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Prospective Study Evaluating Whether Standard Peripheral Intravenous Catheters Can Be Used for Blood Collection Throughout Hospital Stay

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ABSTRACT

Blood collection via venipuncture is the most common invasive procedure for inpatients, who experience an average of 1.6 to 2.2 blood collection episodes per day, for a total of approximately 450 million in US hospitals annually. In addition to being painful, venipuncture incurs the risk of vessel depletion, infection, and staff needlestick injury. A possible alternative is to use peripheral intravenous catheters (PIVCs), because PIVCs are placed in the majority of patients admitted to the hospital. Although there are anecdotal accounts of successfully using PIVCs for inpatient blood collection, the utility of this method has not been rigorously studied. The authors conducted a single-center prospective study among inpatients to evaluate blood collection success, defined as sufficient sample volume (4 mL) and no or minimal hemolysis, in PIVCs with a dwell time between 12 and 87 hours. Only 27% (28/105) of aspiration attempts were successful within this time frame. There was no difference in success rate with respect to PIVC dwell time, gauge, or location. These findings highlight the continued need for innovative, alternative solutions to meet the high demand for inpatient blood collection.

Key words: blood aspiration, blood collection, blood draw, inpatient, line draw, peripheral intravenous catheter, phlebotomy, venipuncture

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INTRODUCTION

Inpatient clinical management depends heavily on laboratory results from blood collection, so patients experience many blood collections while hospitalized. For accurate laboratory analysis, an acceptable blood sample must have both sufficient volume and quality; the sample cannot be hemolyzed, clotted, contaminated, or diluted. Venipuncture, the most common invasive inpatient procedure used to collect blood, provides high-quality samples but is associated with pain for patients and risks for providers. In addition to pain, patients can experience disturbance of sleep, infection, nerve damage, inadvertent arterial puncture, thrombus, vessel depletion, and hematomas (especially in patients on anticoagulation therapy, which is prevalent in the hospital setting).[1,2] For providers, there is a risk of accidental needlestick injury.[2] Failed attempts, especially in the growing population with difficult venous access, lead to significant clinical delays, lost productivity, and frustration for patients and providers.[3,4]

Alternatives to venipuncture are either more invasive or are not well studied. Central venous catheters provide ready and reliable access for delivery of medicine and blood draws, but generally they are not used for short-term hospital stays outside of the intensive care unit setting. Midline catheters may carry a lower risk of infection than central lines[5]; however, there is a lack of evidence regarding whether midline catheters are a viable method for blood sampling.[1] While a recent study looking at the use of midline catheters for blood collection found a low rate of hemolysis (0.69%) in collected samples, the rate of successful aspiration fell off quickly after 2 dwell days,[6] suggesting that midline catheters are not a useful means of blood collection for longer hospital stays.

Peripheral intravenous catheters (PIVCs) are one of the most used medical devices in hospitalized patients, but the 2021 Infusion Nurses Society *Infusion Therapy Standards of Practice* (the *Standards*) advises a careful risk/benefit analysis before using PIVCs for routine blood draws. The *Standards* states that sampling from a PIVC increases the risk of hemolysis of the sample, contamination of the sample from infusing solutions and medications, local complications from excessive catheter movement, and dislodgement of the PIVC.[1] In the emergency department (ED), where the benefits of PIVC blood draw outweigh the risks, it is common practice to draw blood upon insertion of a PIVC, and these draws are mostly successful.[7,8] Although it is widely assumed that the ability to draw blood from a PIVC decreases as dwell time increases, the extent and timeline of PIVC blood-drawing feasibility have not been carefully studied.

A systematic review of studies conducted within approximately the last 20 years reports highly variable PIVC blood-collection success rates, and their meta-analysis of samples collected from PIVCs versus venipuncture found higher rates of hemolysis in PIVCs.[9] However, these studies have multiple confounding factors, including whether the samples analyzed were obtained upon insertion, in a newly inserted PIVC, or in an existing PIVC. A more recent cohort study found that the rate of hemolysis was associated with increased tourniquet duration, tube fill level, increased age of patient, and the difficulty of cannulation/venipuncture and increased number of attempts, but not with the method of sample collection—rates of hemolysis were equal in samples drawn from the PIVC or venipuncture.[8] However, this was upon insertion of the PIVC in the ED, and the researchers did not examine success as dwell time increased. Currently we are unaware of any studies that systematically assess PIVC blood collection capability over multiple inpatient dwell days.

We set out to test whether standard PIVCs can reliably be used for inpatient blood collection in a prospective study of hospitalized patients. We examined the performance of PIVCs as a method of blood collection over multiple dwell days and assessed the effects of PIVC gauge and location on blood collection success.

METHODS

This institutional review board–approved prospective study was conducted on a sample of inpatients at a large medical center over a 9-month period. The purpose of the study was to evaluate the blood aspiration capabilities of PIVCs over their dwell time in a medical/surgical inpatient population. The eligibility criteria for patients included the following: (1) ability to provide consent, (2) not having a high risk of anemia, and (3) presence of a PIVC in place for at least 12 hours. Patients meeting the eligibility criteria were asked to consent to repeated sampling from the PIVC. Eighty-eight patients were enrolled in the study (average age, 58 years; range, 23–92 years; 68% men). All participants had a 1-inch peripheral intravenous catheter (B. Braun, Melsungen, Germany) connected to a needleless connector with 6-inch minibore tubing (Caresite, B. Braun). All PIVCs were secured with standard dressing (Tegaderm IV advanced securement, 1683, 3M, St. Paul, MN).

The time and date of PIVC placement was noted, along with PIVC location and gauge. PIVCs were used routinely before blood draw. At the time of blood draw, the needleless connector at the end of the PIVC extension set was flushed with 5 mL of 0.9% NaCl. If the PIVC was flushable, a vacuum tube holder with sheathed needle (Vacutainer Luer-Lok access device, Becton, Dickinson and Company, Franklin, NJ) was attached to the needleless connector. Blood collection was attempted with vacuum tubes attached to the tube holder (4-mL serum separator tubes, Becton, Dickinson and Company). If possible, 2 tubes were collected from each patient, including a first waste tube and a second sample. If a second tube was obtained, the sample was measured for hemolysis and compared with the hospital laboratory hemolysis index chart ($\geq$50 mg/dL was considered hemolyzed, $<$50 mg/dL was considered not hemolyzed or having minimal hemolysis). Samples

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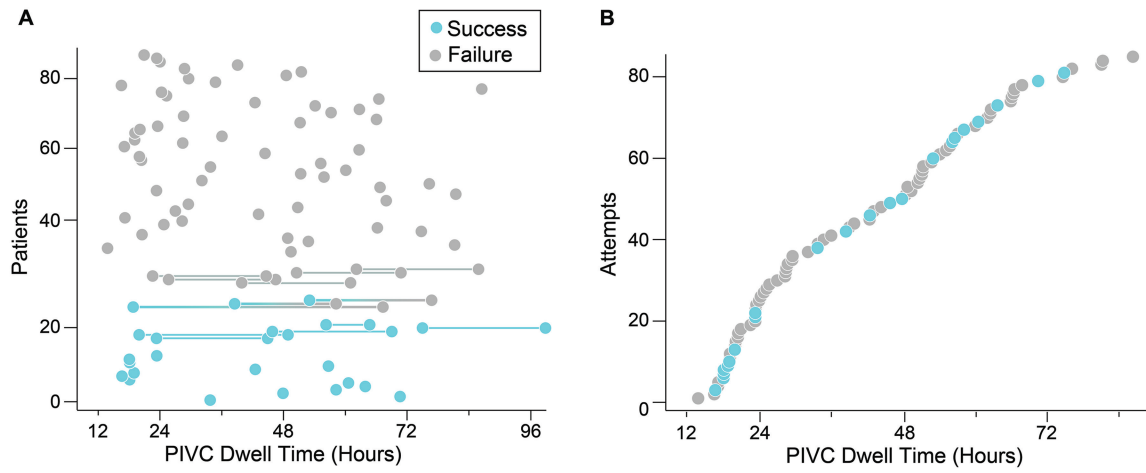

Figure 1 Scatter plots showing attempted blood draws in each patient. A, Attempts sorted by success and/or failure. Lines connecting markers show multiple attempts in a single patient. B, Attempts sorted by dwell time, showing only the first attempts in each patient.

were centrifuged at 2500 rpm for 15 minutes. A blood draw was considered successful if a second sample tube was obtained and the sample showed no/minimal hemolysis.

RESULTS

At least 1 blood collection attempt was made from each of the 88 patients enrolled; the overall success rate was 27% (28/105 attempts). Five of the patients had a PIVC present upon admission to the hospital and were excluded from further analysis because the exact dwell time was unknown. In the remaining 83 patients (age average: 58.1 years; range, 23–92 years; 67.5% men), there were a total of 85 PIVCs, because 2 patients had a second PIVC placed later in their hospital stay from which blood collection was attempted. In 13 of the PIVCs, a second blood collection was attempted later in their hospital stay; these attempts were analyzed separately.

The success rate of first attempts from a given PIVC was 26% (22/85 attempts, 95% confidence interval [CI], 17.8–36.1, Wilson Score Interval; Figure 1 and Table 1). There was no significant difference in success rate at 12–24, 24–48, 48–72, and 72–87 hours (Table 1, $\chi^2 = 2.10$, $P = .55$). Given the high success rate of PIVC blood draws usually at the time of insertion,[7] these results suggest that the drop in success rate occurs within the first 12 hours of dwell time. There was also no effect of patient age or PIVC dwell time on success rate. The success rate of PIVC blood draws was higher in male patients than in female patients (males, 33.3% [95% CI, 22.5%–46.3%]; females, 10.7% [95% CI, 3.7%–27.2%]; 1-way analysis of variance, $P < .05$; Table 2), most likely due to larger vessel sizes in men (see Discussion).

A second attempt to collect blood in the same PIVC was made in 13 patients (average age: 64.5 years; 69% men; Figure 1 and Table 3). The average dwell time of the PIVC in these patients was 40.9 hours for the first attempt and 64.4 hours for the second attempt. The outcome of the first attempt significantly predicted (10/13, $P < .05$, binomial test) the outcome of the second attempt (5 double successes, 5 double failures, 3 disparate outcomes). In the 3 patients with disparate outcomes, all 3 exhibited successful first draws and unsuccessful second draws.

Blood draw success rate was also recorded and analyzed with respect to PIVC gauge and location (Table 4). In all but 4 blood draws, 18-, 20-, or 22-gauge PIVCs were used. Blood draw success was also examined with respect

TABLE 1

PIVC Success as a Function of Dwell Time

PIVC Dwell Time (Hours)			% Successful (No. of Successes/No. of Attempts)	95% CI
Groups	Range	Average		
12-24	13.8-24.0	19.9	36.0 (9/25)	20.3-55.5
24-48	24.3-47.9	34.1	20.0 (5/25)	8.9-39.1
48-72	48.5-70.6	57.8	24.1 (7/29)	12.2-42.1
72-87	74.7-86.5	79.2	16.7 (1/6)	3.0-56.4
Total	42.4	41.2	25.9 (22/85)	17.8-36.1

Abbreviations: CI, confidence interval; PIVC, peripheral intravenous catheter.

TABLE 2

Age, Gender, and Dwell Time in Successful and Failed PIVC Blood Draws

	All Successes (n = 22)	All Failures (n = 63)	Statistics
Age in years (mean, SD)	57.5, 18.2	58.5, 14.7	F-stat = 0.0634; $P = .8019$
Gender (men, women)	N = 19, n = 3	N = 38, n = 25	χ^2 stat = 5.01, $P < .05$
Average dwell time for first attempts in hours (mean, SD)	39.9, 19.7	41.7, 19.6	F-stat = 0.1316; $P = .7177$

Abbreviations: PIVC, peripheral intravenous catheter; SD, standard deviation.

to PIVC location (Table 4). A majority of PIVCs (76%) were located in the forearm (n = 40) or antecubital (AC) region (n = 25), and the remainder were in the hand (n = 13), wrist (n = 5), and upper arm (n = 2). There were no statistical differences in success rate between the different PIVC gauges or locations.

DISCUSSION

To the best of our knowledge, the present study is the first to systematically evaluate PIVC blood collection success rates over multiday dwell times in an inpatient setting. We found that the success rate of blood draws from PIVCs with greater than 12-hour dwell time was very low, at 26%, compared with the 72% to 88% success rate of venipuncture.[10,11] These results suggest that PIVC blood collection is not a viable alternative to venipuncture during a hospital stay, consistent with the *Standards* recommendation against using PIVCs for routine blood draws.

TABLE 3

Outcomes for Second Attempts

	Success on second attempt	Failure on second attempt
Success on first attempt (8/13)	5	3
Failure on first attempt (5/13)	0	5

We found no significant decrease in blood draw success with dwell time longer than 12 hours. Because evidence suggests that PIVC blood draws immediately postinsertion in the ED are highly successful,[7] these results suggest that the conditions leading to PIVC blood collection failure develop within 12 hours of PIVC placement. Of note, PIVCs are routinely placed in the AC region in the ED, whereas only 29% of PIVCs in this study were placed in the AC region. A controlled study examining PIVC placement and blood draw success rate could determine whether this was a factor in the low success rate after 12 hours of dwell time.

The possible mechanisms of PIVC blood collection failure were also not within the scope of this study but include mechanical failures related to the PIVC such as kinking, compression of the vessel from the PIVC setup/dressing, PIVC diameter obstructing flow, PIVC thrombus or fibrin tails at tip; and vessel-related complications such as wall thrombus, vein wall edema or phlebitis, vein spasm or constriction, and valves blocking access to downstream circulation/branches. Other variables that were also not in the scope of this study were factors related to the daily care of the PIVCs, such as routine flushing and flush volumes, and the type of equipment used for blood collection.

TABLE 4

Success Rate by PIVC Gauge and Location

	PIVC Gauge					
PIVC Location	16	18	20	22	24	All Gauges
AC	0.0 (0/1)	20.0 (1/5)	42.1 (8/19)	____	____	36.0 (9/25), [20.3-55.5]
Forearm	____	22.2 (2/9)	13.3 (2/15)	12.5 (2/16)	____	15.0 (6/40), [7.1-29.1]
Hand/wrist	100.0 (2/2)	0.0 (0/3)	27.3 (3/11)	0.0 (0/2)	0.0 (0/1)	27.8 (5/18), [12.5-50.9]
Upper arm	____	____	100.0 (2/2)	____	____	100.0 (2/2), [34.2-100.0]
All locations	66.7 (2/3), [20.8-93.9]	17.6 (3/17), [6.2-41.0]	31.9 (15/47), [20.4-46.2]	11.8 (2/17), [3.3-34.3]	0.0 (0/1), [0.0-79.4]	25.9 (22/85), [17.8-36.1]

Data show the percentage successful (No. of successes/No. of attempts), [95% CI].
Abbreviations: AC, antecubital; CI, confidence interval; PIVC, peripheral intravenous catheter.

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We observed a higher success rate in men than in women (33.3% vs 10.7%), which we hypothesize is due to a larger vein-to-catheter size ratio in men versus women.[12] Ideally, to maintain adequate blood flow, a vein should be larger than twice the diameter of a catheter. There is evidence to suggest that in 50% of women (and only 14% of men), a 20-gauge catheter could occlude too much lumen and limit blood flow[12]; in this study, more than 75% of the PIVCs used either a 20- or 18-gauge catheter. A controlled study examining vein-to-catheter ratio in men and women could determine whether differences in this ratio explain the lower PIVC blood draw success rates for women seen in our study or if another mechanism is responsible.

Previous studies have shown an increase in the rate of hemolyzed samples collected from PIVCs as compared with venipuncture, but this was not observed in our study. There was no or minimal hemolysis in all of the samples in our study. This is consistent with recent findings that hemolysis rates are dependent on factors other than the method of sample collection.[8]

CONCLUSIONS

The results of this study corroborate the *Standards* and confirm anecdotal teaching practices that using PIVCs for blood collection is not a viable technique in the inpatient setting. Although the generalizability of this study could be extended with a larger, multicenter trial, these results highlight the need for further research into the mechanisms behind blood collection complications and the continued need for innovative, patient-centric, and reliable alternatives to venipuncture for blood collection.

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