



ORIGINAL RESEARCH CONTRIBUTION

Use of Butterfly Needles to Draw Blood Is Independently Associated With Marked Reduction in Hemolysis Compared to Intravenous Catheter

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Abstract

Objectives: Hemolysis of blood samples drawn in the emergency department (ED) is a common problem that can interfere with timely diagnosis and appropriate treatment. The objective of this study was to identify the smallest number of remediable factors that independently increases the risk of hemolysis to design an effective strategy to address this issue.

Methods: This was a prospective, observational, cross-sectional study of blood specimens obtained by ED staff in an urban, academic, adult ED in a tertiary care center. The staff member who drew the specimen recorded data on a standardized data collection instrument about device (intravenous [IV] catheter or butterfly needle), needle size, anatomic site, fullness of collection tube, tourniquet time, and difficulty of venipuncture. Specimens were sent to the laboratory by a vacuum-powered tube system. A standard automated process that measures free hemoglobin was used to identify hemolysis. A multivariable logistic regression and a tabular analysis stratified by device were performed. Ninety-five percent confidence intervals (CIs) were calculated around the odds ratios (ORs) and around the difference between hemolysis rates.

Results: Data were collected on 5,118 blood specimens. There were 4,513 specimens with complete data on all characteristics of the blood draw included in the analyses. The overall hemolysis rate was 12.5% (95% CI = 11.6% to 13.5%), 14.6% in blood drawn from IV catheters and 2.7% from butterfly needles (difference = 11.9%; 95% CI = 10.2% to 13.4%). Device was the strongest independent predictor of hemolysis (OR = 7.7; 95% CI = 4.9 to 12.0). In specimens drawn by IV catheter, hemolysis was significantly higher when blood was drawn from locations other than the antecubital fossa, with small-gauge catheters, collection tubes \leq half full, tourniquet time \geq 1 minute, and difficult venipuncture. In contrast, none of these factors was associated with hemolysis when blood was drawn by butterfly needle.

Conclusions: The device used to collect blood was the strongest independent predictor of hemolysis in blood samples drawn in the ED in this study. This finding suggests that the most effective strategy to reduce the rate of hemolysis in the ED is to use butterfly needles for phlebotomy rather than IV catheters.

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In vitro hemolysis is a common problem in blood specimens drawn in the emergency department (ED). Estimates of hemolysis rates in EDs in the United States vary markedly, ranging from 8.1%¹ to 32.0%.² All exceed the commonly referenced 2% best-practice benchmark rate of hemolyzed specimens

recommended by the American Society of Clinical Pathology.³

Previous investigations of ED phlebotomy have sought to identify remediable factors associated with in vitro hemolysis, including the role of straight needles (variably referred to as straight needles, butterfly

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needles, or steel needles) versus intravenous (IV) catheters,¹⁻⁹ the gauge of the IV catheter,^{1,2,4,6-8} use of vacuum tube collection system or syringe,^{2,4,6,7} extension sets,^{7,10,11} anatomic location of the phlebotomy,^{1,3,6,7,9} perceived difficulty of blood draw,^{6,9} specimen tube size,¹² fullness of the tube,^{4,7,9} and the method of tube delivery to the laboratory.^{13,14} The strongest finding was that the rate of hemolysis is higher when blood is drawn through IV catheters than through straight needles. Many of these studies are limited by small sample size, include only one or a small number of these factors, and most important, lack multivariable analysis to identify independent predictors.

The occurrence of a hemolyzed specimen can alter important laboratory results. Hemolyzed samples may require a second blood draw, which delays timely diagnosis and appropriate treatment.

The overall goal of this investigation was to identify the smallest number of independent remediable predictors of hemolysis among ED specimens so that targeted interventions would entail the fewest changes in phlebotomy technique for staff. The specific aim was to test the hypothesis that there is a strong independent association between hemolysis rate and phlebotomy device.

METHODS

Study Design

This was a prospective, observational, cross-sectional study. Blood specimens were collected from February 7, 2012, to March 19, 2012. The institutional review board of Albert Einstein College of Medicine performed an expedited review and approved the study. The requirement of obtaining written consent was waived.

Study Setting and Population

The study took place in the urban, academic ED of Albert Einstein Medical Center, a tertiary care center in Bronx, New York, with annual census over 100,000 adult patients per year. The population served is predominantly Latino and African American. Approximately 80% of the blood specimens are obtained by registered nurses, 15% by patient care technicians, and 5% by physicians, physician assistants, and nurse practitioners. Blood specimens drawn for a basic metabolic panel were included.

Study Protocol

Phlebotomy was performed by ED staff members during the course of providing clinical care. Neither additional phlebotomy training nor information about the study hypothesis was provided. Staff members could choose the device and size of needle. The person who performed the phlebotomy recorded study information about the blood draw on a standardized data collection instrument at the time of accessioning the blood specimens.

Blood was drawn through a butterfly needle collection set (BD Vacutainer, Becton, Dickinson & Co., Franklin Lakes, NJ), push-button blood collection set with 21 or 23-gauge butterfly needles, or catheter (BD Nexiva) closed IV catheter system—dual-port IV catheters (16, 18, 20, or 22 gauge), both attached to a BD

Vacutainer Luerlock access device holder with preattached multiple-sample adaptor into 8.5-mL BD Vacutainer tubes. The blood collection tubes were immediately sent to the laboratory by a vacuum-powered tube system. The specimens were processed in the hospital laboratory using the Roche Modular System (Roche Diagnostics, Indianapolis, IN).

Measures

The outcome measure was the rate of hemolysis, defined as the percentage of ED blood samples that were hemolyzed. Hemolysis is determined by measurement of free serum hemoglobin levels. A hemolysis index of 150 or higher was used to define hemolysis for this study. Hemolysis index values of 60 to 200 indicate moderate hemolysis and interfere with accurate measurement of potassium as well as creatine kinase, cardiac biomarkers, prothrombin time, D-dimer, lactate dehydrogenase, and glucose.¹⁵ Our hospital laboratory does not report potassium at or above a hemolysis index of 150 because this level of hemolysis increases potassium by 10% or more.

Characteristics of the blood draw recorded on the standardized data collection sheet by the person who drew the blood were device (IV catheter or butterfly needle), bore size of needle or catheter, site of blood draw (antecubital or "other"), tourniquet time (<1 minute or ≥ 1 minute), "difficult stick?" (yes/no), and amount of blood in the collection tube (< half full or \geq half full). The latter three characteristics were estimated by the staff member who performed the phlebotomy.

Data Analysis

We calculated the rate of hemolysis and the 95% confidence intervals (CIs) around the difference between rates. We used multivariable logistic regression to assess the independent association between each of the remediable characteristics of the blood draw and hemolysis. While difficulty of venipuncture is not a remediable factor, it was included in the multivariable regression analysis as it is a possible confounder. All variables were entered simultaneously into the regression equation. We also calculated the difference between rates and constructed 95% CIs around the difference for each device separately. SPSS version 19 (IBM SPSS, Armonk, NY) was used for all analyses.

RESULTS

Data were collected on 5,118 blood specimens. Data were missing on 1.2% of reports for difficulty of the venipuncture, 1.2% for anatomic location of venipuncture, 1.7% for length of time of tourniquet, and 8.5% for amount of blood in the collection tube. The analyses were conducted on 4,513 blood specimens for which there were complete data.

The overall rate of hemolysis was 12.5% (95% CI = 11.6% to 13.5%). The lowest rate of hemolysis was in specimens drawn by butterfly needle (Table 1). After controlling for difficulty of the venipuncture as well as for other characteristics of the blood draw, hemolysis continued to be strongly associated with device used to draw blood (Table 1). The odds ratio (OR) of hemolysis

Table 1
Rate of Hemolysis by Characteristics of the Blood Draw

Characteristic	N	% Hemolyzed	% Difference (95% CI)	Adjusted OR (95% CI)
Device				
IV catheter	3,727	14.6	11.9 (10.2 to 13.4)	7.7 (4.9 to 12.0)
Butterfly needle	786	2.7	—*	—
Site of blood draw				
Other site	1,353	19.2	9.5 (7.2 to 11.9)	2.1 (1.7 to 2.5)
Antecubital fossa	3,160	9.7	—	—
Needle/catheter size (gauge)				
14–18	373	7.8	4.6 (1.4 to 7.8)	†
20	2,922	13.9	10.7 (8.4 to 12.5)	
21	322	1.9	–1.3 (–3.6 to 1.0)	
22	432	25.5	22.0 (17.7 to 26.6)	
23	464	3.2	—	—
Fullness of collection tubes				
< half full	639	23.0	12.2 (8.9 to 15.7)	1.9 (1.5 to 2.4)
≥ half full	3,874	10.8	—	—
Tourniquet time				
≥1 minute	1,221	17.5	6.8 (4.5 to 9.3)	1.3 (1.0 to 1.6)
<1 minute	3,292	10.7	—	—
Difficulty of venipuncture				
Difficult	954	23.5	13.9 (11.1 to 16.8)	2.0 (1.6 to 2.5)
Not difficult	3,559	9.6	—	—

*— indicates reference group.
†Size of needle cannot be included in the multivariable analysis as size and device are perfectly collinear.

in specimens drawn through IV catheter compared to butterfly needle, 7.7 (95% CI = 4.9 to 12.0), was more than three times larger than the OR for any other characteristic.

Table 2 shows that none of the characteristics of the blood draw were associated with the rate of hemolysis in blood drawn via butterfly needle. In contrast, there were large differences in rates of hemolysis between blood drawn from different anatomic locations, bore size of the catheter, amount of blood in the collection tube, tourniquet time, and difficulty of the venipuncture when blood was drawn through an IV catheter.

DISCUSSION

This study confirmed the hypothesis that the rate of hemolysis is lower in blood specimens drawn through butterfly needle than through IV catheter. This result is consistent with findings from a recent meta-analysis that there is evidence of a strong bivariate association between hemolysis and blood drawn through straight needle (straight needle, butterfly, venipuncture) versus IV catheter.¹⁶ An estimated risk ratio of 0.16 (95% CI = 0.11 to 0.24) was calculated with IV catheter as reference group (i.e., OR = 6.3; [95% CI = 4.2 to 9.1] with

Table 2
Rate of Hemolysis by Characteristics of the Blood Draw Stratified by Device

Characteristic	N	IV Catheter, % Hemolyzed	% Difference (95% CI)	N	Butterfly Needle, % Hemolyzed	% Difference (95% CI)
Site of blood draw						
Other site	1,010	24.9	14.1 (11.2 to 17.0)	343	2.6	–0.1 (–2.4 to 2.5)
Antecubital fossa	2,717	10.8	—	443	2.7	—
Needle/catheter size (gauge)						
14–18	373	7.8	–17.7 (–22.5 to –12.6)			
20	2,922	13.9	–11.6 (–16.1 to –7.5)			
22	432	25.5	—			
21				322	1.9	–1.3 (–3.6 to 1.1)
23				464	3.2	—
Fullness of tubes						
< half full	535	27.1	14.6 (10.8 to 18.7)	104	1.9	–0.9 (–2.9 to 4.1)
≥ half full	3,192	12.5	—	682	2.8	—
Tourniquet time						
≥1 minute	999	20.6	8.2 (5.5 to 11.1)	222	3.6	1.3 (–1.1 to 4.8)
<1 minute	2,728	12.4	—	564	2.3	—
Difficulty of venipuncture						
Difficult	788	27.9	16.9 (13.7 to 20.3)	166	2.4	–0.3 (–2.5 to 3.4)
Not difficult	2,939	11.0	—	620	2.7	—

straight needle as reference). After a multivariable analysis was performed, the OR was 7.7 (95% CI = 4.9 to 12.0) in this study. The similarity of the ORs controlled and not controlled for difficulty of venipuncture as well as for other characteristics of the blood draw supports the inference that the association between device and hemolysis is independent.

Three studies of hemolysis in the ED used multivariable analyses. Ong et al.⁹ calculated an adjusted OR of 3.5 (95% CI = 0.9 to 13.2) for hemolysis from IV catheter versus venipuncture after controlling for nine characteristics of the blood draw. The magnitude of this association may be attenuated as size of needle was included in the analysis, dichotomized as ≤ 21 and >21 gauge. Tanabe et al.¹ found an adjusted relative risk of 6.7 (95% CI = 2.1 to 21.8; steel needle as reference) after controlling for anatomic site, clinical site (ED vs. labor and delivery), sex, and patient's age in 605 specimens. In contrast, although Burns and Yoshikawa⁷ found a strong bivariate association between device and hemolysis in a small study, after analytic control of anatomic site and amount of blood in the collection tube, the association was no longer statistically significant (OR not reported).

To the best of our knowledge, this is the first study to examine the association between characteristics of the blood draw separately for specimens collected by butterfly needle and IV catheter. For blood drawn through an IV catheter there is consistent evidence that the rate of hemolysis is higher when blood is drawn from anatomic sites other than antecubital^{1,6,7} and when smaller gauge catheters are used.^{1,4,6-8} In contrast, neither of these factors played a discernible role in altering the rate of hemolysis when blood was drawn through a butterfly needle in our study.

An intervention that only targets one behavior has a greater likelihood of succeeding than interventions that require multiple behavioral modifications. The findings from our study of an independent association between device and hemolysis suggest that changing the method for drawing blood from IV catheter to butterfly needle can reduce the rate of hemolysis without requiring any other modifications to phlebotomy method. This inference is supported by results from an interventional study that compared the hemolysis rate before and after initiation of a policy requiring use of a butterfly needle to collect blood for laboratory analysis.⁵ The investigators found the rate of all hemolysis fell from 23% in a 1-week observation period when blood was drawn via IV catheters to 6.6% in the 4 weeks after the change in policy.

There are substantial barriers to introducing a policy that requires both insertion of an IV catheter and a separate venipuncture to collect blood. While not specifically measured in this investigation, it is clear that there would be additional material costs of (minimally) one butterfly needle, skin prep set, and dressing per phlebotomized patient who also required an IV catheter. Additional labor costs would include the time to complete a full butterfly phlebotomy in the same population, multiplied by the hourly rate of the provider(s) performing this task. There would likely be significant staff resistance to a change from a single IV insertion/blood draw

process. Finally, there may be decreased patient satisfaction due to increased procedure time and multiple needle sticks.

We expect that solutions to implementation will involve use of lower-cost ED technicians to obtain some blood specimens in lieu of nurses, staff education, and scripting about quality of care to address patient expectations and satisfaction. There may be some patients who currently receive IV catheters but only need blood drawn; a more targeted approach might actually reduce labor costs and increase patient satisfaction.

Understanding the mechanisms that increase risk of hemolysis from drawing blood via IV catheter may provide alternative directions for prevention. One hypothesis is that the pliable nature of the catheter material may contribute to hemolysis, as it can collapse and crimp under the negative pressure of drawing blood.² Raisky et al.¹⁷ speculate that lubricants and solvents used to manufacture IV catheters can cause hemolysis through mechanical and chemical processes. Future developments in material science may allow the standard practice of drawing blood through an IV catheter to be used without the negative consequences of hemolysis.

LIMITATIONS

We did not collect identifying information about the phlebotomist; therefore, the analysis could not be controlled for possible differences between nurses, physicians, and technicians in both hemolysis rate and blood drawing device. Data from two other studies suggest that this potential bias is unlikely to affect inference, as they had similar findings to our own while only using experienced, trained nurses to draw blood.^{3,4}

We did not assess the severity of illness, age, sex, or other demographic characteristics of patients that may be associated both with device and risk of hemolysis. One study that used a multivariable regression to control the analysis for patients' age and sex found an OR of hemolysis in specimens drawn by IV catheter compared to straight needle to be similar to the OR in our study.¹

The investigation was performed in one urban, academic, adult ED in a tertiary care center. Phlebotomy training and practice may differ in other EDs, thus limiting generalizability. A further limitation to generalizability is the use of a single model of IV catheter and one butterfly blood collection set. Different materials used in the manufacture of IV catheters are associated with variable rates of hemolysis.^{8,17} Our findings may not directly generalize to catheters made by different manufacturers or with different materials.

CONCLUSIONS

The device used to collect blood is the strongest independent predictor of hemolysis in blood samples drawn in the ED. The findings suggest that the most effective strategy to reduce the rate of hemolysis in ED specimens is to use butterfly needles for phlebotomy rather than IV catheters.

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