Impact of Use of Smaller Volume, Smaller Vacuum Blood Collection Tubes on Hemolysis in Emergency Department Blood Samples

Article *in* American Journal of Clinical Pathology · October 2017

DOI: 10.1093/ajcp/aqx082

Impact of Use of Smaller Volume, Smaller Vacuum Blood Collection Tubes on Hemolysis in Emergency Department Blood Samples

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Key Words: Hemolysis; Emergency department; Small volume collection tube; Preanalytic

Am J Clin Pathol October 2017;148:330-335

DOI: 10.1093/AJCP/AQX082

ABSTRACT

Objectives: *Hemolyzed blood samples commonly occur in hospital emergency departments (EDs). Our objective was to determine whether replacing standard large-volume/high-vacuum sample tubes with low-volume/low-vacuum tubes would significantly affect ED hemolysis.*

Methods: *This was a prospective intervention of the use of small-volume/vacuum collection tubes. We evaluated all potassium samples in ED patients and associated hemolysis. We used χ^2 tests to compare hemolysis incidence prior to and following utilization of small tubes for chemistry collection.*

Results: *There were 35,481 blood samples collected during the study period. Following implementation of small-volume tubes, overall hemolysis decreased from a baseline of 11.8% to 2.9% (*P *< .001) with corresponding reductions in hemolysis with comment (8.95% vs 1.99%;* P *< .001) gross hemolysis (2.84% vs 0.90%;* P *< .007).*

Conclusions: *This work demonstrates that significant improvements in ED hemolysis can be achieved by utilization of small-volume/vacuum sample collection tubes.*

Optimizing emergency department (ED) efficiency is critical in our ever more crowded EDs. Many variables can affect ED patient throughput, one of which is the time required to report reliable laboratory values that aid physicians in clinical decision making. Hemolysis of laboratory specimens can delay this process, resulting in prolonged length of stay and decreased patient satisfaction.[1] Hemolysis is much more common in EDs than in inpatient settings,[2,3] with rates reported as high as 35%.[4-9] This is well above the best practice benchmark of 2% established by the American Society for Clinical Pathology.[2]

Importance

The additional resource utilization required to address hemolyzed ED specimens (repeat blood draws, repeat analysis in the laboratory) as well as potential delays in patient care and impact on patient satisfaction may be significant. Opportunities for process improvement can significantly affect ED hemolysis rates and therefore positively influence patient care. A recent meta-analysis identified seven preanalytic factors that can affect hemolysis.[4] One variable found to be a suggestive, albeit inconclusive, cause of hemolysis is the use of vacuum collection tubes and their size. Vacuum tubes are commonly used in EDs to obtain blood samples from intravenous (IV) catheters. Smaller vacuum collection tubes create lower vacuum pressures during specimen collection. Previous studies yielded conflicting results when examining the effect of various sizes of collection tubes on hemolysis.[4,5,10]

Goals

Our objective was to determine whether the use of smaller vacuum collection tubes would reduce hemolysis incidence in our ED blood samples.

Methods

Study Design and Setting

This prospective, interventional study was part of a larger performance improvement program aimed at reducing hemolysis in blood specimens obtained in an urban, tertiary referral ED with an annual census of 64,000 visits. Because this initiative was part of a quality improvement project, our institutional review board deemed it exempt from consent procedures.

Selection of Participants

All ED blood samples in which a potassium value was ordered during the study period were included in this analysis. Samples analyzed in the ED point-of-care laboratory were excluded from this analysis. Analysts maintaining the hospital's computerized laboratory information system (Sunquest, Tucson, AZ) created an automated, monthly query-generated report for the hemolysis index (HI) on all potassium results from specimens obtained in the ED at the start of the quality improvement project.

Interventions

Our usual ED practice was to obtain all blood specimens for electrolyte analysis using 6-mL, 13 × 100-mm Vacutainer collection tubes containing lithium heparin anticoagulant (Becton Dickinson, Franklin Lakes, NJ). Like many EDs, most blood samples obtained in our ED are drawn when an IV catheter is placed. These tubes were replaced with smaller volume/vacuum 2-mL, 13 × 75-mm Vacutainer collection tubes containing lithium heparin anticoagulant during two distinct periods of the study (see dates below). None of the usual practices for sample collection (handling, transportation, and analysis) were otherwise modified throughout the study period.

Methods and Measurements

We compared incidence of hemolysis in four distinct study periods. The first period (baseline) was prior to the first introduction of small tubes (January 1, 2015, to February 22, 2015). During the test period (February 23, 2015, to February 28, 2015), we removed all large-volume chemistry tubes and replaced them with the small-volume/vacuum collection tubes. During the third period (March 1, 2015, to August 24, 2015), coinciding with the initiation of several performance improvement projects focused on best practices and education to reduce hemolysis incidence, we removed the small-volume/vacuum tubes and reintroduced the large-volume tubes. For the fourth and final period (August 25, 2015, to December 31, 2015), the small tubes were reintroduced permanently as part of standard blood collection practice. Hemolysis was calculated based on the HI, a quality assessment measure determined for most routine chemistry samples in the automated chemistry laboratory. HI is measured quantitatively on the Cobas 8000 automated chemistry system (Roche Diagnostics, Indianapolis, IN). Analytic results from mildly or moderately hemolyzed specimens (HI 80-300) are reported with an accompanying comment, warning the clinician of the hemolyzed results. The laboratory appends a code, "HK," which generates the following comment with the result:

"This specimen is hemolyzed. Hemolysis artifactually increases potassium, magnesium, iron, folate, LD, and phosphorus results significantly above their true value. This result should NOT be used as a sole criterion for clinical decisions and potassium values above 6.0 will not be called as critical values."

Specimens with an HI of 300 or above are rejected, and the laboratory releases a "GHEMO" comment, indicating results will not be reported because of the presence of gross hemolysis.

Monthly hemolysis data were sent in an Excel (Microsoft, Redmond, WA) spreadsheet and evaluated and checked for accuracy by the principal investigator monthly.

Outcomes

The primary outcome was the overall incidence of hemolysis, which was defined as the proportion of samples with a potassium component that received an HK or GHEMO comment.

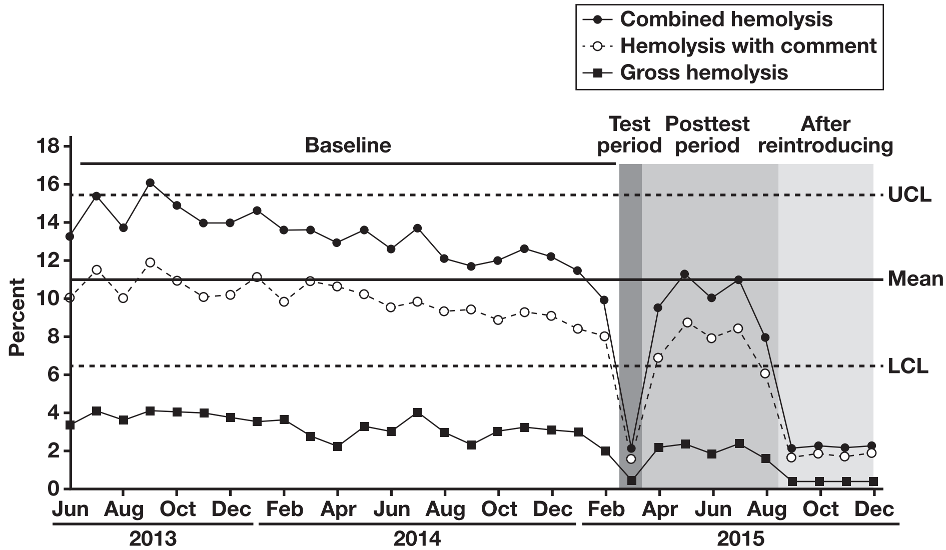
Analysis

We compared hemolysis incidence (HK, GHEMO, and HK + GHEMO) between the study periods using χ^2 tests. *P* values were reported based on a two-sided type I error probability of .05. All analyses were performed in SAS (v.9.4; SAS Institute, Cary, NC).

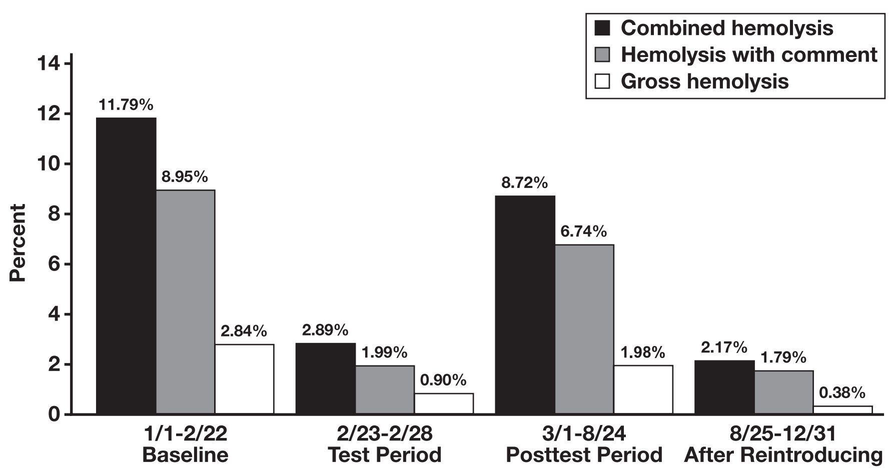
Results

Hemolysis was documented regularly and reported during the course of the study, as combined hemolysis (HK

DOI: 10.1093/AJCP/AQX082



▌Figure 1▌ Combined (hemolysis with comment + gross hemolysis), hemolysis with comment, and gross hemolysis rates. Hemolysis rates in emergency department–collected potassium laboratory samples: baseline, pilot study period (February 23-28), posttest period, and after reintroduction of small tubes on August 28, 2015, showing reduction and sustained reduction of hemolysis rate to about 2%. Control limits represent combined hemolysis. LCL, lower control limit; UCL, upper control limit.



▌Figure 2▌ Hemolysis rates during various periods: baseline, small tube test period, posttest period, and reintroduction of small tubes. Comparisons of combined ($P < .001$), hemolysis with comment ($P < .001$), and gross hemolysis ($P = .007$) between test period and baseline all statistically significant. Comparisons of combined ($P < .001$), hemolysis with comment ($P < .001$), and gross hemolysis ($P < .001$) between after reintroduction and baseline all statistically significant.

+ GHEMO) and individually (HK or GHEMO) ▌Figure 1▌. A total of 35,481 blood samples for potassium analysis were collected during the study period (January 1, 2015, to December 31, 2015) (Figure 1). The incidence of combined hemolysis during the baseline period was 11.79% (557/4,724; 95% confidence interval [CI], 10.9-12.7), of which 8.95% (423/4,724; 95% CI, 8.2-9.8) were hemolyzed with comment and 2.84% (134/4,724; 95% CI, 2.4-3.4) were grossly hemolyzed ▌Figure 2▌. After implementation of the use of small-volume tubes, the incidence of combined hemolysis (HK + GHEMO) during the test period was significantly lower in the small-volume tube group (11.79% vs 2.89%; $P < .001$), with significant reduction also found in the incidence of both hemolysis with comment (HK) (8.95% vs 1.99%; $P < .001$) and gross hemolysis (GHEMO) (2.84% vs 0.90%; $P = .007$) (Figure 2).

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Incidence of hemolysis increased significantly following the test period after reintroduction of large tubes ($P < .0001$) for each category of hemolysis (Figure 2). However, this period ("posttest period"), during which other performance initiatives were introduced, also had overall lower hemolysis than the original baseline period ($P < .001$ for HK + GHEMO, HK, and GHEMO) (Figure 2). After permanent reintroduction of the small tubes in period 4 ("after reintroducing"), hemolysis declined significantly relative to period 3 and the baseline period ($P < .001$) for HK + GHEMO, HK, and GHEMO (Figure 2).

Discussion

We found that replacing large-volume/vacuum specimen tubes with smaller volume/vacuum tubes for the collection of blood samples in the ED significantly reduced the incidence of hemolysis. These findings add to a growing body of evidence that the use of smaller, lower vacuum pressure collection tubes can result in significant reduction in hemolysis in the ED. Sixsmith et al[5] were the first to examine the effect of smaller collection tubes in relation to sample hemolysis. They reported a significant reduction, from 11.4% to 2.6%, with the use of low-vacuum tubes. Cox et al[11] also found a significant decrease, from 2% to 1.1% in hemolysis, when using 5-cc vs 10-cc vacuum tubes. Heileger-Duckers et al[12] and Giavarina et al[13] reported that hemolysis decreased by at least 50% with the use of smaller tubes.

Not all studies, however, have produced favorable results when switching to smaller tubes. Lippi et al[10] showed the opposite effect, reporting an increase in hemolysis after switching to 3.5-cc collection tubes from standard 5-cc tubes. Although the tubes used in Lippi et al[10] differed in volume, the vacuum pressures of the tubes were similar (120 vs 130 mm Hg).[14] This observation differs from those of Cox et al[11] and Heiligers-Duckers et al,[12] who reported that vacuum pressures varied nearly 30% between the various tube sizes (53 vs 75 mm Hg and 95 vs 130 mm Hg, respectively). These results suggest that tube volume may be less significant than vacuum pressure in causing cell hemolysis.

With lower vacuum pressures, the pressure gradient and velocity of blood flow into the collection tube are decreased.[15,16] The result is a decrease in shear stress on the cells, thereby reducing cell hemolysis.[16,17] Sharp et al[14] determined a time threshold at which blood flow and shear stress on cells will cause hemolysis. The higher vacuum pressures in the small tubes examined in Lippi et al[10] likely did not bring the velocity of flow and shear stress below this threshold to reduce cell hemolysis. This would also explain low baseline hemolysis in Cox et al,[11] as their 10-mL standard tubes already provided a low pressure of 75 mm Hg and might have already been below the required threshold. Further supporting the theory that the pressure gradient across the sample tube, rather than the volume of the tube, affects cell hemolysis, Ong et al[18] evaluated the effect of varying filling volumes within the same tube size and found no difference in hemolysis.

In addition, since the value for defining a specimen as hemolyzed is not standardized, each laboratory must determine what cutoffs are appropriate for its patients, analytes, and instruments. Some instruments offer a qualitative or semiquantitative indication of hemolysis, allowing further variance between laboratory practices.[19-21] Since numerous factors contribute to both the amount and detection of hemolysis, it is difficult to definitively resolve the discrepant findings that have been reported regarding the use of small-volume/vacuum tubes.

In our facility, the lower hemolysis incidence returned after reintroduction of small-volume/vacuum tubes at the end of August 2015 and has persisted. In the original study, the small-volume/vacuum tubes were removed after a 6-day trial period. Subsequently, hemolysis returned to a level similar to that prior to implementation. Coinciding with this period, we introduced several interventions (education for nurses and the use of certain paramedics to increase straight-stick utilization), targeting a reduction in hemolysis. Although hemolysis increased following the 6-day small-tube trial, it was somewhat lower than baseline prior to the study, which might be explained by these other interventions. However, in September 2015, we permanently reintroduced small tubes for collection, and hemolysis returned to the low levels observed during the trial period. This reproducible effect strengthens our conclusions (Figures 1 and 2). It should be noted that implementation of the lower volume tubes did not increase the incidence of "quantity not sufficient" samples. Because we had anticipated this as a potential problem, we requested an additional small tube (three small vs two large) when we switched to the smaller volume tubes.

Despite the growing body of research examining the causes of blood cell hemolysis and ways to reduce it, EDs continue to have high hemolysis. Hemolyzed specimens can lead to patient discomfort (through repeat blood draws), delays in care and ED throughput, and increased cost of care.[18,20] The two techniques identified in the meta-analysis by Heyer et al[4] as being highly effective in reducing hemolysis are the use of a straight stick to obtain blood samples and drawing from the antecubital vein, but these approaches are not universally used. Many studies have confirmed the reduced hemolysis associated with straight-stick blood draws,[6-8,18,20-22] although this practice results in two skin punctures ("pokes") if

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the patients requires IV access, increasing patient discomfort.[23] Patients in the ED also often require repeat blood tests and IV medications, which necessitate subsequent pokes. This is why it is common practice in EDs to place IV catheters initially and then draw blood samples using vacuum tubes. IV placement in the antecubital fossa has also been shown to reduce hemolysis, and because the vein in this area is large and easy to access, it should be considered the "first line" for blood sampling through an IV catheter, but practitioner preference and patient factors play a role in which vein is selected. There are practical barriers to adoption of these techniques, especially utilization of the straight-stick technique to draw blood, as this may result in a second skin puncture if an IV is required with resultant patient pain and discomfort.

The use of smaller volume/vacuum tubes appears to solve this problem by providing the benefit of significantly reducing hemolysis without increasing patient discomfort with a second skin puncture. Dietrich[23] described the dilemma of "one poke or two," noting that lower hemolysis can be achieved while using IV catheters, which suggests that low hemolysis can be achieved without the use of straight sticks. Our investigation of small tubes, with the resulting reduction in hemolysis, prompted us to consider the findings of a recent IV-drawn sample study with low hemolysis.[23] Our personal communication with Dietrich[24] revealed that, during his study period, he was also using small tubes but did not consider their effect on hemolysis. Heyer and colleagues[4] concluded that the existing evidence was not sufficient to support the association of lower hemolysis with small tubes. Our study provides strong evidence that hemolysis actually can be reduced in the ED setting with use of smaller tubes.[4]

Reducing the number of repeat blood tests and possibly decreasing ED throughput times because less time is spent on repeated testing may lead to cost savings for health systems. Hemolyzed samples, when considered on a national scale, can have a considerable impact, since each 1% increase in hemolysis is associated with an additional 300,000 laboratory samples and resultant delays in patient care, greater demands on laboratory processing, and an overall decrease in quality and efficiency.[25] Ong et al[18] estimated savings of more than \$500 per day and more than \$200,000 per year after implementing smaller collection tubes. In future studies, we plan to assess the effect of our lower hemolysis on patient satisfaction and financial performance.

There are several limitations worth noting. As this study was performed at a single urban tertiary center, results may not be generalizable to other settings. In addition, the analyses used a historical control (prior to interventions). We considered an analysis to evaluate the overall effect of introduction of small tubes. However, we determined that this comparison was somewhat inappropriate given that the follow-up periods (after baseline) included several different quality initiatives at different times, including the introduction of the small tubes, removal of small tubes, and other quality improvement initiatives. Thus, combining all of these data did not accurately estimate the effect of small tubes per se. Thus, we feel the current analyses with specific period comparisons were the most appropriate way to convey the results. While there were no other interventions that we are aware of occurring during the study period that could have affected hemolysis rates, we cannot exclude the potential that other secular changes in processes of care and technological components of laboratory methods contributed to results. A randomized controlled trial would be required to more rigorously assess a cause-and-effect relationship. Finally, we cannot exclude the effect of other potential confounding factors not collected for this study such as patient or provider characteristics or other processes of care.

Conclusion

Small-volume/vacuum collection tubes significantly reduced hemolysis among ED blood samples compared with the incidence associated with the use of large-volume/vacuum tubes. Any institution struggling with a high incidence of hemolysis that uses IV-obtained blood samples in the ED should consider implementing the use of smaller collection tubes in their sample collection protocol. The findings suggest a significant potential opportunity to reduce redundant pre- and postanalytical processes and health care expenditures associated with ED hemolysis.

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This study was funded by a cooperative agreement with the Centers for Disease Control and Prevention (CDC project number 5U47OE000053-02).

Acknowledgments: The manuscript was copyedited by Linda J. Kesselring, MS, ELS. We appreciate the help provided by nursing staff and paramedics in the main emergency department, especially paramedics Paul McClintock and Shawn Murphy.

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DOI: 10.1093/AJCP/AQX082