Examining the Push Pull Method of Blood Sampling From Central Venous Access Devices

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Examining the Push–Pull Method of Blood Sampling From Central Venous Access Devices

Kathleen Adlard, MN, RN, CPON, CCNS

The placement of a central venous access device (CVAD) has revolutionized supportive care for pediatric cancer patients. The CVAD is used to administer chemotherapy/biotherapy, blood products, total parenteral nutrition, antibiotics, and many other supportive medications. CVADs also provide the ability to obtain blood samples without the trauma associated with venipuncture. Frequent blood sampling is often needed to monitor the side effects and response of the cancer treatment. Unfortunately, the most common method requires discarding blood (0.5-10 mL, depending on the institution's protocol) with each lab draws, for various reasons. For pediatric oncology patients, this can result in a large volume of blood being discarded and subsequently increase the need for blood transfusions. Repeated exposure to allogeneic (donor) blood products can put this patient population at additional risk for alloimmunization and febrile reactions. The purpose of this study is to test the limits of agreement between laboratory values (chemistry panel 18 and complete blood count) obtained using the push–pull and standard methods of blood sampling from CVADs in pediatric oncology patients.

Key words: *push–pull method, blood sampling, central venous access devices, pediatric oncology, diagnostic blood loss*

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Background: Significance of Diagnostic Blood Loss (DBL)

Although most of the literature about the adverse effects of DBL deals with critically ill patients, the same issues are relevant to pediatric oncology patients, especially those undergoing aggressive treatment, including hematopoietic stem cell transplantation. According to Shaw (1993), blood sampling is one of the major causes of anemia in infants and children. MacGeorge, Steeves, and Steeves (1988) reported that adult bone marrow transplant (BMT) patients lose an average of 95.7 mL of blood per week if 6 mL of blood is discarded with each lab draw. This does not include the blood volume necessary for diagnostic testing. Although the blood loss was reported on an adult population, the discard volume is similar to that used for pediatric patients. The consequences of blood loss may be even more significant in infants and children. For example, they have a smaller vascular volume compared with adults (Wilson & Gaedeke, 1996), which can result in additional stress on the cardiovascular and respiratory systems. Dech and Szaflarski (1996) reported a mean blood loss of 18 to 377 mL/d in critically ill patients; discard volumes accounted for 24% to 30% of this

Kathleen Adlard, MN, RN, CPON, CCNS, is a clinical nurse specialist at the Children's Hospital of Orange County, Dove Canyon, California. Address for correspondence: Kathleen B. Adlard, MN, RN, CPON, CCNS, 455 South Main Street, Orange, CA 92868; e-mail:kadlard@choc.org.

blood loss. They concluded that blood loss resulting from discard contributed to volume depletion and that blood loss for diagnostic purposes may result in "nosocomial anemia" and the need for transfusions. Sensitization issues and transmission of infectious diseases, such as cytomegalovirus, are of particular concern for pediatric oncology patients because of their need for repeated blood product transfusions.

Keller (1994) surveyed 34 pediatric BMT units about their method of blood sampling from central venous access devices (CVADs), rationale for its selection, and the clinicians' concerns regarding blood sampling. Seventy-five percent of the BMT units reported using the discard method, 14% used the reinfusion method, and 11% used the mixing method. The rationale for selection of blood sampling method varied among the units, with only a small percentage citing research as the basis for their decision. Discard volumes ranged from 0.5 mL to 10 mL, with the majority of units (61%) reporting a discard volume of 4 to 6 mL. Risk of infection to patient, blood loss, and accuracy of laboratory results were noted to be the 3 most common clinician concerns related to blood sampling methods.

In a review article, Frey (2003) summarized the advantages, disadvantages, and recommendations for practice for the 3 methods of blood sampling from a CVAD: (1) discard, (2) reinfusion, and (3) push–pull. Frey concluded that there was insufficient research to support one method over the others. As a result, there continues to be inconsistent practice for a very common nursing procedure, which indicates the need for further research.

Methods of Blood Sampling

The literature provides little direction for determining the optimal method of blood sampling from CVADs. The 3 methods of blood sampling from CVADs discussed most frequently in the literature are (1) discard, (2) reinfusion, and (3) push–pull (formerly known as "mixing" method).

Discard Method

In the discard method, blood is aspirated into a syringe to clear the catheter of intravenous solutions and medications, and is then discarded. A second syringe of blood is obtained for analysis. The advantage of this method is that no blood is returned to the child that might introduce pathogens. The disadvantage of this method is that it can result in a significant amount of blood loss with frequent blood draws. The blood loss may be significant enough to necessitate blood replacement, which exposes the child to the risks associated with repeated blood transfusions. In addition, there is a risk of blood exposure for the clinician and the potential to confuse the blood sample with the discard syringe (Frey, 2003). This is the most commonly used method in the clinical setting.

Reinfusion Method

Reinfusion is an alternative method that minimizes blood loss associated with diagnostic blood sampling. The steps are similar to the discard method, except that the first syringe of blood is reinfused after the lab sample is obtained. The advantage of this method is a decrease in the volume of blood loss associated with diagnostic testing (Dech & Szaflarski, 1996). Disadvantages of this method are (1) the potential for reinfusion of blood clots (Cosca et al., 1998); (2) blood hemolysis or hemodilution (MacGeorge et al., 1988); (3) the potential for contamination of the blood being reinfused (Hinds et al., 1991); and (4) the potential for mixing up lab specimen and reinfusion syringes. As a result of these concerns, the reinfusion method has not gained wide acceptance among clinicians.

Push–Pull (Mixing) Method

Another alternative method, push–pull, limits both blood loss and potential exposure to pathogens. Blood is aspirated into a syringe and reinfused 3 times without disconnecting the syringe. After the third aspiration/reinfusion cycle, the syringe is disconnected. A second syringe is used to obtain the volume of blood necessary for lab analysis. The advantage of this method is that no blood is discarded. In addition, this method reduces the risk of catheter contamination or blood exposure and uses less equipment (Frey, 2003). The disadvantage of this method is the potential for hemolysis of the blood caused by turbulence in the catheter and syringe, and for patients with malfunctioning catheters, it may be difficult to obtain enough blood for 3 to 4 push–pull sequences.

Comparison of Blood Sampling Methods

Several researchers have compared the various methods of blood sampling from CVADs. Adult studies comparing the push–pull method with the reinfusion method (MacGeorge et al., 1988) and the discard method (Holmes, 1998) reported no significant difference in laboratory results and no evidence of hemolysis or hemodilution. The first pediatric study comparing the push–pull and discard methods was conducted by Barton, Chase, Latham, and Rayens (2004). Paired blood samples were obtained from 28 pediatric oncology inpatients, 6 months to 12 years of age. Using a standardized procedure and a 3-way stopcock, the discard volume (4 mL) was aspirated into the first syringe, and then the stopcock was closed to the syringe with the aspirated blood. The stopcock was opened to the empty syringe, and the blood volume necessary for lab tests was aspirated. The syringe with the initial 4 mL of aspirated blood was used to obtain a research sample using the push–pull method. The paired blood samples were sent for analysis. The lab values (hemogram, glucose, and electrolytes) were compared for limits of agreement. Although the differences in several lab results were statistically significant, they were not clinically significant. There were no reported catheter infections in children enrolled in the study during data collection.

Previous adult and pediatric studies comparing the push–pull method with the discard and reinfusion methods have yielded similar results and have suggested that the push–pull method is an acceptable blood sampling method. However, the discard method continues to be the most widely used method in the clinical setting. Therefore, more research is needed to provide evidence-based support for changing clinical practice to incorporate the push–pull method as the standard blood sampling method for patients with CVADs.

Specific Aims

The primary aim of this study is to compare the laboratory values obtained using the push–pull and standard methods of blood sampling from CVADs in pediatric oncology patients. A second aim of this study was to determine if there was evidence of hemolysis or hemodilution in the paired blood samples. The third aim was to determine if using the push–pull method increased the risk of bloodstream infections (BSIs).

Methods

This study was conducted using a within-subjects comparative design, comparing 30 paired blood samples. The site was a 212-bed free-standing children's hospital in Southern California.

Sample

Thirty pediatric oncology patients, ranging in age from 8 months to 17 years, with tunneled or implanted CVADs were enrolled using a convenience sampling method. Patients meeting eligibility criteria were approached during their hospital stay. The inpatient setting was selected to control for the laboratory processing of the paired blood samples. Patients in the ambulatory care setting have their lab tests processed at various laboratories depending on their third-party payer.

Children and adolescents were eligible to participate in the study if they met the following criteria: They (1) were between the ages of 6 months and 18 years; (2) had inpatient status; (3) had patent CVADs; (4) had tunneled or implanted CVADs; (5) had an existing order for serum chemistry panel 18 and complete blood count (CBC); and (6) were English or Spanish speaking. The exclusion criteria were the following: (1) known blood disorders or BSIs, (2) malfunctioning CVADs, (3) febrile status, and (4) outpatient or ambulatory status. Patients with fever or existing BSIs were excluded because one of the study's aims was to determine if the push–pull method increased a child's risk for BSIs. Given the emotional stress parents/legal guardians experience when dealing with diagnostic testing, invasive procedures, and initiation of treatment, newly diagnosed patients were not approached regarding this study during their initial hospital stay.

Participant Recruitment

Following institutional review board approval of the study, the nursing staff in the 28-bed hematology/oncology unit and in the 12-bed hematology/oncology

Table 1. Standardized Procedure for Obtaining Paired Blood Samples

1. Assemble equipment: five 10 mL sterile syringes, one 10 mL prefilled normal saline syringe, 1 prefilled heparin syringe (as needed), alcohol prep pads, 1 pair nonsterile gloves, 2 sets of blood tubes (1 set for labs ordered by MD/NP and 1 set for research samples)
2. Identify patient verbally and verify patient identification by checking the patient's name and medical record number on the patient identification band
3. Perform hand hygiene
4. Don nonsterile gloves
5. Turn off all infusing intravenous fluids from both lumens, if applicable, and clamp both lumens
6. Cleanse the injection cap or tubing connection with alcohol prep pad by rubbing vigorously for 10 seconds. Allow to air dry for 10 seconds
7. Remove IV tubing and place cap on end of tubing, if applicable
8. Connect first sterile syringe to CVAD injection cap and aspirate 5 mL of blood; return blood, and repeat twice
9. Return blood and disconnect first syringe
10. Connect second syringe and aspirate blood volume necessary for research labs
11. Transfer blood from syringe to lab tubes using blood transfer device
12. Label specimen tube(s) with patient label and "research" sticker
13. Using a third syringe, aspirate blood volume necessary for ordered lab tests
14. Transfer blood from syringe to lab tubes using blood transfer device
15. Apply patient label to second set of specimen tube(s)
16. Place both sets of specimen tubes in separate plastic bags for transport to laboratory for processing
17. Flush catheter with normal saline per protocol, 10 mL for external catheters and 20 mL for implanted ports

NOTE: CVAD, central venous access device.

intensive care unit received in-services on the study and were asked to assist in identifying potential participants. One of the research assistants was a Spanish-speaking nurse and was able to assist in obtaining consents from Spanish-speaking patients. Once parental/legal guardian permission was obtained, the children and adolescents were approached and given age-appropriate information about the study. They were given an opportunity to ask questions and were assured that it was okay to decline participation. Per hospital policy, children and adolescents between the ages of 12 and 18 years signed the same consent form as their parent/legal guardian. Children between the ages of 7 and 11 years signed a separate written assent form. All forms were available in English and Spanish. Only 2 parents did not give permission to approach their child regarding study participation. As a token of appreciation, the children received a $10.00 gift card.

Data Collection

Two hematology/oncology registered nurses with 6 and 18 years of experience were trained on obtaining the paired blood samples using a research protocol (Table 1), and interrater reliability of 100% was established. The data collection occurred on a morning when the routine labs (chemistry panel 18 and CBC) were ordered. The paired blood samples were collected by either the principal investigator (PI) or one of the 2 research assistants. The research lab tubes and requisition were prepared with a bright neon "research" sticker. The first blood sample was obtained using the push–pull method and transferred to the appropriate lab tubes, which were labeled "research." Samples were placed in a separate plastic bag with a special research requisition that did not contain the patient's medical record number or date of birth. This was done to avoid the possibility of the research lab results appearing in the medical record. The second blood sample, which served as the control, was transferred to the appropriate lab tubes with lab-generated labels containing the patient's medical record number and date of birth and placed in a separate plastic bag with the lab-generated requisition. The paired samples were attached and hand-carried to the inpatient laboratory for analysis. Paired samples were processed sequentially by the same lab technician. Twenty-four hours after the paired blood samples were collected, the medical record was reviewed for documentation of a fever, which could possibly indicate a BSI.

Data Management

The lab results for the paired blood samples were reported separately. Printed results of the research labs were retrieved from the lab by the PI. The routine lab results (controls) were retrieved from the medical record by the PI. The PI entered data including participant number, demographic information, CVAD information, research lab values (rv) and control lab values (cv) onto individual data collection forms. The data were transcribed into an Excel database by a research assistant. Transcription was checked for accuracy by the PI and a second research nurse.

Data Analysis

Statistical analysis was performed using SPSS for Windows 11.0 (SPSS Inc., 2001). Agreement between the 21 laboratory assays (chemistries, hemoglobin, hematocrit [HCT], and platelets [PLT]) of the paired blood samples was examined using 3 criteria: intraclass correlation (ICC; Winer, 1971) to look for amount of variance agreed on by both methods; paired *t* tests to test for overall mean differences between the 2 methods; and the Bland-Altman analysis (Bland & Altman, 1999) that looks for highly disparate values.

Results

Thirty pediatric oncology inpatients participated in the study. Their demographic characteristics are presented in Table 2. There was a fairly equal distribution of boys (53%) and girls (47%). Ages ranged from 8 months to 17 years, with an average of 7.5 years (standard deviation [SD] = 4.9 years). Ethnicity of the participants was similar to the population of the inpatient unit: 50% Hispanic/Latino, 43% White/ Caucasian, and 7% Asian/Pacific Islander. Children with a variety of diagnoses were represented in the sample: More than half the participants had leukemia (57%), followed by solid tumors (23%), central nervous system tumors (10%), bone marrow transplant (7%), and histiocytosis (3%). Both types of catheters commonly used in this population were included in the study: Hickman catheters accounted for 73%, and implanted ports accounted for the remaining 27%. There was no statistical difference in the lab results either based on the type of catheter or based on the nurse obtaining the paired samples.

Table 2. Demographic Characteristics of the Sample (N = 30); Mean Age = 7.5 years (SD = 4.9 years, range = 1-17 years)

	n	Percentage
Gender		
Female	16	53.3
Male	14	46.7
Diagnosis		
Leukemia	17	56.1
Solid tumor	7	23.3
CNS tumor	3	10.0
Bone marrow transplant	2	6.7
HLH (a form of histiocytosis)	1	3.3
Catheter type		
Broviac	22	73.3
Port-a-cath	8	26.7
Ethnicity		
White/Caucasian	14	43
Hispanic/Latino	15	50
Asian/Pacific Islander	1	7

NOTE: SD = standard deviation; CNS = central nervous system.

The laboratory values of the research sample obtained using the push–pull method and the control values had an extremely high degree of agreement. As can be seen from Table 3, almost all the ICCs were above 0.90, which means that for every assay examined, more than 90% of the variance observed was attributable to agreement between the 2 methods. Furthermore, 17 of the 21 labs had an ICC above 0.95 (95% agreement). A second measure of disagreement between the 2 methods was examined using paired *t* tests. There were only 3 assays that were statistically significant: glucose ($P = .001$), PLT ($P = .037$), and alanine aminotransferase ($P = .007$). A series of Bland-Altman analyses was performed to examine these assay differences more closely. The Bland-Altman analysis performed on glucose (Figure 1) showed a statistically significant higher glucose level in the research assay as reflected in the largely positive standardized residuals. In addition, the plot indicates that the inflation in the glucose value in the research samples correlates with increases in the control values, which indicates that the level of bias increases with increasing blood glucose levels. For alanine aminotransferase, there was a bias of –0.6; this appears to be more like a chance event (Figure 2). The Bland-Altman analysis of the PLT (Figure 3) is similar, with normally distributed residuals across the range of PLT control values. There is such close agreement between the mean laboratory values

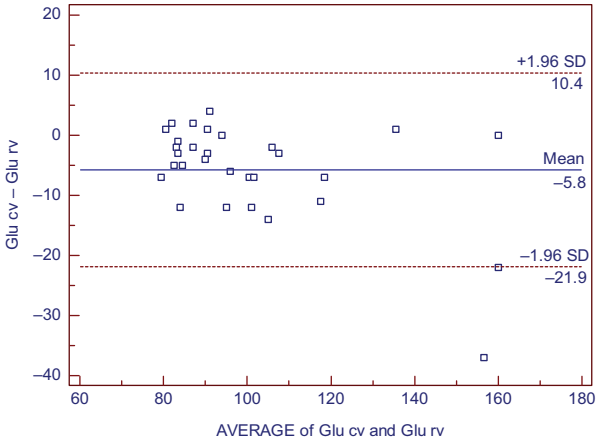

Figure 1. Bland-Altman Plot for Glucose (Glu)
NOTE: SD = standard deviation; rv = research lab values; cv = control lab values.

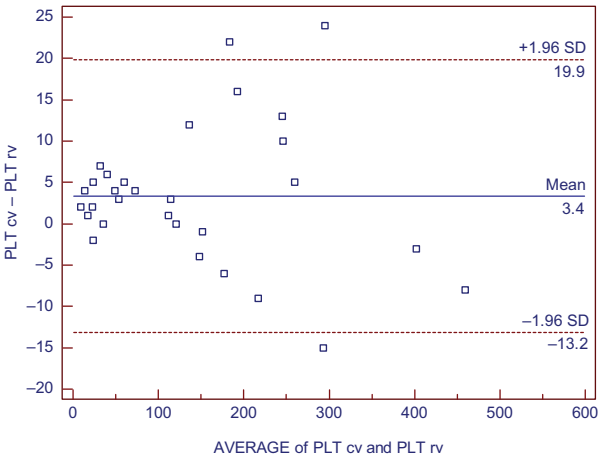

Figure 3. Bland-Altman Plot for Platelets (PLT)
NOTE: SD = standard deviation; rv = research lab values; cv = control lab values.

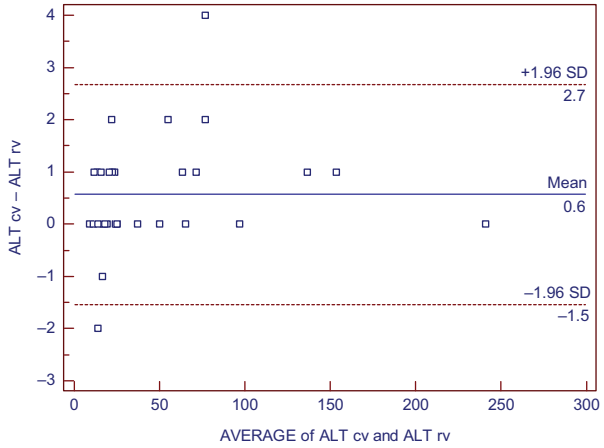

Figure 2. Bland-Altman Plot for Alanine Aminotransferase (ALT)
NOTE: SD = standard deviation; rv = research lab values; cv = control lab values.

when comparing the push–pull and standard methods that it results in a very small SD. Therefore, the occasional value that falls outside the SD range is well within the normal range for each lab assay. Even those values that were statistically significant were not clinically significant. For example, glucose had the largest SD of the 3 statistically significant lab values; yet the actual difference was a mean of 98.23 for the standard method compared with a mean of 104.00 for the push–pull method. In summary, the analyses suggest excellent agreement between assays using the 2 methods of blood sampling.

There was no hemolysis observed in the paired samples as evidenced by the potassium levels (K cv 3.933 vs K rv 3.943), which are usually elevated in the presence of hemolysis. There was no evidence of hemodilution as evidenced by the HCT levels (HCT cv 29.323 vs HCT rv 29.317), which are lower in the presence of hemodilution. None of the 30 children developed a fever during the data collection period. Therefore, using the push–pull method of blood sampling did not appear to increase the risk of BSIs in these 30 pediatric oncology inpatients. The lab values between the paired blood samples were equivalent as evidenced by the highly similar means and SDs.

Discussion

Blood sampling from CVADs is a common procedure in the pediatric oncology setting. Currently, the discard method, which results in additional blood loss for these children, is the most widely used method. The push–pull method is an alternative method of blood sampling that does not require the discard volume. The purpose of the study was to compare the laboratory values of paired samples obtained using the push–pull and standard methods to determine the level of agreement. The participants in this study were representative of the children on this inpatient hospital unit. Study enrollment occurred over a 4-month period, with only 2 parents refusing participation citing reasons unrelated to concerns about using the push–pull method. The nursing

Table 3. Summary of Means and SD, Paired *t* Tests, and ICC Analysis for 30 Paired Blood Samples (N = 30)

	Standard Discard Method		Trial Push–Pull Method			
	Mean	SD (±)	Mean	SD (±)	Paired *t* Tests	ICC
Sodium	135.90	2.41	136.00	2.74	–0.46	0.895
Potassium	3.93	0.48	3.94	0.50	–0.38	0.958
Chloride	103.40	3.60	103.60	3.93	–1.000	0.958
CO_2	26.80	2.19	26.73	2.21	0.40	0.915
BUN	8.00	7.07	7.93	6.77	0.24	0.994
Glucose	98.23	21.52	104.00	25.86	–3.83***	0.940
Creatinine	0.40	0.15	0.40	0.17	0.00	0.917
Calcium	9.08	0.55	9.08	0.53	–0.17	0.980
Bilirubin, total	0.69	0.45	0.69	0.45	0.28	0.955
Uric acid	2.48	0.84	2.48	0.85	0.30	0.997
Albumin	3.19	0.48	3.17	0.48	1.41	0.991
Protein, total	5.56	0.87	5.54	0.84	1.10	0.993
Phosphorous	4.47	0.97	4.45	0.97	1.88	0.998
AST (SGOT)	35.80	29.70	35.93	29.66	–0.63	0.999
ALT (SGPT)	48.47	52.07	47.90	51.88	2.89**	1.000
Alkaline phosphatase	146.77	146.41	145.40	147.16	1.68	1.000
LDH	198.27	125.69	197.43	126.29	0.45	0.997
Total cholesterol	135.30	41.55	133.90	41.42	1.66	0.992
Hemoglobin	9.93	1.45	9.91	1.42	0.59	0.994
HCT	29.32	4.15	29.32	4.01	0.08	0.993
Platelet count	141.83	119.65	138.47	120.33	2.19*	0.998

NOTE: SD = standard deviation; ICC = intraclass correlation; BUN = blood, urea, nitrogen; AST = aspartate aminotransferase; SGOT = serum glutamic oxaloacetic transaminase; ALT = alanine aminotransferase; SGPT = serum glutamic pyruvic transaminase; LDH = lactate dehydrogenase; HCT = hematocrit.
*$P < .05$. **$P < .01$. ***$P < .001$.

staff were helpful in identifying potential participants and stated that they were often concerned about the amount of blood that was being discarded, especially in the infants and young children. Parents readily supported their child's participation in the study for the following reasons: (1) They were familiar with the PI and research assistants; (2) the research did not result in any additional blood loss because the volume used for the research sample was equivalent to the discard volume; and (3) several parents expressed concern about the additional blood loss associated with the discard method and believed that it was a contributing factor to their child's anemia, resulting in the need for transfusions. The inpatient population usually comprises approximately 50% Hispanics; therefore, having a Spanish-speaking research assistant helped ensure a better representation of the Hispanic population in the study.

These results are similar to those reported by MacGeorge et al. (1988), Holmes (1998), and Barton et al. (2004), which reported no clinical significance in lab values obtained using the push–pull method of blood sampling. Additionally, the push–pull method does not appear to increase the incidence of hemolysis, hemodilution, or BSIs. It could be concluded that discarding blood is not necessary to obtain accurate laboratory results when obtaining blood samples from CVADs. The blood draw policy at the author's institution was changed based on the results of this study. However, the discard method will continue to be used for blood cultures, drug levels, and coagulation studies.

Limitations

These findings only reflect a comparison of the 21 lab assays included in this study, which were 18 serum chemistries and 3 values from the CBC (hemoglobin, HCT, and PLT). The study did not include other labs commonly monitored in the

pediatric oncology population, such as drug levels and coagulation studies. Additional research studies using the push–pull method for obtaining drug levels and coagulation studies will need to be conducted to determine if similar results can be achieved. The distribution of the types of CVADs was not equal: 75% were external catheters (ie, Broviacs and Hickmans), and 25% were implanted CVADs. It would be important to have a study that included an equal distribution of catheters to further examine differences in lab values that may be caused by the type of catheter and a possible increase in hemolysis caused by turbulence in the implanted catheters.

Future Research and Clinical Implications

Previous studies in both adults and children suggest that laboratory results obtained using the push–pull method are similar to those obtained using the discard and reinfusion methods. Additional research studies in this area can add to the existing body of knowledge and provide clinicians with evidence needed to change practice in the clinical setting. The findings may also be relevant to other pediatric and adult settings, such as intensive care units, where frequent blood sampling from CVADs occurs. Although there did not appear to be a statistical difference between the types of CVADs, external versus implanted, further research needs to be conducted with a larger number of implanted CVADs. It would also be important to replicate this study in additional settings, such as pediatric intensive care units or outpatient settings, and using a variety of laboratories.

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