access patients

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ABSTRACT

*Objectives:* Ultrasound guided peripheral intravenous catheters (USPIV) are frequently utilized in the Emergency Department (ED) and lead to reduced central venous catheter (CVC) placements. USPIVs, however, are reported to have high failure rates. Our primary objective was to determine the proportion of patients that required CVC after USPIV. Our secondary objective was to determine if classic risk factors for difficult vascular access were predictive of future CVC placement.

*Methods:* We performed a retrospective review for patients treated at a large academic hospital. Patients were identified by electronic health record and were restricted to age older than 21 years, had received USPIV, and admittance. Exclusion criteria included an existing CVC. Descriptive statistics, *t*-tests, chi-square proportions, and logistic regression were performed to test associations.

*Results:* Of 363 eligible patients, 20 were excluded allowing for 343 for analysis. Of 343, 45 (13.1% 95% CI 9.9–17.1%) required CVC after USPIV. For secondary outcomes, no expected characteristics (diabetes, end-stage renal disease, IV drug abuse, peripheral vascular disease, or sickle cell disease) were predictive of CVC placement. The only predictive variables were admission to ICU/stepdown and length of stay. Each additional day of hospitalization had an OR 1.11 (95% CI 1.06–1.16%) of having a CVC placed.

*Conclusion:* Of those admitted after USPIV placement, approximately 7 out of every 8 patients did not require a subsequent CVC. Of the nearly 1 in 8 patients that required a CVC, factors associated with CVC placement were admission to a higher level of care and length of stay.



## 1. Introduction

### 1.1. Background

Obtaining intravenous (IV) access is the most common hospital procedure performed [1]. IV access is often necessary to provide medical care, however it is estimated that one in every nine patients is considered a difficult vascular access patient (DiVA) [2]. DiVAs often require multiple attempts at placing an IV or a rescue procedure [2-5]. IV access options that have qualified as rescue procedures are cannulation of the external jugular vein, ultrasound guided peripheral IVs (USPIV), intraosseous devices (IO), or central venous catheters (CVC).

Previous work has found specific characteristics to be predictive of patients being DiVAs. Factors reported to be associated with difficult vascular access include obesity, end-stage renal disease, sickle cell disease, IV drug abuse (IVDA), peripheral vascular disease (PVD), and diabetes [2,6]. USPIVs are a frequent rescue procedure for DiVAs and nearly 1800 UGPIVs are placed annually in our emergency department (ED) alone. Despite the frequent use of USPIVs, which has reduced CVC placement, failure rates for USPIVs have been reported to be as high as 47% [7-9].

### 1.2. Goals of investigation

Given the high reported failures of USPIVs, the primary objective was to determine the incidence of patients who receive a USPIV that go on to require a CVC. As a secondary objective we wished to determine if patients with known risk factors for receiving USPIVs are at higher risk of subsequent CVC placement than those without having risk factors for difficult vascular access. The rationale for the investigation was to determine how often, despite placing an USPIV, a patient still goes on to receive a CVC. Our hypothesis was that at least one in ten patients who received a USPIV will go on to receive a CVC and

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those patients with known risk factors for being a DiVA would be at higher risk of receiving a CVC. For our study we defined a CVC as either a triple lumen device or peripherally inserted central catheter (PICC).

## 2. Methods

### 2.1. Study design

This was a retrospective cohort analysis of patients who received an USPIV as a part of routine clinical care and were admitted from a large urban level one trauma center. The ED sees over 135,000 patients annually, and is associated with an emergency medicine residency. USPIVs are placed by MDs with training. The catheters routinely used for USPIVs are a 1.88 in. BD angiocatheter (Mississauga, ON Canada).

Patients were identified for inclusion by query from electronic health records, EPIC (Verona, Wisconsin), for patients admitted from the ED between January 2015 and August 2015. We selected this timeframe as there were changes to the workflow after this period, which lead to possible variations in documentation reliability. Search results were restricted to patients documented to have had a procedure note placed for a USPIV and were admitted from the adult ED (age > 21 years). Resulting medical record numbers were imported into REDCap for chart abstraction. All records were manually reviewed and enrollment criteria confirmed. Patients were excluded if there was a CVC placed in the ED or if they arrived with a CVC (example PICC from a rehab facility). This study was approved by the university Internal Review Board.

### 2.2. Data collection

Records were reviewed and documented in a standardized form by one of two trained medical professionals (SP or JRP). SP is a medical student and JRP is an ED physician and principal investigator. SP was trained by JRP, and SP's first 10 records were reviewed for accuracy and completeness. JRP and SP met regularly to review abstraction and questions related to data collection. Data obtained from the medical record included basic demographics, medical history, length of hospital stay, and details about the hospitalization including type of CVC placed and admitting level of care (ICU, stepdown, or telemetry/floor). The primary outcome measured was failure of an USPIV to avoid the subsequent placement of a CVC during hospitalization. Secondary outcome measures (including but not limited to diabetes, end-stage renal disease, IV drug abuse, peripheral vascular disease, sickle cell disease, and length of stay) were selected *a priori* to assess for the primary outcome occurring.

### 2.3. Statistical analysis

Statistical analysis included performing two independent sample *t*-tests and chi-square proportion tests for continuous and categorical variables respectively, in addition to multivariable logistic regression to assess the association between the clinical predictors (length of stay, age gender, BMI, and any risk factors) with the dichotomous outcome, receipt of a CVC. ROC (Receiver Operating Characteristic) curve analysis was performed to gauge how well any statistically significant predictors from the regression model were able to ascertain the patient's outcome (CVC placement or not) by AUC (area under the ROC curve) [10]. From the total records reviewed, 5% were randomly selected for dual abstraction of 10 key variables by both reviewers to assess data reliability by Cohen's Kappa or interclass correlation coefficient (ICC) as appropriate [11]. All descriptive statistics and analyses were performed using SAS v9.4 (Cary, NC) and STATA v13.1 (College Station, TX).

## 3. Results

### 3.1. Demographics and primary outcome measure

A total of 363 patients were admitted who had an USPIV placed in ED during the study period. Of these patients, 20 were excluded due to already having a CVC at time of ED visit or having one placed during their ED visit, leaving 343 patients for analysis. Of the 343 patients, 45 (13.1% 95% CI 9.9–17.1%) went on to require a CVC during their hospital stay. Demographics and clinical information for the patients who had a USPIV placed are provided (Table 1).

### 3.2. Secondary outcome measure

Based on those patients undergoing CVC after USPIV, none of the classic risk factors described in DiVA patients were predictive of patients going on to receive a CVC (diabetes, peripheral vascular disease, IVDA, end-stage renal disease, sickle cell disease, or body mass index; Table 2). We also wished to assess if five additional variables of potential clinical interest were predictive of needing a CVC placed (Table 3). It was noted that hospital length of stay was the strongest predictor found to be indicative of a patient requiring a CVC after USPIV. As a predictor of whether a patient would receive a CVC or not, length of stay had an AUC of 0.801 (95% CI 0.729–0.872) based upon the ROC curve. It was noted that patients with a length of stay of 7 days had the optimal cutoff on the ROC curve. Additionally, the odds ratio of having a CVC placed was 1.11 (95% CI 1.06–1.16%) for each extra day spent in the hospital after adjusting for predictors in the multivariable logistic regression model. Admittance to a higher level of care (ICU or stepdown unit) was also predictive of needing a CVC. Data between chart reviewers was found to have a high degree of chance-corrected agreement for the 5% of charts selected for dual abstraction; Cohen's kappa and ICC ranged 0.84 to 1 for each of the 10 variables examined, indicating very strong to perfect chance-corrected agreement.

## 4. Discussion

This is the first study we are aware of that investigates the incidence and predictors associated with patients who require placement of a CVC after being admitted with an USPIV. We found that approximately 1 in 8 patients will go on to require a CVC once admitted from the ED with a USPIV. It is presumed that prior to the use of the USPIV these patients likely would have required a CVC or alternative rescue procedure

**Table 1**
Patient demographics.

| Characteristics | ($N = 343$) |
|---|---|
| Age-median years (IQR) | 58.0 (43.0–70.0) |
| Race (%) | |
| White | 103 (30.0) |
| Black | 206 (60.1) |
| Asian | 4 (1.2) |
| Not reported/unknown | 30 (8.8) |
| Ethnicity-Hispanic/Latino (%) | 41 (12.0) |
| Gender - male (%) | 142 (41.4) |
| Primary outcome measure: CVC (%) | 45 (13.1) |
| BMI - mean kg/m$^2$ (SD) | 29.6 (8.4) |
| Length of stay - days (SD) | 7.3 (8.9) |
| Level of care (%) | |
| Floor/telemetry | 236 (68.8) |
| Stepdown/ICU | 107 (31.2) |
| Peripheral vascular disease (%) | 41 (12.0) |
| Diabetes (%) | 154 (44.9) |
| End stage renal disease (%) | 57 (16.6) |
| Sickle cell disease (%) | 18 (5.3) |
| Intravenous drug abuse (%) | 49 (14.3) |

Abbreviations: IQR interquartile range, SD standard deviation, CVC, central venous catheter.

**Table 2**
Clinical variables as predictors for CVC placement.

| Predictors | USPIV/CVC ($n = 45$) | USGPIV only ($n = 298$) | Difference [95% CI] | $p$-Value |
|---|---|---|---|---|
| BMI (kg/m$^2$) | 29.2 (SD = 7.8) | 29.7 (SD = 8.5) | −0.46% [−3.1% to 2.2%] | 0.72[a] |
| Length of stay (days) | 15.9 (SD = 15.6) | 6.0 (SD = 6.4) | 9.9% [5.1% to 14.6%] | <0.0001[a] |
| ICU/stepdown | 22 (48.9%) | 85 (28.5%) | 20.4% [5.1% to 35.5%] | 0.006[b] |
| Peripheral vascular disease | 4 (8.9%) | 37 (12.4%) | −3.5% [−11.6% to 7.6%] | 0.63[c] |
| Diabetes | 20 (44.4%) | 134 (45.0%) | −0.5% [−15.6% to 15.0%] | 0.95[b] |
| End stage renal disease | 5 (11.1%) | 52 (17.5%) | −6.3% [−15.4% to 5.6%] | 0.39[c] |
| Sickle cell disease | 2 (4.4%) | 16 (5.4%) | −0.9% [−6.8% to 8.2%] | 1.00[c] |
| Intravenous drug abuse | 5 (11.1%) | 44 (14.8%) | −3.7% [−12.6% to 8.1%] | 0.65[c] |
| Any DiVA risk factor[d] | 28 (62.2%) | 209 (70.1%) | −7.9% [−23.1% to 6.5%] | 0.28[b] |

Abbreviations: CVC central venous catheter, ICU intensive care unit.
[a] Student's *t*-test.
[b] Chi-square test.
[c] Fisher's exact test.
[d] DiVA risk factors: Peripheral vascular disease, diabetes, end stage renal disease, sickle cell disease, intravenous drug abuse.

performed. These findings support that USPIV can reduce the number of central lines placed in DiVA patients [8,9]. Despite this improvement, about 13% of DiVA patients still go on to require a CVC as an USPIV may fail or be insufficient for care.

As a secondary aim, this study sought to determine if risk factors for DiVA patients might also be predictive of requiring a CVC. It was our hypothesis that patients with known risk factors for being a DiVA, would be at higher likelihood of requiring a CVC. However, our results suggested an opposite trend, though this was inconclusive with p-values >0.05 in the single-variable and multivariable regression models. It is unclear why classic risk factors for DiVAs had a negative association for requiring a CVC. We suspect patients who did not have classic factors for being a DiVA, but required a USPIV were more likely to be critically ill, which resulted in standard IVs not being able to be placed. Therefore, we hypothesize placement of an USPIV in a patient without classic DiVA factors may be an independent predictor of severity of illness. We postulate severity of illness, length of hospitalization, and the clinical illness are most predictive drivers of patients requiring CVC after USPIV, however this requires additional clinical investigation.

While USPIVs reduce the need for CVCs, 7 out of 8 patients in our study did not go on to require a CVC. This means that for 87% of patients an USPIV was a sufficient vascular access option to initiate care. Further research into the cohort that did require a CVC may help to guide physicians when selecting catheters and counseling patients.

It is not surprising that patients who were admitted to a higher level of care, ICU or stepdown, were more likely to require a CVC. Given that only 1 in 5 patients did require a CVC in this cohort, we again see that USPIVs are sufficient in a majority of cases, even in those critically ill. Our study did not analyze whether the CVC was placed for centrally administered medications or for vascular access only, as we felt it was unlikely a physician would be able to predict this outcome. If a physician could predict the clinical course of a patient and expect a hospitalization for 7 days or longer, placing a device other than a USPIV may be better for the patient and possibly more cost effective. Further research into the comparison of USPIV against longer dwell devices such as midlines and CVCs is needed.

**Table 3**
Multivariate logistic regression where the outcome is CVC.

| Predictor | Odds ratio (95% CI) | $p$-Value |
|---|---|---|
| Length of stay (days) | 1.11 (1.06–1.16) | <0.001 |
| Age (years) | 1.00 (0.98–1.02) | 0.73 |
| Gender (male) | 0.93 (0.46–1.88) | 0.84 |
| BMI (kg/m$^2$) | 1.01 (0.97–1.05) | 0.77 |
| At least one or more DiVA risk factor[a] | 0.83 (0.40–1.70) | 0.61 |

[a] DiVA risk factors: Peripheral vascular disease, diabetes, end stage renal disease, sickle cell disease, intravenous drug abuse.

### 4.1. Limitations

Challenges include those inherent to retrospective chart reviews, which includes insufficient documentation. We may have missed patients in our analysis due to physicians not recording their USPIVs in the medical record. A lack of documentation could have been seen with CVCs as well, however we find this less likely. While the 1.88 in. angiocatheter is the preferred device at our hospital for USPIVs, and is stocked on the ultrasound machines, it is possible physicians could have selected a shorter 1.25 in. angiocatheter. It is unclear how differences in these devices may have affected failure rates and the subsequent need to have a CVC. This study did not investigate if USPIV failures were more likely to require CVC placement. Finally, we did not look at clinical diagnosis or indications for placement of CVCs. Further research into these areas is appropriate for future directions for DiVA patients.

### 4.2. Conclusions

We found use of USPIVs to be sufficient for a majority of patients with difficult vascular access to avoid a CVC. While it would be ideal to place the most appropriate access device upfront to limit IV attempts in DiVAs, we were only able to identify level of care and length of stay as predictive of having a CVC placed. Although it is not likely PICC lines will be routinely and easily accessible for ED patients, there may be a subset of patients who may benefit from having a PICC or CVC placed as their first form of vascular access in the ED. Since this study has concluded, we have seen our institution incorporate the use of midlines more frequently. The integration of midlines when indicated could help to reduce the incidence of central line associated blood infections if able to replace the use of a CVC. Further research into selecting the correct vascular access device is needed to limit painful procedures, avoid complications, and reduce costs. Physicians have numerous IV devices to select from (IO, standard IV, USPIV, Midline, PICC, standard CVC) and

additional investigative work will be important to guide physicians in selecting the right device, at the right time, for the right patient.

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## References

[1] Helm RE, Klausner JD, Klemperer JD, Flint LM, Huang E. J Infus Nurs 2015;38:189–203.
[2] Fields JM, Piela NE, Au AK, Ku BS. Am J Emerg Med 2014;32:1179–82.
[3] Paladini A, Chiaretti A, Sellasie KW, Pittiruti M, Vento G. BMJ Paediatr Open 2018;2:e000244.
[4] Panebianco NL, Fredette JM, Szyld D, Sagalyn EB, Pines JM, Dean AJ. Acad Emerg Med 2009;16:1298–303.
[5] van Loon FHJ, Puijn LAPM, Houterman S, Bouwman ARA. Med (Baltimore) 2016;95:e3428.
[6] Sebbane M, Claret P-G, Lefebvre S, Mercier G, Rubenovitch J, Jreige R, et al. J Emerg Med 2013;44:299–305.
[7] Dargin JM, Rebholz CM, Lowenstein RA, Mitchell PM, Feldman JA. Am J Emerg Med 2010;28:1–7.
[8] Au AK, Rotte MJ, Grzybowski RJ, Ku BS, Fields JM. Am J Emerg Med 2012;30:1950–4.
[9] Shokoohi H, Boniface K, McCarthy M, Khedir Al-Tiae T, Sattarian M, Ding R, et al. Ann Emerg Med 2013;61:198–203.
[10] Sullivan Pepe M. Oxford University Press; 2003.
[11] Cohen J. Educ Psychol Meas 1960;20(1):37–46.