2013

Effect of Blood Collection Practices on Emergency Department Blood Specimen Rejection Rates

Barbara K. Vernoski

EFFECT OF BLOOD COLLECTION PRACTICES ON EMERGENCY DEPARTMENT BLOOD SPECIMEN REJECTION RATES

by

Barbara Klos Vernoski

A project submitted to the School of Nursing
in partial fulfillment of the requirements for the degree of

Doctor of Nursing Practice

UNIVERSITY OF NORTH FLORIDA

BROOKS COLLEGE OF HEALTH

March, 2013

Certificate of Approval

The project of Barbara Klos Vernoski is approved: Date: _____

_____
M. Catherine Hough, Committee Member

_____
Patrick Monaghan, Committee Member,

_____
Kathaleen C. Bloom, Committee Chairperson

Accepted for the School of Nursing:

_____
Lillia Loriz, Director, School of Nursing

Accepted for the College:

_____
Pamela S. Chally, Dean, Brooks College of Health

Accepted for the University:

_____
Len Roberson, Dean of the Graduate School

Dedication

I dedicate this paper to my parents, Jerry and Rosemarie, who viewed education as a life long investment and taught me anything was possible if I put my mind to it. Thank you for your love and support all these years; I love you both!

I am extremely thankful to my Chair and mentor, Dr. Kathaleen Bloom, for her guidance and stamina keeping me on task, and for refocusing me when I got derailed. I sincerely appreciate the many hours of personal time that Susan Depalma spent manually building the laboratory rejection rate reports that provided the data central to this study. I will forever be indebted to her for her unwavering contribution to this project. I am extremely grateful to my boss, Greg Miller, who supported my doctoral journey every step of the way, and to Patrice Jones, VP Patient Care Services and CNE, who helped facilitate a smooth and timely project start. I appreciate the guidance Berta Christopher provided me in navigating the IRB requirements, editing my submission, and getting my package through the IRB process while maintaining my sanity! I extend a special thanks to all of the ED staff who made this study possible; you are an awesome group of professional nurses and EDTs!

My success in this project and throughout all of my program studies is due in a very large part to my spouse, Ken, who was always coaxing me to refocus when I lost my way. And finally I thank my children Josh, Katie, and Nick for all of their support and encouragement from both near and far. You all were the anchor that kept me from drifting too far off course! I love you all!

Table of Contents

List of Tables

Abstract

The practice of obtaining blood as part of the placement of a new peripheral venous access device (p-VAD) is a frequent practice in the emergency department (ED). Of the concerns related to this practice is the possibility of laboratory specimen rejection due to p-VAD catheter size, use of the wrong collection device, and the absence of a standardized collection process. The objective of this study, therefore, was to examine the effect of the use of evidence-based venipuncture and p-VAD blood collection protocols on the rejection rate of blood specimens drawn by staff in the adult areas of an urban academic medical center ED.

A convenience sample of 28 ED nurses and 39 ED technicians (51.94% of all eligible ED employees) consented to using these evidence based protocols when they collected blood from adult ED patients. Blood specimen rejections rates were measured for four consecutive weeks prior to and at weeks 1-4, 5-8, 9-12, and 1-12 after the evidence-based blood collection practices training intervention. Laboratory analysis of all specimens was automated with rejection results provided in the form of computerized reports.

There was a significant decrease in the 12-week rejection rates for two of the three ED adult care areas, with the overall ED adult area rejection rate significantly decreased from 3.19% to 2.38% (X^2 at $Df_{1,}$ $p < .05$). The most common reasons for rejection were hemolysis (65.39%) and clotting (10.68%) followed by specimen mis-labeling, tube missing, insufficient quantity for testing, incorrect packaging, specimen contamination or dilution, and label missing, Though the use of theses evidence based blood collection protocols significantly decreased the overall rejection rate, the high percent of rejections due to hemolysis may further be reduced by having all ED staff use these protocols, and by exploring other collection techniques in the literature that have been found to significantly decrease rejection rates.

Chapter 1: Introduction

Blood specimens provide a window into the body's internal status at the time the sample is collected, making laboratory blood analysis one of several mechanisms used by Emergency Department (ED) providers, i.e. physicians, physician assistants and nurse practitioners, to diagnose and treat patients. With laboratory test results comprising about 80% of the information base used by clinicians in their treatment decisions (Boone, 2004), correct and timely blood specimen collection is integral to appropriate patient diagnosis and treatment. Working in direct opposition to obtaining high quality blood specimens is the over-crowded, high pressure ED work environment that demands rapid laboratory turnaround times leading to a "need for speed" atmosphere that fosters errors in blood collection, handling and transport processes caused by incorrect patient identification, specimen trauma, incorrect order of the draw, and inadequate mixing of the collected specimen tubes (Smith, 2007). These demands and errors can result in rejected specimens that require recollection and thus give rise to delayed treatment, extended ED stays, overcrowding, poor ED patient throughput, and provider, staff and patient dissatisfaction (Dugan, Leech, Speroni, & Corriher, 2005; Lowe et al., 2008).

The first phase of the laboratory testing cycle, the pre-analytic phase, begins with the written order for the laboratory test, identification of the patient, specimen collection and labeling, and ends with specimen transportation to the laboratory (Plebani, 2007). Blood specimen rejection rates in this phase have been the subject of many studies and remain an issue of concern with some studies finding up to 68.2% of all errors occurring in this phase (Plebani, 2006). Lippi, Guidi, Mattiuzzi and Plebani (2006) and Smith (2007) identified the absence of

standardized blood collection procedures as a key reason for the errors that continue to occur in the total testing cycle. The greater the number of personnel involved in specimen collection and the lower their adherence to specimen collection policies, the greater the opportunity for errors to occur in this phase. The pre-analytic phase, as it occurs in the ED, is the focus of this project.

Specimen rejection can increase staff dissatisfaction with laboratory services, result in blood specimen recollection, and extend patient ED lengths of stay in some cases up to 60 minutes (Stauss et al., 2012). The ED staff commonly believe the cause of specimen rejection lies with the laboratory and not with the ED member's blood collection process (Carraro & Plebani, 2007). Decreasing the incidence of blood specimen recollection rates can lead to shorter laboratory specimen turn-around-times (TAT) and ED patients wait-to-be-seen times thus facilitating more timely diagnosis, treatment and ED patient discharge (Fernandes, Walker, Price, Marsden & Haley, 1997).

Steindel and Howantiz (2001) reported the majority of ED providers are highly dissatisfied with laboratory TAT delays, believing these lead to treatment delays and increased ED lengths of stay. The facility that is the subject of this project has witnessed increased ED lengths of stay leading to a backlog in patient throughput, increased ED wait-to-be-seen times, overcrowding, and patients leaving the ED without being seen by a provider resulting in decreased ED patient volumes and revenue. The Clinical and Laboratory Standards Institute (CLSI, 2007), an internationally known center for clinical laboratory standards and accreditation, noted that laboratory TAT delays have been associated with errors occurring in the specimen collection, handling and transport steps of the laboratory pre-analytic phase, and with post-analytic phase results reporting. The institute further declared that non-analytic phase errors could best be prevented through the use of established processes that target error prevention.

The Institute of Medicine (IOM, 2000) listed medical errors as the eighth leading cause of death and proposed they can best be decreased by delivering care that is safe, timely, efficient, effective, equitable and patient-centered. In response to the Institute of Medicine reports, a Quality Institute Conference was held in 2003 that focused on improving patient safety. The attendees included the Centers for Disease Control and Prevention (CDC) and 41 partners in laboratory services. The conference identified improved pre- and post-analytic testing processes, development and use of a set of testing process core indicators, improved laboratory-clinician communication, improved laboratory practice and service surveillance, and the use of evidence-based best practices as ways to improve laboratory services safety and efficacy (Boone, 2004). In response to a call by the World Health Organization to provide test results that are timely and accurate, the Education and Management Division of the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC, n.d.) established a working group to focus on laboratory errors and patient safety. In support of the Institute of Medicine's call to decrease medical errors and an IFCC work group project to decrease laboratory errors through safer processes, the focus of this project is to determine if the use of evidence-based blood collection processes by ED staff will reduce the rejection rate of ED blood specimens.

Problem Statement

The clinical question posed by this study is: "In laboratory blood specimens collected by emergency department nurses and technician staff, will the use of evidence-based practice venipuncture and p-VAD blood collection practices by that staff decrease the ED blood specimen rejection rate?"

The current facility rate of rejected blood specimens is 2% with a rate of 4% in the ED compared to a 0.3% rate in the critical care units. Rejection rates in the critical care units are

hypothesized to be low due to the controlled nurse-to-patient ratio of 1:2 along with a less rushed patient care setting as compared to the ED. Limited laboratory phlebotomy personnel resources has restricted the assignment of laboratory technologists to the inpatient non-critical care areas leaving ED laboratory specimen collection in the hands of the nurses, emergency department technicians (EDTs), and to emergency medicine residents.

The vast majority of ED blood specimens are obtained as part of the insertion of a newly placed peripheral venous access device (p-VAD). Despite the higher rejection rates of specimens obtained from p-VADs as compared to venipuncture acquisition (Grant, 2003; Kennedy et al., 1996; Lowe et al., 2008), the staff view the p-VAD method as negating the need for an additional venipuncture, decreasing patient discomfort, and as a time saver for the staff charged with obtaining the blood specimen. Though all ED clinical staff are licensed to collect blood samples, the vast majority of laboratory specimens are obtained by the EDTs allowing the nurses to provide higher levels of patient care in an overcrowded ED.

The ED nurses are trained in blood specimen collection venipuncture and p-VAD techniques during their orientation by their nurse preceptor. The extent of the training is directly dependent on the nurse preceptor's knowledge, skills and experience base. Criteria to become a preceptor includes two years of emergency nursing experience, evaluation ratings of average or above average, ability to work well with others and no disciplinary actions within the last 6 months. Currently training is not guided by any specific policy or procedure, and no processes exist to verify nurse preceptor or staff nurse phlebotomy competency skills on a recurring basis.

The two experienced lead EDTs train and verify the EDT staff in blood specimen collection venipuncture and p-VAD technique competencies according to a skills competency checklist based on published blood collection techniques found in national nursing procedure

reference books. No process exists to validate the two lead EDTs blood collection skills. Training is provided to EDT staff during orientation and annually thereafter. Though a laboratory evidence-based practice venipuncture blood collection policy is available on the hospital's electronic information network, it has not been adopted by the ED staff. Neither an established hospital nor ED policy exists that governs blood specimens obtained via a p-VAD.

The high ED blood specimen rejection rates, the use of p-VADs as the primary source for obtaining blood samples, the absence of written ED blood collection policies, the failure of ED staff to follow the hospital's laboratory venipuncture policy, and the absence of annual skill competency assessment for all staff has led to exploring the use of evidence-based blood collection practices as a means to decrease pre-analytic phase blood specimen collection errors in the ED.

Purpose

The purpose of this study is to examine the effect of the use of two evidence-based practice blood collection protocols, the existing laboratory venipuncture protocol and the p-VAD protocol developed for this project, on the rejection rate of blood specimens drawn by staff in an urban academic tertiary care medical center ED. This study focuses on the ED portion of the laboratory test cycle pre-analytic phase which extends from the time the specimen is ordered until it is received in the laboratory for accessioning prior to analysis.

The project will compare blood specimen rejection rates in samples drawn after staff have been trained in the two evidence-based practice blood collection processes as compared to specimens collected by ED staff prior to training. The hypothesis to be tested is that there will be a decrease in the rejection rate of ED blood specimens drawn after ED staff have been trained in evidence-based practice blood collection practices. This project was approved by the

Institutional Review Boards located at the principal investigator's university and the hospital in which the study was conducted, and is in compliance with the federal Health Insurance Portability and Accountability Act (HIPAA) of 1996.

Definition of Terms

ED Staff

For the purposes of this study, ED staff refers to registered nurses, licensed practical nurses, and emergency department technicians. The registered nurses and licensed practical nurses are jointly referred to as nurses.

p-VAD

A p-VAD is a peripherally inserted venous access device that is typically placed in the patient's hand, forearm or antecubital area. The device may be in the form of an intravenous catheter with a continuous infusion, or an intravenous catheter saline lock device (SLD) in which the hub of the catheter has been capped with a port adapter that allows for intermittent infusions and blood collections. The latter is kept patent by an intermittent flush of normal saline. The location of p-VAD placement is usually left to the discretion of the staff member inserting it. For the purpose of this study, the blood collected will only be obtained from the SLD type of p-VAD as current ED protocol does not allow p-VADs with infusing fluids to be used for the collection of laboratory blood specimens.

The blood specimens included in this study are limited to those tests resulted through the main core laboratory information system and include, but are not limited to, hematology studies such as complete blood counts, coagulation studies including prothrombin time/partial thromboplastin time, chemistry studies such as basic metabolic panels and troponin levels, and blood specimens submitted to transfusion services. These tests comprise the bulk of all blood

ED collected for laboratory analysis with rejection rates automatically reported on a computer-generated report.

Order-of-Draw

The order-of-draw refers to the order in which the tubes are filled with blood. This sequence of blood tube collection was first identified in the late 1970s when the presence of additive carryovers into collection tubes was found to occur (Ernst & Calam, 2004). Established to prevent errors caused by the carryover of additives when multiple tubes are collected, it has been revised over the years to stay current with changes in collection tube additives. The current Clinical and Laboratory Standards Institute (2007) standard specifies blood tubes be filled in the following order-of-draw sequence: blood culture tube, light blue top, red top, green top (light or medium green), lavender, pink or white or royal blue, and gray.

Specimen Rejection

The term specimen rejection refers to specimens that the laboratory determines are unable to be analyzed or must be recollected due to, but not inclusive of, a wrong or missing patient label, an incompetent specimen container, inadequate specimen volume, hemolysis, and failure of the specimen to arrive in the laboratory (Dale & Novis, 2002). Hemolysis causes almost 60% of all rejected blood specimens (Lippi, Salvagno, Montagnana, Brocco & Guidi, 2006), and is defined as "the rupture of red blood cells with release of hemoglobin and other intracellular contents into the plasma that can alter laboratory test results" (Lowe et al., 2008, p. 27). Unless cancelled by the ordering provider, or found to be an actual duplicate specimen, hospital policy requires rejected specimens to be recollected. For the purpose of this study, a test specimen is considered rejected if the automated laboratory rejection report lists it as clotted, contaminated, diluted, hemolyzed, labeling missing or specimen mislabeled, too old to be analyzed, packaged

incorrectly (no on ice, specimens from two different patients in the same zip-lock bag), quantity not sufficient for testing, questionable results, tube empty or missing, and wrong tube for test submitted. Though a national hemolysis rate benchmark is available, no national benchmark for blood specimen rejection rate could be found in the literature. Some authors have identified rates as low as 0.28% to 0.62% in organizations focused on improving this metric with ED rejection rates from 2.2% to 27.4%, and as much as twice the rate of inpatient units (Shahangian & Snyder, 2009; Starke et al., 2007; Zarbo et al., 2002).

Training

Didactic training was the modality used to educate and train consented ED staff in the evidence-based blood collection practices. Training occurred in the ED conference room and included a video made by the principal investigator on the blood collection practices that employed the supplies currently used and available in the ED. Staff who orally consented to participate were then trained by the principal investigator. Training began with a discussion of the key blood specimen collection elements and related rationale and reinforced with the video. The session ended with participants verbalizing the venipuncture and p-VAD blood collection methods and their rationale to the principal investigator. Participants were determined to be competent when their responses were consistent with the evidence-based competency checklist. Every two weeks, for the first eight weeks post-intervention, newly reporting staff were given the opportunity to meet with the principal investigator and be orally consented to participate in this study.

Chapter 2: Review of the Literature

This chapter provides an overview of the literature related to factors influencing pre-analytic rejection rates of blood specimens collected from patients. The literature search strategies will be identified followed by an evaluation and synthesis of the evidence regarding evidence-based practices for blood collected from p-VADs that have shown to decrease specimen rejections rates in the pre-analytic laboratory phase. Over half of the literature reviewed focused on decreasing hemolysis as related to blood specimen rejection rates.

The CLSI is a voluntary consensus standards organization that has grown since its creation in 1967 to become a World Health Organization Collaborating Center for Clinical Laboratory Standards and Accreditation dedicated to improving healthcare quality through the development of best practice based clinical and laboratory standards. A review of the most current CLSI procedure for collecting blood specimens by venipuncture was obtained from the hospital microbiology clinical supervisor, reviewed and found to include evidence-based practice processes aimed at controlling for many of the errors previously mentioned (CLSI, 2007).

The Laboratory Specimen Total Testing Process

The total laboratory specimen testing process is comprised of the pre-analytic, the analytic and the post-analytic phases. Boone (2004) describes this process as follows. The pre-analytic phase begins with the treating provider developing the clinical question that leads to the identification and ordering of laboratory tests followed by specimen collection and transport to the laboratory. This phase ends in the laboratory after the specimen has been received, processed and prepared for analysis. The next phase is the analytic phase in which the specimen is

analyzed with the results interpreted and verified. The post-analytic phase is the final phase and is comprised of the formation of the results report, provider or originator results notification, provider's interpretation of the results, and subsequent follow-up treatment decisions.

Plebani & Carraro (1997) found the distribution of laboratory errors in these phases to be 68.2% in the pre-analytic phase, 13.3% in the analytic phase, and18.5% in the post-analytic phase. Thought the overall error rate decreased significantly in the replication study they conducted 10 years later, the error distribution changed little with rates listed as 61.9%, 15% and 23.1% for the phases respectively (Carraro & Plebani, 2007). Of the errors found, the initial study revealed 74% were preventable with 6% resulting in inappropriate treatment outcomes while the latter study revealed 73% preventable errors with 24% having a negative patient care outcome. Given its consistently high error rate, the pre-analytic phase is the phase most in need of improvement, and will be the focus of the remainder of this discussion.

Pre-Analytic Phase

Overall responsibility for and quality control of all the intra-ED variables in this phase lies entirely with the ED member collecting the blood. This phase begins with the written order for the laboratory test, correct patient identification, specimen collection, specimen container labeling and handling, and ends with specimen transportation to the laboratory (Plebani, 2007). Errors may occur anywhere in the pre-analytic phase and often result in rejected specimens - specimens that are not processed through to test result reporting. Errors in this phase may be heightened by the absence of an established blood collection policy, the failure of staff to adhere to one, or the lack of staff refresher training (Burns & Yoshikawa, 2002; Dugan et al., 2005).

Potential pre-analytic phase process errors include duplicate test orders from the same or multiple clinicians, incorrect patient identification by the person performing the blood specimen

collection, or mislabeled or unidentified specimens (Smith, 2007; Wagar, Tamashiro, Bushra, Lilborne, & Bruckner, 2006). The use of an existing peripheral intravenous line for blood collection, use of small fragile veins for a direct venipuncture, inappropriate catheter or needle size, vein trauma due to vigorous needle probing, failure to allow the puncture site skin to dry after cleansing, and excessive shear force when using a needle-syringe collection system are all associated with a higher level of rejected specimens (Becan-McBride, 1999; Bush & Mangan, 2003; Lippi, Salvagno, Montagnana, Brocco, & Guidi, 2006; Smith, 2007; Wagar et al., 2006).

Hemolysis of laboratory specimens is the most common cause of rejected specimens, responsible for 60% of all rejections (Lippi, Salvagno, Montagnana, Brocco, et al., 2006) and is due primarily to improper specimen collection and handling (Bush & Mangan, 2003). Errors commonly associated with hemolysis include the use of the wrong collection container, inappropriate specimen volume, failure to follow the order of draw, failure to adequately rotate the filled tubes to ensure thorough specimen-additive mixing, specimen trauma through vigorous shaking, contamination, improper handling, compromised collection container integrity, and improper transport from the time of draw to arrival in the laboratory (Becan-McBride, 1999; Bush & Mangan, 2003; Smith, 2007; Wagar. Tamashiro, Bushra, Lilborne & Bruchner, 2006).

Delays in pre-analytic specimen collection and transport to the laboratory may be attributed to increased patient care loads caused by high ED patient volumes or understaffing, the temporary absence of the patient who is out of the ED for diagnostic testing or delays in delivering specimens to the laboratory. The absence of an electronic health record (EHR) system may contribute to delays in locating paper healthcare records containing the laboratory test orders resulting in delayed order entry by clerical staff particularly during times of peak patient volumes. Inattention to detail and multi-tasking by overworked ED staff members may lead to

failures in following established blood collection procedures resulting in a variety of errors that could lead to specimen rejection.

Consequences of Rejected Specimens and Delayed Test Results

Rejected specimens carry with them consequences to the patient, to beside ED staff, to ED providers, to the laboratory, and to the hospital. This ED has seen the rejection and subsequent recollection of blood tests result in extending ED patient's length of stay up to three hours with the ordering provider having to wait this amount of time to finalize the patient's treatment plan. Recollection requires patients to undergo an uncomfortable second venipuncture, which carries with it the risk of infection inherent to any disruption of the skin's integrity.

ED staff are faced with having to interrupt their care delivery processes to recollect rejected blood samples. This additional unplanned workload can delay their care delivery, slow down ED patient throughput due to delayed discharges pending repeat laboratory analysis, and increase costs (Ong, Chan, & Lim, 2008). All of these consequences may in turn increase staff frustration with their workload and the laboratory, and lead to decreased work satisfaction. The time spent recollecting rejected specimens can leave ED provider staff frustrated and highly dissatisfied with the laboratory, believing the resultant care delays and longer patient lengths of stay are the fault solely of the laboratory staff (Steindel & Howantiz, 2001).

The hospital may be affected financially by rejected specimens and specimen collection inefficiencies that may lead to higher costs (Ong et al., 2008). With the advent of the Centers of Medicare and Medicaid Services (CMS) mandated Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS®) discharge survey, the facility is concerned that admitted ED patients may give the hospital low scores based on the recollection of blood specimens and subsequent prolonged ED stay. At 30 percent of the composite score, HCAHPS® directly

contribute to the hospital's final value-based purchasing score that determines federal healthcare CMS reimbursement dollars for hospitals (Lehman & Goldstein, 2012). A lower CMS reimbursement could be financially devastating for non-profit healthcare organizations. Additionally, the availability of these scores on the Internet enables prospective patients to use them in selecting where they want to spend their healthcare dollars. For facilities located in a hospital-rich community environment, low HCAHPS® scores could lead to a decline in their consumer base resulting in lower revenue generation and leaving the organization scurrying for ways to recover from these losses and still meet their budgeted bottom line.

Evidence Regarding Blood Collection Processes

An electronic review of the literature was conducted using the university library composite database of internal documents, ProQuest Health and Medicine, CINAHL, and the Cochrane Library using the following search terms: blood sample, blood draw, emergency department, hemolysis, pneumatic tube, phlebotomy, peripheral catheter, peripheral device, and saline lock. Articles were retained for analysis if they pertained to an ED or ED-like setting, had a study population limited to adult patients, focused on decreasing specimen rejection rates, addressed collection devices and methods (p-VADs and venipuncture), explored the use of discard blood volumes or use of pneumatic tube system specimen transport, and demonstrated sound statistical analysis. The strength of the evidence cited was rated according to the evidence hierarchy identified by Melnyk and Fineout-Overholt (2005) with the selected articles summarized in Appendix A. Following is a synthesis of the evidence-based best practices used to develop the resultant p-VAD blood collection policy.

IV Catheter Size

Several studies identified catheter size as a factor that significantly affected the viability of blood specimens submitted for laboratory analysis. Kennedy et al. (1996) conducted a randomized prospective study comparing the effect of various factors on blood hemolysis in specimens obtained two groups of adult ED patients. They compared hemolysis rates between blood specimens collected via direct venipuncture with a 21-gauge needle, the control group A, to those collected from peripheral intravenous catheters with a 12-ml syringe and an 18-gauge syringe-to-tube transfer needle, group B. The catheter gauges used in the study were 14, 16, 18, 20, 22, and 24, and were found to have respective hemolysis rates of 0%, 0%, 10%, 15%, 25% and 100%. A data regression analysis revealed a significant inverse correlation between the degree of hemolysis and catheter size. This study was categorized as a level-2 study as it contained a well-designed randomized control trial.

Burns and Yoshikawa (2002) conducted a concurrent observational study of 204 ED blood specimens collected by ED staff and was a weaker level-6 body of evidence due to its descriptive nature. Specimen hemolysis was found to be statistically higher in samples collected from 22-gauge peripheral intravenous (IV) catheters as compared to 20g catheters regardless of the collection device used or presence of extension tubing. Dugan et al. (2005) conducted a prospective observational study that examined blood collected by ED staff from newly inserted peripheral IV catheters in ED patients and revealed a level-6 hierarchy of evidence. A total of 100 observations were done that yielded 382 specimens. The findings revealed that blood obtained from peripherally inserted IV catheters 22-guage and smaller significantly contributed to hemolysis rates. The majority of these findings support eliminating blood collection through 22-gauge or smaller IV catheters as a means of decreasing rejection rates due to hemolysis.

The findings of these studies suggests that ED phlebotomists could experience lower hemolysis rates by obtaining blood samples through 18- to 21-gauge needles and IV catheters. Employing this evidence-based practice should lead to fewer specimen rejections.

Blood Collection Devices

Blood specimens are commonly collected from peripheral IV catheters using either a vacuum collection system, the most common being the Vacutainer® product, or a syringe-needless adapter or a syringe-needle collection system. Sharp and Mohammad (1998) estimated the former system contains a preset pressure vacuum of about 70kPa that allows the blood to flow directly into the blood collection tube. The latter system requires the phlebotomist to apply negative pressure to the syringe plunger to first draw the blood into the syringe and then inject the blood into the collection tube thus subjecting the blood to a second transfer.

Grant (2003) studied factors contributing to hemolysis in an academic medical center ED with staff being asked to submit a completed questionnaire with each specimen identifying the collection method and devices used to obtain the blood. This body of evidence is classified as a level-6 due to its descriptive observational nature. A total of 454 competed questionnaires and blood specimens were analyzed with samples obtained from an existing peripheral IV catheters (77) or a central lines (5), or new sites (372) via a newly place peripheral IV catheter (255) or direct venipuncture (117). Collection devices included peripheral IV catheter sizes of 14-gauge to 20-gauge, 21-gauge and 23-gauge venipuncture needles, 5-ml, 10-ml and 20ml syringes, and a Vacutainer® collection holder. The statistical analysis revealed a significantly higher hemolysis rate in blood obtained via a Vacutainer® device than from a syringe in newly placed peripheral IV catheters ($p < .02$). No analysis was done to determine if there was a relationship between syringe size and hemolysis.

Ong et al. (2008) conducted a level-6 evidence-based observational study of ED staff consultants, registrars, medical officers, nurses and medical/nursing students to determine factors associated with hemolysis of collected laboratory blood urea and electrolyte blood specimens obtained from ED patients. Staff were asked to complete questionnaires with each blood draw that addressed seven blood sampling related factors (staff type, draw method, collection system used, needle size, blood flow speed, difficulty of cannulation or venipuncture, and specimen source). A syringe of unspecified size was the collection system of choice for 146 (64%) draws with a Vacutainer® used for 81 (36%) draws. Of the 227 blood collections studied, staff overwhelmingly chose the IV cannula method (74%) over the direct venipuncture method (26%) to obtain blood specimens. The findings revealed a significant number of Vacutainer® draws hemolyzed (35.8%) compared to 11% of the syringe draws as evidenced by an OR 4.5, CI (2.3, 9.0).

The statistical significance of these studies indicate that hemolysis, which has previously been identified as a major cause of blood specimen rejection by the laboratory, was found to be higher in samples obtained from a peripheral IV catheter with a vacuum collection device as compared to a syringe-needle transfer system. Based on this, ED staff phlebotomists should use a syringe-needle system over a vacuum collection system when obtaining blood from an IV catheter.

Use of a Discard Volume

The practice of first collecting a discard volume of blood before obtaining specimens for analysis is strongly recommended by Lippi, Salvagno, Montagnana, Franchini, and Guidi (2006) as a method for improving laboratory test results. They contend that a discard volume, which is

an amount of blood evacuated from the catheter unit prior to sampling, decreases contamination of blood specimens by venipuncture-induced tissue and intravascular elements.

Himberger and Himberger (2001) studied blood specimens obtained from adult ED patients with peripheral intravenous lines as an alternate site to venipuncture that could produce viable laboratory results. This study was a well-designed non-randomized controlled trial and was consistent with a level-3 rating in the evidence hierarchy as defined by Melnyk and Fineout-Overholt (2005). Following an infusion of 100-ml of intravenous fluid, the infusion was stopped for 30-seconds, a tourniquet applied, and a 5-ml discard blood volume obtained. A 10-ml blood specimen was then collected with an 18-gauge needle adapter and 10-ml syringe device from the IV tubing port closest to the catheter hub. A second 10-ml sample was drawn with a 20-gauge needle and 10-ml syringe device via direct venipuncture from the opposite arm. All blood was transferred from the syringe to the collection tubes using an18-gauge needle. The findings revealed no significant statistical differences between the paired peripheral intravenous line and venipuncture blood specimen results.

Corbo, Fu, Silver, Atallah, and Bijur (2007) explored the use of a saline lock device as a viable alternate source for laboratory blood samples as compared to specimens obtained via venipuncture. Using each adult ED patient as their own control, a discard blood volume of 5-ml was aspirated from an existing saline lock device followed by three vacuum tubes collected via Vacutainer®. Three identical blood tubes were collected by venipuncture from the opposite arm with a Vacutainer® device. The analysis revealed no significant statistical differences in lab values collected from the saline lock as compared to the direct venipuncture method. This study was a non-randomized control trial that produced a level-3 hierarchy of evidence.

These study findings demonstrate that accurate laboratory results can be obtained from peripheral IV catheters by withdrawing discard blood prior to specimen collection for laboratory analysis. Based on these findings, and considering the variety of peripheral IV catheters in use, the design of saline locks, and IV tubing lengths that comprise the peripheral IV collection unit, the a universal discard volume of one 4.7-ml red vacuum tube, or 5-ml syringe volume, was selected as the standardized discard volume for the evidence-based p-VAD catheter blood collection protocol developed for this study.

Blood Specimen Transport

Transport of ED specimens to the laboratory can be accomplished either by hand carrying the samples or sending them by way of a pneumatic tube system. Fernandes, Worster, Eva, Hill, and McCallum (2006) examined the effect of two delivery systems, human couriers and the Translogic CTS-20 pneumatic tube system, on serum hemoglobin and potassium test result turnaround times. The test was conducted over eight days in two emergency departments in different locations within a multi-site tertiary care academic medical center. Using specimen hemolysis as the transport method outcome measure, no significant difference was found in hemolysis rates of specimens transported to the laboratory by human couriers as compared to those sent by the pneumatic tube system. Additionally, the turn-around time for the pneumatic tube system was found to be significantly less as compared to the human courier.

Wallin, Soderberg, Grankvist, Jonsson, and Hultdin (2008) studied the effect of a pneumatic tube system on blood specimens collected for hematology and coagulation studies from subjects who were given 75 mg of acetylsalicylic acid daily for 1 week. Comparing paired samples collected prior to and after one week of treatment, they found the transport of blood using a pneumatic tube system produced no analytical errors in 21 commonly ordered chemistry

and coagulation tests. Their analysis of global coagulation revealed a significant difference between pneumatic tube system blood specimen transport and the non- pneumatic tube system transported blood leading to the investigators recommending manual transport for blood requiring thromboelastographic analysis to ensure valid laboratory results.

Both of these studies were consistent with a level-3 hierarchy of evidence as they were well-designed non-randomized control trials. These studies suggest that pneumatic tube transport of blood specimens to the laboratory has a negligible effect on commonly ordered chemistry and coagulation test rejection rates.

Reliability of IV Catheters as a Source for Blood Specimens

Though the Clinical and Laboratory Standards Institute (2007) lists venipuncture as the current standard for collecting blood specimens due to related low specimen rejection rates, the studies presented above indicate that obtaining blood specimens from peripheral IV catheters can produce viable laboratory specimens when the evidence-based practices presented are followed. These include collecting or transferring blood through a needle or p-VAD catheter size of 18- to 21-gauge, using a syringe-needle rather than a vacuum collection system device, and obtaining a 5-ml discard volume prior to obtaining the blood sample. The transport of collected blood specimens via a pneumatic tube system has a negligible effect on specimen rejection rates.

Training in Blood Specimen Collection

Burns and Yoshikawa (2002) conducted a retrospective study to identify hemolysis rates in blood specimens obtained by ED staff as compared to laboratory phlebotomists. Their findings revealed hemolysis rates were significantly higher at 12.4% for trained but uncertified ED staff as compared to 1.6% for trained and certified laboratory phlebotomists who obtained blood from inpatient medical unit patients. Unfortunately no operational definitions were

provided for phlebotomists who were trained and those who were certified. Dugan et al. (2005) revealed that 36 months prior to their study, all ED staff had been trained in a revised blood collection policy in an effort to decrease the 25.7% ED blood speciment rejection rate. This training initiative led to the rate falling to 10.7%. However, over the course of 16 months it had increased to 19.5%. The authors attributed this to staff turnover, the absence of an annual training requirement, and no routine training of new staff. During the second phase of the study all participating ED staff followed a strict blod collection protocol resulting in the post-study rejection rate significanlty dropping to 12.4%. Based on this, the authors stressed that mandatory staff annual retraining and quarterly new staff training in established blood collection techniques, and consistent staff adherence to those protocols was key to achieving and maintaining low specimen rejection rates.

The results of studies on the effect of blood collection techniques on ED laboratory test hemolysis rates have led several authors to identify the use an evidence-based practice blood collection protocol by trained staff and regular checks of this skill competency as ways to decrease hemolysis and thus overall rejection rates (Dugan et al., 2005; Lowe et al., 2008).

Summary

The intent of the study is to examine the use of evidence-based blood collection practices. Given that no formal ED policy or procedure exists for the collection of blood specimens, consented ED staff will be trained to collect blood according to the hospital's existing laboratory department's evidence-based practice venipuncture procedure, and a newly developed p-VAD collection technique that is based on the evidence presented in this chapter (see Appendix B).

Chapter 3: Design and Methodology

This chapter provides a description of the design, setting and sample for the project. This is followed by an overview of the current blood collection processes and a new evidence-based p-VAD blood collection procedure and ends with a discussion of the methods and procedures for the study.

Design

The study design is a single group pretest-posttest with the study group comprised of a single group of consented ED nurses and EDT staff members. The intervention is the education of all study group members in the hospital's existing evidence-based venipuncture and a new p-VAD evidence-based blood collection techniques, the latter that was developed by the principle investigator specifically for this project. The design allows for the comparison of a 4-week pre-intervention rejection rate to three consecutive 4-week post-intervention rejection rate intervals and a total 1-12 week post-intervention rejection rate interval as noted in the following design description:

NR	O_1	X	O_2	O_3	O_4	O_5
Non-Random	pretest	intervention	post-test			

Setting and Sample

The setting for this project is a combined 69-bed adult ED comprised of a 22-bed critical care area, and a 14-bed clinical decision unit (ECC), a 15-bed flex care unit area inclusive of 2 single isolation rooms (EFX), and a 16-bed adult admission holding area (EIA) located on the ground floor of a 695-licensed bed urban academic medical center in the Southeastern United

States. Situated in the lower socioeconomic area of the city, the combined adult ED sees an average of 63,000 patients annually and is staffed by 83 nurses and 46 EDTs.

The sample is comprised of blood specimens, excluding blood cultures, ordered by emergency department providers as part of the patient's normal course of treatment and reported out by the main core laboratory information system. Blood obtained either by peripheral venipuncture or from a p-VAD in adult patients over the age of 18 years served as the study specimens. On average 13,688 blood specimens are collected monthly from adult ED patients, with the vast majority obtained for hematology, coagulation, and chemistry testing.

Blood specimens collected from patients located in the Pediatric ED and the Trauma Center are excluded from this study. This study did not target any specific patient population for blood specimen collection.

Current Blood Collection Practices

Adult ED blood specimens are collected primarily by the EDT staff, with a lesser number collected by nurses and even fewer by emergency medicine residents. Though there are no written procedures or specified blood collection procedures that guide blood collection in the ED, the nurses and EDTs undergo training as outlined in chapter one. Since the vast majority of patients in the adult ED are ordered to have a p-VAD placed, common practice is to obtain ordered blood specimens through newly placed p-VADs. The venipuncture collection technique is used mainly for patients who are not ordered to have a p-VAD, when attempts at placement and obtaining blood from an established one are unsuccessful, for specimen recollection due to initial specimen rejection, or for blood culture studies.

The anatomical sites commonly used by staff to obtain blood from adult patients are the back of the hands, the forearms, and the antecubital fossa. The venipuncture technique employs

the use of a 21-gauge winged butterfly needle with pre-attached 12-inch tubing connected either to a Vacutainer® holder, into which blood collection tubes are placed, or to a 12-ml syringe that requires the operator to manually withdraw the blood and then transfer it into the collection tubes using a 20-gauge blunt transfer needle. The tubes are collected in an ED specified order-of-draw which differs from the long established order of draw identified by the CLSI. Each collection tube is removed once the internal vacuum has ceased drawing blood into it. Based on the ED staff phlebotomist's assessment of the patient's vasculature, a 23- or 25-gauge butterfly needle may be used to access smaller veins.

The p-VAD blood collection technique used begins with the placement of an 18-gauge 1.25-inch long, a 20-gauge 1-inch long, or 20-gauge 1.25-inch long polyurethane peripheral IV catheter with staff encouraged to place an 18-gauge catheter whenever possible. Once the catheter is positioned securely in the vein the majority of staff attach a 10- or 12-ml syringe directly to the catheter to collect the blood samples. Some staff elect to first place a luer-lock port on the end of the catheter and then aspirate the blood into a 10-or 12-ml syringe using a 17-gauge plastic cannula needless adaptor and then transferring the blood into the collection tubes using a 20-gauge blunt transfer needle. Most staff prefer not to use a vacuum collection system citing that the veins appear to collapse under the vacuum suction exerted by the collection tube making it more difficult to obtain the blood sample. Once all specimens are obtained, a luer-lock port is attached to those catheters without one, the port is flushed with 5-ml of sterile normal saline, and the p-VAD is dressed. The draw volumes for the majority of the blood tubes used for non-specialized blood study specimens range from 2.7 ml to 4.0 ml. The principal investigator was informed by consented staff during the training sessions that it was common practice for staff to collect a rainbow series of blood tubes from newly placed p-VADs prior to laboratory orders

being written. Staff then held the specimens until the orders were written, which averaged 60-90 minutes, before sending them to the laboratory for analysis.

In cases where blood is collected from an existing p-VAD, the device is first flushed with 5-ml of normal saline to check for patency and followed immediately by the withdrawal of 10-ml of blood with the same syringe prior to blood sample collection for laboratory analysis. The samples are then collected as mentioned above. All p-VADs are routinely flushed with 5-ml of normal saline once every 12-hour shift, and whenever blood is obtained or medications are administered through them.

Discussions with senior EDTs who either instruct new EDT staff in blood collection techniques or have over 10 years blood collection experience, identified that current collection techniques do not address the need to limit tourniquet time to less than one minute, to allow the cleansed skin to dry prior to puncture, to limit the size of catheters and needles used to 18- to 21-gauge, to limit the size of blood collection syringes to no larger than 10- to 12-ml, to rotate the filled blood tubes 8-10 times to mix the blood and tube additives, and to follow the correct order-of-draw specified by the Clinical and Laboratory Standards Institute (2007).

The commonalities among the venipuncture techniques currently taught to ED staff and the hospital's evidence-based venipuncture process include verification of the provider ordered test(s), bedside patient identification using two patient identifiers, appropriate skin cleansing with an antimicrobial agent, use of universal precautions and gloves, application of pressure to and bandaging of the puncture site post venipuncture, proper bedside labeling of collected blood tubes inclusive of the time and date drawn and the phlebotomist's initials, placement of the specimens in a biohazard bag, and the placement of the bag into a cushioned pneumatic system transport tube.

Laboratory specimens are commonly transported to the laboratory accession area via the TransLogic CTS pneumatic tube system with a small number being hand delivered by a staff member. The ED staff report using rolled towels or other linen rather than the foam liners available from the PTS vendor to cushion the specimens placed in the PTS tubes because the foam liners are missing from the returned tubes within days of their being delivered to the ED. All laboratory studies ordered on ED specimens are of a STAT priority requiring tests results to be available within one-hour of the specimen being received in the laboratory. The laboratory employs auto-verification for all of the test results studied for this project.

Though the residents receive no formal blood collection technique training, they do receive training from the ED attending physicians or other residents at the bedside as they are collecting the blood. The content of the training is unknown.

Evidence-based p-VAD Blood Collection Procedure

Currently no written policy exists for the ED, the laboratory, or the hospital to guide the collection of blood from a p-VAD. The ED staff use p-VADs as the source of blood collection regardless of the catheter size, do not routinely obtain a discard volume from p-VADs, aspirate blood using either vacuum collection or syringe-needle transfer systems, commonly use 20-ml syringes to withdraw laboratory blood specimens, do not follow the correct blood tube order-of-draw as specified in the hospital venipuncture policy, and transport blood in un-cushioned tubes when cushioning is not available. Over the time of this project, there was great emphasis by the ED to correct their high blood culture contamination rates by following an existing laboratory blood culture collection protocol. This initiative originated in the ED-Laboratory Nurse Council and led to the addition of a discard volume and a shift to using syringe-needle collection devices about six months prior to the start of this study. These changes may have contributed to the

decrease in the original 4% ED rejection rate mentioned in chapter one to the 3.19% rate identified in this study's pre-intervention period.

Based on the absence of a p-VAD blood collection policy for the ED and the evidence presented in the previous chapter, the policy described in Appendix B was developed. Emergency Department p-VAD blood specimens obtained following this policy are less likely to be rejected if the phlebotomist collects the blood only from an 18-guage to 21-gauge size p-VAD by withdrawing an initial 5-ml discard volume, then collecting the blood specimen using a 10- to 12-ml syringe, and transporting the specimen in a pneumatic tube with internal cushioning in a timely manner.

Methods

Subject Recruitment

The principal investigator met with the ED nurse director and nurse managers to explain the project, ED staff participation, and answer questions to ensure they have a clear understanding of this study. Two weeks prior to the start of the training, flyers announcing the study project and information sessions further explaining it, were posted throughout the staff only ED areas. Staff were verbally informed by the nursing director, nurse manager or the shift charge nurse of the study project during the daily day and night shift change-of-shift huddles.

The nurse manager or shift charge nurse assigned staff members to attend the information sessions to ensure all nurses and EDTs had an opportunity to learn about the study. The information sessions were scheduled for 5:30 a.m. and 8 a.m. with attendance contingent on workload acuity. Once in the study information session, the principal investigator explained the study specifics by reading from the informed oral consent form and answering questions.

Staff desiring to participate were consented, asked to anonymously complete the Participant Demographic Questionnaire for the purpose of identifying the participant group's characteristics (see Appendix C), and personally placed their completed form in a sealable collection device prior to the start of training. Participants who declined to complete the form were asked to strike through the form and place it in the collection device. The participants then underwent the training as outlined below with the collection device carried back to the office by the PI for data entry and placement in locked cabinet. Staff members not consenting to participate were excused and asked to leave all study related documents behind before they left the room.

Intervention Plan

All training was provided by the principal investigator for the purpose of maintaining consistency in the information presented. Training occurred in the ED conference room using the same blood specimen collection and IV supplies available in the clinical setting. An ED Competency Checklist was developed and listed key evidence-based venipuncture and p-VAD blood collection practices that were central to the collection of healthy blood specimens (see Appendix D). The principal investigator first reviewed it with each group of participants and explained the rationale for each competency listed. This was followed with a review of a training video made by the principal investigator and ended with the participants' correctly verbalizing the key evidence-based practice collection steps for each collection technique. Once this step was finished and all participant questions were answered, the principal investigator provided each participant with a full and downsized competency checklist to use as a reference. New staff would also be offered the opportunity to participate in this study during their ED orientation. Their recruitment and training mirrored that outlined above.

Laboratory Analysis

The ED blood specimen tubes arrived in the laboratory accession area primarily by pneumatic tube transport with a small number being hand delivered. Upon arrival a laboratory technician removed the specimens and related documents from the pneumatic tube, inspected specimen container integrity, and verified the presence of a patient identification label. The laboratory staff then validated the labeled specimens matched the test orders found in the electronic medical record to ensure the specimen patient label matched the patient for whom the test was ordered, the correct tubes were submitted, and that tubes arrived correctly packaged. Specimen tubes not meeting accession requirements were removed from further analysis and listed as rejected with the ED notified of the rejection and the need to recollect the specimen. The remaining blood tubes were placed in an accession bin from which a laboratory technician entered label information into the electronic laboratory information system database. All specimens were placed in staging racks and delivered to their respective analysis stations.

Hematology specimens were analyzed on the Sysmex® HST Line with two XE-5000 analyzers obtained from Sysmex America, INC in Mundelein, IL. A laboratory technologist loaded the specimens into sample racks and then into the analyzer. Equipment quality control checks were conducted every eight hours. Specimens for coagulation testing were analyzed on the STA Compact® Hemostasis and STA-R Evolution® Systems obtained from Diagnostica Stago Inc. The laboratory technician visually inspected each tube for the correct blood volume and rejected those that were under-filled. The technician then removed the tube stopper and rimed the interior of each tube with two side-by-side thin wooden applicator sticks to visually check for clots. Specimens that were positive for clots were rejected with all others recapped, centrifuged, and then placed into the analyzer for testing.

Based on the chemistry test ordered, these specimens were placed into either the Roche Modular Cobas® 6000 or Roche Modular Cobas® 8000 analyzer modular pre-analytic system (MPA) rack obtained from the Roche Diagnostics Corporation of Indianapolis, Indiana. Once filled each MPA rack was placed onto the MPA machine's core transport conveyor belt where it automatically and sequentially moved through a test selection sorter, an automatic centrifuge, a de-stopper to remove the tube cap, an online aliquoter, an automatic labeler for secondary sample tubes if ordered, and placed into sample sorting trays based on tests ordered prior to being sent on for final test analysis. This process took anywhere from five to fifteen minutes depending on the volume of chemistry specimens arriving for analysis. Test values within the normal pre-established ranges were automatically sent from the analyzer to the laboratory information technology interface system. Test results outside of the accepted range were automatically rerun and auto-verified by the analyzer.

Quality control checks were performed as required on all laboratory analyzers with results within acceptable ranges. All test results for this study were automatically uploaded by respective analyzers into the laboratory interface system data base that pushed the data to a laboratory-to-electronic medical record interface for viewing in the respective patient's health record by ED staff. Results analyzed as rejected or outside of the normal ranges were reported as abnormal and immediately called to the ordering ED provider or nurse by a laboratory technologist.

Data Collection

All study results data were manually extracted by the core laboratory manager and provided to the principal investigator either semi-monthly or monthly based on the supervisor's workload requirements. The ED rejection reports were broken down by 24-hour period

extending from 00:01 a.m. to 24:00 p.m. and listed the area of the ED from which the specimen was obtained, the laboratory specimen identification number, the test name, the rejection code and reason, and the date and time the specimen was analyzed as rejected. These reports were sent electronically to the principal investigator who moved them into a designated project file on the hospital's secure IRB research drive. The PI then quantified the data and entered it into a separate spreadsheet for final data analysis.

Summary

The study flowed as planned over a 19-week period and was completed on time. The support of the ED nurse managers and shift charge nurses in ensuring staff attended the study information sessions was commendable and contributed to the number of staff who consented to be study participants. The core laboratory manager and technical support staff team created and delivered rejection rate reports within two weeks of the end of the previous month thus enabling the principle investigator to maintain a steady flow of data input into the master data analysis spreadsheet.

Chapter 4: Results

This chapter provides the findings of this study to determine if the use of an evidence-based practice p-VAD blood collection process by staff would decrease ED blood specimen rejection rates. A description of the participant demographics, the study intervention and data analysis is followed by the study results.

Participant Demographics

A total of 83 nurses and 46 EDTs working in the adult ED care areas were eligible to participate in this study. Forty-two nurses (50.60%) and 45 EDTs (97.83%) with a total of 87 (67.44%) eligible staff attending the study information sessions. The final participant group was comprised of 28 nurses (41.79%), and 39 EDTs (58.21%) for a total eligible staff participation rate of 51.94%. One reason for the lower numbers among the nurses may be attributed to a frequently heard comment from nurses that EDTs collected their patients' blood so they saw no reason to participate. The EDT participants were very engaged during the training sessions and voiced an eagerness to adopt practices that could decrease rejection rates. Collectively 34.33% of the participants had been in their profession for less than 2 years with 41.79% employed in the current ED for that same time period (see Table 4.1).

The majority (67.86%) of the nurses entered nursing with an associate degree in nursing and four (14.29%) held nursing practice certifications relevant to emergency nursing. Thirty-four (87.18%) EDTs were educated as either emergency medical technicians or paramedics. All EDTs are required to hold certification as a pre-requisite to hire. Ten EDTs (25.64%) held dual certifications while one held three (see Table 4.2).

Table 4.1

Work Experience of Participants

Category		Total Participants	# RN (N = 28)	% RN	# EDT (N = 39)	% EDT
Time in Current Profession	< 2 yrs	17	1	1.49%	16	23.88%
	2-4 yrs	19	7	10.45%	12	17.91%
	5-10 yrs	19	12	17.91%	7	10.45%
	11-15	3	2	2.99%	1	1.49%
	> 15 yrs	9	6	8.96%	3	4.48%
Time worked in EDs	< 2 yrs	23	7	10.45%	16	23.88%
	2-4 yrs	20	7	10.45%	13	19.40%
	5-10 yrs	16	8	11.94%	8	11.94%
	11-15	6	5	7.46%	1	1.49%
	> 15 yrs	2	1	1.49%	1	1.49%
Time worked in current ED	< 2 yrs	28	11	16.42%	17	25.37%
	2-4 yrs	20	9	13.43%	11	16.42%
	5-10 yrs	14	5	7.46%	9	13.43%
	11-15	5	3	4.48%	2	2.99%
	> 15 yrs	0	0	0.00%	0	0.00%

Note: RN = Registered Nurse; EDT = Emergency Department Technician

Study Intervention Completion

Based on the recommendations of the ED nurse director, a consecutive 18-day training period was set aside during which a one-hour study introduction and training session was scheduled twice daily at 5:45 a.m. and 8:00 a.m. These times were determined best for the staff who worked 12-hour shifts that began at either at 6:45 a.m. or 6:45 p.m. The principal investigator flexed start times by up to 60 minutes at the request of the shift charge nurses based on patient care workload demands. Shift charge nurses requested 11 of the total 36 sessions be cancelled due to high workloads that would not allow staff to attend. Though each shift patient care assignment sheet identified staff to attend study sessions, no staff members reported to four of the remaining 25 sessions resulting in a total of 21 staff sessions provided. Two additional sessions were offered to four new staff members, one in week six and the other in week eight. None of the new staff hires elected to participate.

Table 4.2

Education and Certifications of Participants

Participants	N	%
Registered Nurses	28	
Entry Level RN Education		
Associate Degree in Nursing	19	67.86%
Bachelor of Science in Nursing	7	25.00%
Other – not specified	1	3.57%
No response	1	3.57%
Certifications[1]		
Certified Emergency Nurse	2	7.14%
Certified Pediatric Emergency Nurse	1	3.57%
Certified Critical Care Nurse	0	0.00%
Trauma Nurse Core Course Certification	1	3.57%
Emergency Department Technicians (EDT)	39	
Entry Level EDT Education		
Emergency Department Technician	4	10%
Emergency Medical Technician	19	49%
Paramedic	15	36%
Other – not specified	2	5%
Certifications and Degrees[2]		
Emergency Department Technician	4	10.26%
Emergency Medical Technician	26	66.67%
Paramedic	21	53.85%
Associates Degree	4	10.26%
Other – not specified	4	10.26%

[1]One RN participant held 2 certifications for a total of 4 (14%) certified RNs.
[2]Ten EDT participants held 2 certifications and one held all 3 certifications.

Though it was planned that participants would provide successful return demonstrations for venipuncture and for IV catheters blood collection, the consistently high ED workloads allowed the participants to be absent from their work area no more than 40 minutes leaving 20 to 25 minutes for training. As a result, the principal investigator focused training on the evidence-based skill competencies that were new to current ED collection practices, i.e. importance of limiting p-VAD specimens to 18- to 21-gauge catheter sizes, the use of a 10- to 12-ml collection syringe, use of a syringe-needle collection system over a vacuum collection system for p-VAD collections, initial aspiration of a discard volume using either a 4.7-ml red top tube or syringe

withdrawal of 5-ml of blood, and the placement of interior pneumatic tube cushioning for the blood tubes. Additional emphasis was placed on adhering to the correct order-of-draw as specified in the hospital's existing evidence-based practice venipuncture blood collection policy. The ED Skill Competency Checklist form (see Appendix D) was used to ensure the participants correctly verbalized the evidence-based collection processes with portions of the training video shown to reinforce key evidence-based practice points. Upon completion of the training, each participant was given a copy of the checklist as a reference and asked not to share it with non-participants as a means of maintaining study integrity. All participants were directed to begin using the evidence-based blood collection techniques immediately. Since no identifiable participant data was collected for this study, it is unknown how many participants may have left the ED during the study period.

Data Analysis

Pre-intervention and post-intervention data were compared using the chi-square method and the Microsoft© Excel 2008 program. To reach the goal of rejecting the null hypothesis with a probability level of .95 and a $p < .05$, the chi-square was calculated at one degree of freedom and had to be greater than 3.841 to reach significance.

The minmum sample size of analyzed tests needed to detect a significant change in the rejection rate of ED blood tests and reach a power level of 95% for any of the three post-intervenion periods as compared to the pre-intervention period, was determined to be 1,900 analyzed tests per 4-week period for a total of 7,600 tests. The final sample size of ED tests analyzed ranged from 16,490 to 17,279 per 4-week period for a total of 67,691 ED tests. Of the 17,279 pre-intervention test ordered for 225 patients, 552 (3.19%) were rejected while 1199

(2.38%) of the 50,412 post-intervention tests ordered for 512 patients were analyzed as rejected. (see Table 4.3).

Table 4.3

Pre- and Post-intervention Specimen Data

Location	Weeks	# Patients	Rejected Specimens	Accepted Specimens	Rejection Rate
Total ED Adult Areas					
Pre-intervention	1-4†	225	552	16,727	3.19%
Post-intervention	1-4	135	347	16,678	2.04%
Post-intervention	5-8	189	443	10,047	2.69%
Post-intervention	9-12	188	409	16,488	2.42%
Post-intervention	1-12	512	1,199	50,412	2.38%
ED Critical Care Area					
Pre-intervention	1-4†	162	393	11,314	3.36%
Post-intervention	1-4	94	249	11,418	2.13%
Post-intervention	5-8	135	331	11,162	2.88%
Post-intervention	9-12	137	311	11,241	2.69%
Post-intervention	1-12	366	891	33,821	2.57%
ED Flex Care Area					
Pre-intervention	1-4†	36	81	3,952	2.01%
Post-intervention	1-4	32	74	3,931	1.85%
Post-intervention	5-8	28	46	3,636	1.25%
Post-intervention	9-12	38	69	3,771	1.80%
Post-intervention	1-12	98	189	11,338	1.64%
ED Inpatient Admit Area					
Pre-intervention	1-4†	27	78	1,461	5.07%
Post-intervention	1-4	9	24	1,329	1.77%
Post-intervention	5-8	26	66	1,249	5.02%
Post-intervention	9-12	13	29	1,476	1.93%
Post-intervention	1-12	48	119	4,054	2.85%

†Data are missing for one full day.

A total of four 4-week data periods were collected and compared. The data periods included a 4-week pre-intervention interval, three post-intervention 4-week periods comprised of weeks 1-4, 5-8, and 9-12, and 12-week post-intervention composite period. Each week was measured from Monday through Sunday so both weekend days were in the same measurment week. The first 4-week period was immediately prior to the 18-day education intervention session, the latter which began on a Thursday and ended on a Sunday. A total of 737 patients had

their test results rejected during this study, with 225 patients affected in the pre-intervention period and 135, 189 and 188 patients affected respectively in the post-intervention measurement periods. Data were missing only for the fourth Wednesday of the pre-intervention period due to laboratory computer problems. Archived data were not available for a retrospective report.

Results

Specimen Collection and Rejection

During both the pre- and post-intervention time periods, the majority of ED laboratory tests were ordered on patients in the ED Critical Care area (see Table 4.4) with both the number and percent of rejected tests also highest in this ED area (see Table 4.5). More than half of all rejected specimens were submitted during the day shift. Specimen hemolysis and clotting were collectively responsible for more than 75% of the total rejections with a significant improvement in correct specimen packaging and increased spection rejecton rates for mislabled, contaminated and unspecificed reasons (see Table 4.6).

Table 4.4

Total Tests Ordered in the Three ED Areas

Total Tests Ordered	Pre-intervention (4 weeks)		Post-intervention (12 weeks)	
	Number	%	Number	%
Total ED Area (Adult)	17,279	100%	50,412	100%
ED Critical Care Area	11,707	67.75%	34,713	68.86%
ED Flex Care Area	4,033	23.34%	11,538	22.89%
ED Inpatient Admit Area	1,539	8.91%	4,173	8.28%

Differences in Rejection Rates after Intervention

Data were anlayzed for five time periods (4-weeks pre-intervention and post-intervention weeks 1-4, 5-8, 9-12, and 1-12 for the total ED and for each of the three adult ED areas (Critical

Care, Flex Care, and Inpatient Admit). The results of 16 post-intervention time periods were compared to the 4-week pre-intervention period.

Table 4.5

Rejection Data by ED Area and Work Shift

Category	Pre-intervention (4 weeks)		Post-intervention (12 weeks)	
	Number	%	Number	%
Total Rejected Tests	552/17,279	3.19%	1199/50,412	2.38%
Rejected Tests by ED Area				
ED Critical Care Area	393	71.20%	891	74.31%
ED Flex Care Area	81	14.67%	189	15.76%
ED Inpatient Admit Area	78	14.13%	119	9.93%
				Rejected Test by Shift
Shift Change (0615-0715)	22	3.91%	49	4.09%
Day Shift (0716-1814)	280	49.82%	644	53.71%
Shift Change (1815-1915)	27	4.80%	37	3.09%
Night Shift (1916-0614)	209	37.19%	419	34.95%
Time Unknown	24	4.27%	50	4.17%

Table 4.6

Specimen Rejection Reasons and Pre-and Post-Intervention Comparisons

Test Rejection Reason	Pre-intervention (4 weeks)		Post-intervention (12 weeks)			
	Number	%	Number	%	$X^2_{(1)}$	*p*
Hemolyzed	375	67.93%	784	65.39%	1.096	≥ .05
Clotted	64	11.59%	128	10.68%	0.327	≥ .05
Mislabeled†	1	0.18%	63	5.25%	27.626	< .05
Tube Missing	22	3.99%	61	5.09%	1.017	≥ .05
Quantity not Sufficient	18	3.26%	40	3.34%	0.007	≥ .05
Questionable Results	16	2.90%	36	3.00%	0.014	≥ .05
Packaged Incorrectly	45	8.15%	33	2.75%	25.985	< .05
Contaminated†	4	0.72%	31	2.59%	6.682	< .05
Unspecified†	1	0.18%	13	1.08%	3.887	< .05
Diluted Specimen	0	0.00%	5	0.42%	2.309	≥ .05
Label Missing	4	0.72%	2	0.17%	3.444	≥ .05
Specimen Too Old	1	0.18%	1	0.08%	0.317	≥ .05
Tube Empty	0	0.00%	1	0.08%	0.461	≥ .05
Wrong Tube	1	0.18%	1	0.08%	0.317	≥ .05

†Post-intervention data is worse than pre-intervention data.

Significant improvements were noted in 12 of 16 post-intervention rejection rate periods with no significant improvement noted in three ED flex care and one ED inpatient admit area time periods (see Table 4.7). Comparative data in the 1-12-week period were significant for improved rejection rates for the entire ED, the ED critical care area, and the ED inpatient unit. The lack of a significant improvement in the ED flex care area is most likey due to the relatively low pre- and post-intervention rejection rates that were within 0.35% of each other. Pre - intervention rejection rates by day of the week revealed Monday as having the highest number of rejected tests at 5.24%, followed by Friday at 3.73% and Saturday at 3.14%. These rates improved significantly post-intervention for Mondays, Tuesdays and Fridays (see Table 4.8).

Table 4.7

Chi-Square Analysis of Pre- and Post-intervention by ED Area

Location	Weeks	Intervention Rejection Rates		$X^2_{(1)}$	*p*
		Pre- †	Post-		
Total Adult ED	1-4	3.19%	2.04%	44.940	< .05
	5-8		2.69%	7.619	< .05
	9-12		2.42%	18.731	< .05
	1-12		2.38%	39.689	< .05
ED Critical Care Area	1-4	3.36%	2.13%	32.707	< .05
	5-8		2.88%	4.364	< .05
	9-12		2.69%	8.755	< .05
	1-12		2.57%	20.321	< .05
ED Flex Care Area	1-4	2.01%	1.85%	0.275	≥ .05
	5-8		1.25%	6.851	< .05
	9-12		1.80%	0.471	≥ .05
	1-12		1.64%	2.383	≥ .05
ED Inpatient Admit Area	1-4	5.07%	1.77%	22.966	< .05
	5-8		5.02%	< 0.004	≥ .05
	9-12		1.93%	22.139	< .05
	1-12		2.85%	16.589	< .05

†Data are missing for one full day.

Table 4.8

Chi-Square Analysis of Pre- and Post-intervention Rejection Rates by Week Day

Day of the Week	Pre-intervention	Post-intervention	Chi-Square	*p*
Monday	5.24%	2.50%	47.953	< .05
Tuesday	3.01%	2.19%	5.597	< .05
Wednesday	2.12%	2.49%	0.913	≥ .05
Thursday	2.34%	2.49%	0.172	≥ .05
Friday	3.73%	1.90%	27.601	< .05
Saturday	3.14%	2.84%	0.543	≥ .05
Sunday	2.34%	2.27%	0.031	≥ .05

When compared to the overall adult ED area post-intervention rejection rate of 2.38%, the week day rejeciton rates for the same time period were significantly better for blood specimens collected on Fridays and significantly worse for specimens obtained on Saturdays (see Table 4.9).

Table 4.9

Comparison of Post-Intervention Total ED and Week Day Rejection Rates

	Post-intervention Rejection Rates			
Day of the Week	Total ED	Week Day	$X^2_{(1)}$	*p*
Monday	2.38%	2.50%	0.452	≥ .05
Tuesday	2.38%	2.19%	1.021	≥ .05
Wednesday	2.38%	2.49%	0.338	≥ .05
Thursday	2.38%	2.49%	0.321	≥ .05
Friday	2.38%	1.90%	6.336	< .05
Saturday	2.38%	2.84%	5.175	< .05
Sunday	2.38%	2.27%	0.292	≥ .05

Summary

The findings of this study demonstrated a significant improvement in post-intervention laboratory blood test rejection rates for the overall adult ED and the critical care and inpatient admission areas, and in those tests collected on Mondays, Tuesdays and Fridays. As compared

to the total adult ED rejection rate, specimens collected on Friday were significantly better while those collected on Saturday were significantly worse. The majority of tests ordered originated from the ED critical care area, with the highest number of all tests collected on the day shift followed by the night shift. Less than 10% of all tests were drawn at change of shift times. Hemolysis (65.39%) and clotting (10.68%) were the primary reasons for 76.07% of all rejected specimens.

Chapter 5: Conclusions

This chapter includes a discussion of the findings of an evidence-based practice change on laboratory rejection rates in an emergency department. This is followed by a discussion of limtations to the practice change implementation, implications for practice, implications for future research, and a summary.

Post-Intervention Rejection Rates

The study results demonstrated a significant decrease in the overall adult ED laboratory test rejection rate from 3.19% to 2.38% and represents a two-fold improvement of 25.61% made by just over half of all eligible bedside staff trained in a standardized evidence-based protocols for collecting blood via venipuncture and from a p-VAD. These findings are similar to those of Burns and Yoshikawa (2002) who discovered a seven-fold decrease in rejected specimens collected by phlebotomists formally trained and certified in blood collection techniques. Himberger and Himberger (2001) suggested that the strict adherence to a standard p-VAD protocol was central to obtaining healthy blood specimens through infusing intravenous lines while the Quality Institute Conference of 2003 recommended the use of evidence-based best practices as a means to improving patient safety (Boone, 2004).

Hemolysis was the primary cause of rejected specimens and found to be responsible for 65.39% (784) of all post-intervention rejected specimens in this study. This finding is consistent with Lippi, Salvagno, Montagnana, Brocco, et al. (2006) who identified hemolysis as the cause of 60% of all laboratory blood specimen rejections.

Limitations to the Practice Change Intervention

The ED medical leadership, though initially supportive of mandating the use of the evidence-based p-VAD practice protocol, decided against adopting this new evidence-based p-VAD protocol shortly before the study began for reasons unknown. As a result, participation in this study was voluntary with 51.94% of the total staff consenting to participate. The voluntary nature of the participation resulted in a lower participation rate of nurses, with many of them declining to participate because the EDTs were the individuals who drew their patients' blood for laboratory testing.

Though the original plan was to include the ED residents in this study, because they may collect blood from the patients in the resuscitation beds of the ED critical care area, their academic and clinical schedules did not allow for this. As a result, not all staff members who collected blood specimens from patients were provided the opportunity to participate in this study. Of note is that none of the newly reporting nurse and EDT staff elected to participate citing they were too busy with their ED orientation. Additionally, the confidential nature of the participation made it impossible to monitor participants' bedside use of the p-VAD and offer real-time corrective retraining.

Since the outcome variable measured for this study was the laboratory blood test rejection rate, data pertaining to the p-VAD catheter size, the collection device used, the amount and collection of an initial discard volume, and the use of a cushioned pneumatic transport system tube were not obtained and analyzed to determine their relationship to laboratory test rejection rates. As a result it is unknown which parts of the protocol the participants adhered to throughout the study, how each independent evidence-based practice affected the rejection rate, and the collection technique used, i.e. venipuncture or p-VAD collection.

The number of staff who matured out of the study due to termination or reassignment, who adopted the evidence-based blood collection practices though they were not study participants, or who stopped following the study protocol prematurely is unknown. This study was begun about six months after the ED started an initiative to decrease their blood culture rejection rates and may have been a confounding variable that contributed to the low rejection rates found during the pre-intervention period. The laboratory microbiology section reported the 7% blood culture contamination rate remained constant for the six months prior to and during this study.

Implications for Practice

The significantly decreased rejection rates support the training all ED staff in the use of evidence-based blood collection practices for their adult patients. To best hardwire these practices, consideration should be given to requiring all staff to use these practices daily and undergo some form of periodic refresher training. A comparison of rejection rates for the total adult ED to the day of the week revealed a significantly higher rejection rate in blood specimens collected on Saturdays. This finding suggests the weekend staff may need targeted retraining in blood collection techniques. With no significant improvement in the post-intervention hemolysis rate, the need for consistently following evidence-based practice blood collection protocols is central to decreasing specimen rejection.

Based on the reasons listed for specimen rejection, staff members can personally reduce their rejection rates by ensuring the samples are correctly labeled, are submitted using the correct tube that is appropriately filled to the required volume level, avoid submitting empty tubes, deliver tubes to the laboratory correctly packaged, and provide timely specimen delivery to the laboratory.

Implications for Future Research

With the preference of this ED staff to obtain blood through existing or new p-VADs, further study on the use evidence-based collection via p-VADs is needed. Consideration should be given to using matched pairs comparing both the venipuncture and p-VAD evidence-based collection processes so as to determine the blood collection practice with the lowest rejection rates.

Other areas for future research include the effect of rejected ED specimens on the equipment and reagent costs, on time lost and care delays, on the outcomes of treatment delays, and on patient and laboratory test throughput. With the federal government enacting value based purchasing as part of the Affordable Care Act of 2010, future research should also examine the cost of rejected specimens as it relates to direct costs, increased patient disposition times, and its effect on overall hospital patient throughput. These studies should be conducted within busy emergency departments and include patient volumes to determine the effect of workload on rejection rates.

Summary

Though evidence-based practice meta-analyses and systematic reviews by Halm and Gleaves (2009) and Heyer et al. (2012) did not support the use of p-VADs for blood specimen collection because the method was associated with hemolysis rates as high as 77%, this study demonstrated a significant decrease in blood specimen rejection rates when over half of an ED staff who routinely drew blood from a newly placed p-VAD were trained in evidence-based venipuncture and p-VAD blood collection techniques. The high hemolysis rate of 65.39% among rejected specimens in light of a low adult ED rejection rate of 2.38% invites further study and consideration for mandating venipuncture as the primary blood collection technique.

Appendix A

Evidence Summary

Citation	Location	Design	Findings	Evidence Level
Kennedy, C., Angermuller, S., King, R., Noviello, S., Walker, J., Warden, J., & Vang, S. (1996). A comparison of hemolysis rates using intravenous catheters versus venipuncture for obtaining blood samples.	An emergency department in which most blood specimens were historically obtained by Vacutainer® phlebotomy.	Phase 1: A prospective study that was a post-test-only control group randomized experimental design, to identify hemolysis rates based on blood specimen collection method. Group A (87 patients) served as the experimental IV catheter group and Group B (78 patients) as the control venipuncture group. Phase 2: A retrospective comparative descriptive data review was donet to determine relationship between hemolysis and IV catheter size.	1. Significantly lower rates of hemolysis were found: a. In specimens drawn from an IV catheter using a syringe to draw and transfer blood to tube as compared use of a Vacutainer® system ($p < 0.05$). b. As IV catheter diameter increased ($p < 0.05$). The rates were highest for 22- and 24-gauge catheters.	Level 2 (Evidence obtained from at least one well-designed randomized control trial).
Corbo, J., Fu, L., Silver, M., Atallah, H., & Bijur, P. (2007). Comparison of laboratory values obtained by phlebotomy versus saline lock devices.	An urban emergency department.	Prospective comparative study of paired blood samples with the venipuncture specimen as the control. Sample #1 was collected via venipuncture with a Vacutainer® and a 21-gauge needle/needless adaptor. Sample#2 was obtained 5 minutes later via a saline lock device (SLD). An initial 5-ml discard volume was obtained from the SLD. A total of 8 laboratory non-coagulation blood values were measured in each specimen collected (HCT, K^+, CO_2, Cl^-, Glucose, CPK, Troponin). Sample: A convenience sample of 584-paired tests was obtained from 73 non-critically ill adult patients over 2 mos.	1.The use of a SLD to obtain blood samples is an effective method in non-critically ill adult ED patients because a. No specimens were hemolyzed or clotted indicating the use of a SLD to obtain blood samples is an effective method in non-critically ill adult patients. b. None of the paired t-tests were statistically significant for value differences.	Level 3 (A well designed controlled trial without randomization)

Citation	Location	Design	Findings	Evidence Level
Fernandes, M., Worster, A., Eva, K., Hill, S., & McCallum, C. (2006). Pneumatic tube delivery system for blood samples reduces turnaround times without affecting sample quality.	Two emergency departments of a single multisite medical academic medical center. The laboratory analyzers were the same at both sites.	An prospective comparative study examining the effects of ED-to-lab delivery, via pneumatic tube system (PTS) at site #1 as compared to human carrier (HC) at site #2, on turnaround time and hemolysis rates for blood submitted for hemoglobin and potassium analysis. The study period was 8-days at each site. Sample: Convenience sample comprised of 121 test results from site #1 and 200 from site #2.	1. The turn-around times were found to be significantly shorted in specimens transported via the PTS than those delivered via HC, (F[1,66] = 136, p,0.001). 2. There was no significant difference in hemolysis rates between the PTS and HC delivery methods, i.e. the use of a PTS did not degrade specimen quality ($X^2 = 0.1743$, $P > 0.15$)	Level 3 (A well designed controlled trial without randomization)
Himberger, J. R., & Himberger, L. C. (2001). Accuracy of drawing blood through infusing intravenous lines.	Level 1 trauma center & emergency department (ED) at an academic medical center.	A 10-month long quasi-experimental design study that involved a convenience sample of 64 stable adult ED patients who required IV fluid hydration. Patients served as their own control with blood first drawn via venipuncture from the non-PIV arm and then from an IV line. A total of 23 paired CBC (5) and chemistry (7) values were obtained via venipuncture and peripheral IV line (PIV) from each patient by two phlebotomists who strictly adhered to a set protocol.	1. None of the value differences (PIV vs. venipuncture) were found to be clinically significant. 2. If done properly (to include collecting & discarding a 5ml first blood collected sample) PIVs are reliable sources for obtaining blood samples. 3. Identified a need for strict adherence to protocols when collecting blood.	Level 3 (A well designed controlled trial without randomization)
Wallin, O., Soderberg, J., Grankvist, K., Jonsson, P. A., & Hultdin, J. (2008). Preanalytical effects of pneumatic tube transport on routine haematology, coagulation parameters,	A university medical center laboratory department.	Quasi-experimental design in which paired venipuncture blood specimens were collected from volunteers by trained phlebotomists who followed a set protocol. One blood specimen remained in the laboratory (control) with the other sent via a pneumatic tube system (PTS) back to the laboratory for hematology (EDTA tube) and coagulation (citrate	1. The use of a PTS to deliver routine hematology and coagulation studies to the laboratory for analysis does not affect specimen integrity. 2. Specimens requiring analysis for global coagulation with thromboelastographic techniques should be hand delivered to the	Level 3 (A well designed controlled trial without randomization)

Citation	Location	Design	Findings	Evidence Level
platelet function and global coagulation.		tube) analysis. Sample: Convenience sample of 28 healthy volunteers. Paired samples were collected prior to and after a 1-week treatment period of a 75mg daily dose of aspirin.	laboratory.	
Burns, E. R., & Yoshikawa, N. (2002). Hemolysis in serum samples drawn by emergency department personnel versus laboratory phlebotomists.	A hospital emergency department and a medicine inpatient unit.	Phase 1: Retrospective study to identify blood chemistry sample hemolysis rates in 2,992 emergency department (ED) specimens obtained by trained but not certified ED staff phlebotomists, and 1,029 samples drawn by trained and certified laboratory technicians medical unit inpatients. Phase 2: An observational study of ED nurses and technicians by laboratory technician phlebotomists. The latter group documented the anatomical location, collection needle gauge and material (plastic or metal), collection tube fill level, use of extension tubing, use of syringe or Vacutainer® and compared these variables to presence or absence of hemolysis. Sample: Convenience sample of 204 observed blood collections.	Phase 1: The hemolysis rate for the ED staff phlebotomists was 12.4% as compared to 1.6% for the laboratory technician phlebotomists ($p < 0.0001$). This led the authors to recommend the importance of having an established blood collection protocol as a means of decreasing ED hemolysis rates. Phase 2: Obtaining blood from the antecubital site versus distal site and using a 20-gauge or larger needle or cannula versus a 22-gauge were found to result in statistically significant lower hemolysis rates and thus rejected specimens.	Level 6 (A single descriptive or qualitative study)
Dugan, L., Leech, L., Speroni, K. G., & Corriher, J. (2005). Factors affecting hemolysis rates in blood	A 21-bed community hospital emergency department (ED) that had no set blood collection policy nor required periodic staff	Prospective observational descriptive study conducted over a 36-day period during which ED nurses followed a strict policy for collecting blood form newly place peripheral IV sites (PIVs).	1. Hemolysis rates for syringe draws (13.5%) vs. Vacutainer® draws (12.6%) were not significant. 2. There is an inverse relationship between IV size and hemolysis rates, ($p < 0.05$).	Level 6 (A single descriptive or qualitative study)

Citation	Location	Design	Findings	Evidence Level
samples drawn from newly placed IV sites in the emergency room.	recertification for obtaining blood specimens.	Sample: A convenience sample of 100 patients that generated 382 blood samples for laboratory analysis.	3. The decrease in the ED hemolysis rate from 19.5% pre-study to 12.8% post-study led the authors to: a. Require all ED staff phlebotomists to complete an annual blood draw competency. b. Offer new ED phlebotomy staff training quarterly.	
Grant, M. S. (2003). The effect of blood drawing techniques and equipment of the hemolysis of ED laboratory blood samples.	An urban academic medical center emergency department (ED).	Prospective descriptive comparative study conducted over 19 days with ED nurse and technician staff completing a 1-page questionnaire with each blood specimen submitted for laboratory analysis. Sample: Convenience sample with 454 of 598 specimens having completed questionnaires. IV catheters ranged from 14- to 20-gauge, and straight needles from 21- to 23-gauge.	1. The following factors were found to significantly contribute to specimen rejection due to hemolysis with blood drawn: a. From an IV catheter (49% test cancellation rate) as compared to venipuncture with a straight needle (3% test cancellation rate),, with significance at p <0.001. b. Through a new IV catheter using a Vacutainer® (77% hemolysis rate) rather than a syringe (28% hemolysis rate), with significance at P=0.02.	Level 6 (A single descriptive or qualitative study)
Ong, M. E., Chan, Y. H. & Lim, C. S. (2008). Observational study to determine factors associated with blood sample haemolysis in the emergency department.	An academic medical center emergency department (ED).	Prospective observational study. ED staff first obtained blood for urea and electrolyte analysis from ED patients and them complete a questionnaire on the phlebotomy method and equipment used for each blood specimen collected. Sample: Convenience with a total of 227 questionnaires and blood samples obtained.	Of the 10 factors measured, only the use of a Vacutainer® collection device was associated with significantly higher hemolysis rates [OR, 6.0; CI95(2.3, 15.1)].	Level 6 (A single descriptive or qualitative study)

Appendix B

Evidence-based p-VAD Blood Collection Protocol

TITLE: ED Procedure for the Collection of Diagnostic Blood Specimens via an Indwelling Peripheral Vascular Access Device (p-VAD) in ED Adult Patients

PURPOSE:

To establish an Emergency Department policy for collecting blood samples for diagnostic testing through a new or established peripheral vascular access device (p-VAD). Proper collection technique requires both knowledge and skill. Since the literature reports that the collection of blood specimens using this technique carries with it a higher specimen hemolysis and rejection rates, it is imperative that the proper steps be followed to guard against specimen rejection. This policy is based on the laboratory venipuncture collection policy, LAB-02-256[(1)], that follows the national Clinical and Laboratory Standards Institute's evidence-based-blood collection practice.[(2)]

NOTE: *This procedure only applies to 18-21-gauge p-VADs. With 21 or smaller gauge p-VADs, blood should be collected via direct venipuncture to decrease risk of hemolysis.*

POLICY:

All personnel using this technique must be trained in the proper selection and use of equipment and supplies, and in collection techniques. Only staff who have completed the skill competency for this technique are allowed to obtain blood specimens via indwelling p-VADs.

PROCEDURE:

When collecting a blood specimen, qualified trained personnel must properly perform all of the following procedures:

PRIOR TO PERFORMING A VENIPUNCTURE, THE IDENTITY OF THE PATIENT MUST BE VERIFIED USING TWO IDENTIFIERS.

1. Verify the laboratory test orders
2. Identify the patient using **TWO IDENTIFIERS**
3. Assemble the equipment and supplies
4. Explain the procedure to the patient, and reassure them.
5. Position the patient
6. Check paperwork, labels and tubes
7. Wash your hands
8. Apply the tourniquet
9. Ensure the Patient's Hand is Closed
10. Select the vein for VAD placement.
11. Release the tourniquet.
12. Cleanse the expected venipuncture site and allow to dry
13. Prepare all VAD and blood collection supplies for easy access
14. Reapply the tourniquet.
15. Put on sterile gloves
16. Newly Inserted p-VAD and Blood Specimen Collection
17. Existing p-VADs and Blood Collection
18. Properly dispose of materials
19. Label & package specimens properly
20. Examine p-VAD Security & Answer Patient Questions
21. Exit patient's bedside
22. Transport Specimens to the laboratory

Step 1: Verify Order[1]

Check the order and paperwork carefully to ensure that you are familiar with the types of blood specimens needed, including the tube types and specimen volumes needed for each test. If you do not understand an order, get clarification of the order prior to collection.

Step 2: Identify the Patient[1]

TWO PATIENT IDENTIFIERS MUST ALWAYS BE USED TO VERIFY A PATIENT'S IDENTITY PRIOR TO PERFORMING A VENIPUNCTURE.

Always check the identification band. Verification of the patient's identity using two identifiers is critical to ensure the specimen is drawn from the patient indicated on the request order/form or specimen labels.

- Before drawing the blood, identify the patient by checking the armband and comparing it to the lab request or specimen labels.
- Verify that the Name (first and last) and Medical Record Number (MRN) match exactly to the information on the label.
- Follow this by asking the patient to state their name and date of birth, and compare their response to the order label.
- If the patient is unable to respond verbally, check their armband and compare it to the lab request or specimen labels. Resolve all identification problems *prior to* drawing the blood.

Step 3: Assemble Supplies[1,2]

Prepare the following supplies:

1. Gather the collection tubes and arrange them according to the "Order of the Draw" below.
   a. Write DISCARD on a Red Top tube that will be used for the first blood drawn, and then discard according to hospital policy once all blood has been collected.

DISCARD BLOOD → Light Blue → Red → Green/Lt Green → Lavender → Pink/White/Royal Blue → Gray

2. Tourniquet.

3. Cleansing agent per hospital policy.

4. Disposable gloves.
   Note: (1) Always observe Standard Precautions when performing venipuncture. Gloves ***must*** be worn when collecting blood specimens.
   (2) Gloves must be changed and hands washed after contact with each patient.

5. VAD Selection.
   a. Select an 18-21G IV catheter. Larger or smaller catheter sizes have been found to cause increased turbulence during the evacuation of blood with the risk for hemolysis and thus specimen rejection.
   b. Inspect the tip of the needle to ensure that it is free of hooks at the needle point, and that its opening is clear of any small particles that could obstruct the flow of blood.

6. Select the device to evacuate the blood specimen from the p-VAD:
   a). *Syringe:* Evidence-based research suggests this collection system results in fewer rejected specimens when obtaining blood from a p-VAD.[3-4] *When a syringe is used, you must first* move the plunger within the barrel of the syringe to verify freedom of plunger movement prior to blood collection to break the negative pressure seal. Make sure all air is expelled from the syringe prior to use.
   NOTE: To be used only if you are unable to use the Vacutainer® system*. Select a syringe size between 3 to 10-ml. Syringes larger than this have been found to cause increased turbulence during the evacuation of blood with the risk for hemolysis and thus specimen rejection. A 12-*

ml syringe may be used if the dept does not stock a 10ml syringe.[5]

b). *Evacuated system*: This device is preferable to needle and syringe because it is a low-pressure system and allows blood transfer directly from the vein into the evacuated tube. The evacuated system is composed of a sterile blood collection needle, a holder to secure the needle, and the evacuated (Vacutainer®) tube(s) with some containing a pre-measured additive.[6]

Step 4: Explain the Procedure and Reassure the Patient[1]

Introduce yourself to the patient and explain the venipuncture procedure. Assure the patient that although the p-VAD placement will be slightly painful, it will be of short duration. Remember to warn the patient before the needle pierces the skin so the patient is not surprised.

Step 5: Position the Patient[1,2]

Position the patient so the vein is readily accessible and you are able to work in a comfortable position. Ordinarily, the patient will either be sitting or lying down.

NOTE: *Ensure that the patient is not eating, chewing gum, or using an oral thermometer during the procedure to prevent their chance of choking.*

Step 6: Check the Paperwork, Labels and Collection Tubes[1]

Review the blood order/request form and the computer generated specimen labels for the laboratory tests ordered to ensure they are all for the same person. Select the appropriate collection tubes based on the requested tests. (Refer to the color coded stoppers on the tubes, the tube labels, and the tube/ test chart.) Do **NOT** apply any computer-generated labels to, or write any information on the collection tubes at this time.

Step 7: Wash your hands. [1]

Step 8: Apply the Tourniquet [1,2]

A tourniquet is used to increase venous pressure. The increased venous pressure causes the veins to become more prominent and easier to visualize and cleanly pierce with the needle.

Procedure for Applying Tourniquet

Apply the tourniquet 3-4 inches above the anticipated puncture site with enough tension to compress the vein and not the artery.

1. Wrap the tourniquet around the arm 3-4 inches above the venipuncture site.
2. Tuck the end around the last round

Precautions When Using a Tourniquet

Do not allow the tourniquet to be applied for more than 1 minute. Extended application of the tourniquet may result in local stasis and the possible hematoma formation (If the patient has a skin disease or sensitivity, the tourniquet should be applied over the patient's gown or a piece of gauze so that the tourniquet does not contact the skin.

NOTE*: If a tourniquet must be applied for the preliminary vein selection, it should be released and reapplied after a 2-minute rest period.*

Step 9: Ensure the Patient's Hand is Closed[1,2]

The veins become more prominent and easier to enter when the patient forms a fist. Discourage the patient from "pumping" the fist.

Step 10: Select the Vein for VAD Placement[1,2]

The superficial veins of the anterior surface of the arm are the preferred sites for peripheral IV catheter placement as this area provides better anatomical stability than does placement in the hand or antecubital fossa area. The hand veins are also acceptable for venipuncture (see Figure).

NOTE: *DO NOT use the radial veins (wrist area). If the patient has had a mastectomy, select the arm opposite the mastectomy side. For patients with bilateral mastectomies, consult a physician prior to starting the p-VAD.*[2]

Step 11: Release the Tourniquet[2]

Release the tourniquet once the vein for p-VAD placement has been identified, ensuring that it is not left tied beyond 1-minute. The tourniquet can be reapplied only after a 2-minute period has passed.

Step 12: Cleanse the Venipuncture Site & Allow to Dry[2]

1. Remove the skin-cleansing agent from its sterile package.
   a. If using alcohol, cleanse site with a circular motion from the center to the periphery.
   b. If using a different cleansing agent, cleanse the skin according to manufacturer's directions.
2. ***Allow the area to dry*** to prevent hemolysis of the specimen, and to prevent the patient discomfort due to alcohol contamination of the wound

Note: *If the vein cannot be seen well and must be palpated again before venipuncture, re-cleanse the site before proceeding.*

Step 13: Prepare all p-VAD and blood collection supplies for easy access. (See Step 3)

Step 14: Reapply the Tourniquet[2]

1. Reapply the tourniquet as outlined in Step 8.
2. Instruct the patient to unclench the hand.
3. Ensure the patient's hand is open as this reduces the amount of venous pressure as muscles relax.

Step 15: Put on sterile latex-free gloves[1,2]

Step 16: Newly Inserted p-VAD and Blood Specimen Collection

1. Insert an 18-21gauge p-VAD per hospital policy, attach the injection site port and secure.

2. Do NOT infuse anything through the newly placed p-VAD until the blood samples are obtained.

3. If *using a non-syringe evacuation-type collection system*, i.e. Vacutainer®:
   a. Cleanse the p-VAD IV port and allow to air dry.
   b. Using a needless adapter, insert it through the IV port and attach the red 4.7 ml Discard Blood tube. Release the tourniquet as soon as possible once the blood begins to flow into the tube[1].
   c. Remove the discard blood tube once it is filled to capacity and discard.[6,7]
   NOTE:
   (1) This guards against contaminants that can result in rejected specimens for analysis.
   (2) Patients who present on anticoagulant therapy, need only have 4 ml of blood discarded prior to collecting blood for coagulation studies.[7,8]
   d. Once the discard blood has been obtained, collect the blood following the order of the draw as noted below.

DISCARD BLOOD	→ Light Blue	→ Red	→ Green/Lt Green	→ Lavender	→ Pink/White/Royal Blue	→ Gray	***(Tube Inversions)***
	3-4	5	8-10	8-10	8-10	8-10	

***NOTE**: Allow the tube to fill based on its internal negative pressure vacuum until the blood flow stops. If the tube is less than half filled with blood, discard that tube and draw another. For tubes containing additives these actions ensure a correct blood-to-additive ratio for analysis.*

e. Ensure the collection tubes are gently inverted the number of appropriate number of times as noted above.
f. Flush the blood from the p-VAD catheter space with 5ml normal saline flush, or other designated flush solution as ordered.
g. Secure and dress the p-VAD per hospital policy.

4. If *using a syringe* to obtain the blood specimens:
   a. Cleanse the p-VAD IV port and allow to air dry.
   b. Using a 5ml syringe-needless adapter, insert it through the IV port and *first withdraw 4 ml of blood and discard*.
   c. With a new 3-12ml syringe-needless adapter system, collect the blood. If the port has been contaminated, it must be re-cleansed and allowed to air dry.
      ***NOTE**: (1) Release the tourniquet as soon as the blood begins to flow into the last syringe of blood being drawn.*[1]
      (2) If greater than 10-ml of blood is needed, use a new 10-12-ml syringe for reasons explained in Step 3, 7.b.

   d. Remove the syringe, attach a blood transfer device to the syringe, and transfer the blood into the tubes following the order of the draw.
      (1) Ensure the tube is 50% or more filled with blood.[9]
      (2) **Do not remove** the rubber stopper from the tube.

DISCARD BLOOD	→ Light Blue	→ Red	→ Green/Lt Green	→ Lavender	→ Pink/White/Royal Blue	→ Gray
(Tube Inversions)	3-4	5	8-10	8-10	8-10	8-10

***NOTE**: (1) Angle the needless transfer device to direct the blood along the side of the blood collection tube, filling the tubes according to the order of the draw.*
*(2) **DO NOT apply any pressure to the syringe plunger**; allow the blood tube's internal negative pressure to regulate the tube filling. ** These actions work to decrease trauma & hemolysis of the red blood cells during this transfer process.*

   e. Flush the blood from the p-VAD catheter space with 5ml normal saline flush, or other designated flush solution as ordered.
   f. Secure and dress the p-VAD per hospital policy.

Step 17: Existing p-VADs and Blood Collection

1. For existing p-VADs with no continuous IV fluids infusing:
   a. First check the p-VAD for patency.
   b. If patent, collect the discard blood and blood specimens as outlined in Step #16, 3 through 6.

Step 18: Properly Dispose of Materials[1,2]

1. Discard gauze and paper in an appropriate container, and in accordance with current bio-hazardous waste policies.

2. The needle may be removed using a one handed technique by inserting it into the specially designed sharp's collection system and twisting. **Do NOT**:
   a. Recap any needles into their plastic covers.
   b. Remove the used needle from the holder with your fingers.
   c. Shear, bend, or break the needle.

d. Force any item into the container.

Step 19: Label & Package Specimens *(do **NOT** pre-label tubes)* [10]

1. Label the tubes **at the patient's bedside** after blood collection has been completed and legibly write the date and time of the collection, and the phlebotomist's initials on the label
   a. If labels are not available, legibly write the full name and medical record number of the patient on the tube, and include the date, time of collection, and your initials.
2. Place labeled tubes and paperwork in a Biohazard plastic bag for delivery to the laboratory. All specimens from one patient should be placed in the same single bag.

Step 20: Examine p-VAD Security & Answer Patient Questions[1]

1. Inspect the p-VAD site to ensure it is secured properly.
2. Instruct the patient on the need to guard the integrity of the site, and to call staff for any questions regarding the p-VAD.
3. Thank the patient and answer any questions they may have prior to leaving the room.
4. Ensure the call bell is within reach and side rails are in the up position, if needed, to ensure the patient's safety.

Step 21: Exit Room[1]

1. Do not leave any specimens or venipuncture supplies in the patient's room.
2. Remove your gloves and wash hands.

Step 22: Transport Specimens to the Laboratory[10]

1. Place the 'bagged' collected specimens and related paperwork into a cushioned pneumatic tube, place the tube into the pneumatic tube system, and send to the laboratory.
2. Specimens may also be hand delivered to the laboratory.

References:

1. Shands Jacksonville Medical Center. Procedure for the Collection of Diagnostic Blood Specimens by Venipuncture (LAB-02-256).

2. Clinical and Laboratory Standards Institute (2007). Procedures for the collection of diagnostic blood specimens by venipuncture: Approved standard – Sixth Edition (CLSI Document H3-A6). Wayne, PA: Clinical and Laboratory Standards Institute.

3. Ong, M. E., Chan, Y. H. & Lim, C. S. (2008). Observational study to determine factors associated with blood sample haemolysis in the emergency department. *Annals of Academic Medicine Singapore*, 37, 745-748. Retrieved from http://www.annals.edu.sg/pdf/37volno9sep2008/v37n9p745.pdf

4. Grant, M. S. (2003). The effect of blood drawing techniques and equipment of the hemolysis of ED laboratory blood samples. . *Journal of Emergency Nursing, 29*(2), 116-121. doi: 10.1067/men.2003.66

5. Burns, E. & Yoshikawa, N. (2002). Hemolysis in serum samples drawn by emergency department personnel versus laboratory phlebotomists. *Laboratory Medicine*, 5(33), 378-380. Retrieved from http://labmed.ascpjournals.org/content/33/5/378.full.pdf+html

6. Dugan, L., Leech, L., Speroni, K. G., & Corriher, J. (2005). Factors affecting hemolysis rates in blood samples drawn from newly placed IV sites in the emergency room. *Journal of Emergency Nursing*, 31(4), 338-345. doi: 10.1016/j.jen.2005.05.004

7. Himberger, J. & Himberger, L. (2001). Accuracy of drawing blood through infusing intravenous lines. *Heart & Lung*, 30, 66-73. doi: 10.1067/mhl.2001.110535

8. Prue-Owens, K. K. (2006). Use of peripheral venous access devices to obtain blood samples for measurement of activated partial thromboplastin times. Critical Care Nurse, 26, 30-38. Retrieved from http://ccn.aacnjournals.org/content/26/1/30.full.pdf+html

9. Arrants, J., Willis, M., Stevens, B., Gripkey, L., Herman, J., Hernandez-Brooks, L., and Eaker, j. (1999). Reliability of an intravenous intermittent access port (saline lock) for obtaining blood samples for coagulation studies. *American Journal of Critical Care*, 8(5), 344-348. Retrieved from the ProQuest Medical Library

10. Shands Jacksonville Medical Center. Specimen Receipt and Transport (LAB-02-215).

Appendix C

Participant Demographic Questionnaire

Please complete the following demographic information. This information will not be used to identify you as a specific participant. Instead, this data will be used to better understand the aggregated demographic traits of the study population.

[Note: This form will be kept in a double locked secured space available only to the principal investigator who will destroy it once all the study data has been analyzed.]

Directions: Check the answer that best applies to you in each of the following categories.

1. Profession: _____Resident (UF) _____(Nurse: RN or LPN) _____EDT

2. Years employed in your current profession as a Resident, RN, LPN, EDT:

_____ Less than 2 yrs
_____ 2 – 4 yrs
_____ 5 – 10 yrs
_____ 11 - 15 yrs
_____ 16 - 20 yrs
_____ Over 20 yrs

3. Years working in any Emergency Department (ED):

_____ Less than 2 yrs
_____ 2 – 4 yrs
_____ 5 – 10 yrs
_____ 11-15 yrs
_____ Over 15 yrs

4. Years working in the ***Shands Jacksonville Medical Center*** ED:

_____ Less than 2 yrs
_____ 2 – 4 yrs
_____ 5 – 10 yr
_____ 11-15 yrs
_____ Over 15 yrs

The following questions are for EDTs only:

5. What is your EDT entry level preparation:

_____ EDT Program
_____ EMT Program
_____ Paramedic Program
_____ Associates Degree Program
_____ Other

6. Check all active state ***and*** national certifications, registrations and licenses currently held:

____ EDT
____ EMT
____ Paramedic
____ Other→ Please list

The following questions are for nurses (RNs and LPNs) only:

7. Select your entry level nursing education:

_____ Associates Degree in Nursing (ADN)
_____ Bachelors Degree in Nursing (BSN)
_____ Masters Degree in Nursing (MSN)
_____ Other

8. Check all active national certifications currently held:

_____ CEN
_____ CPEN
_____ CCRN
_____ Other → Please list

Appendix D

ED Blood Specimen Collection Skill Competency Checklist

Demonstrated Skill for Blood Collection	Veni-puncture	p-VAD
1. Verifies the laboratory test orders		
2. Identifies the patient using **TWO IDENTIFIERS**		
3. Assembles the equipment and supplies		
4. Explains the procedure to the patient, and reassure them.		
5. Positions the patient		
6. Checks for correct patient paperwork, labels and tubes		
7. Washes hands		
8. Applies the tourniquet → Selects Vein for venipuncture/VAD Placement		
9. Releases tourniquet ensuring "tie-time" less than 1 min.		
10. Cleanses the expected venipuncture site *and allows site to dry*		
11. Prepares all blood collection supplies, to include p-VAD, for easy access		
12. Reapplies the tourniquet → dons sterile gloves → inserts needle (if using p-VAD attaches interlock hub & Secures p-VAD)		
13. If using p-VAD → first *collects discard blood* tube	N/A	
14. Adheres to Order-of-Draw when collecting actual samples ***DISCARD BLOOD*** →Light Blue→Red Green/LtGreen→Lavender→Pink/White/RoyalBlue→Gray		
15. Releases tourniquet when blood begins to flow into tube/syringe (*in less than 1 min after application*) & completes collection of required specimens		
16. Applies Labels with **legible** date & time of draw and phlebotomist's initials → *inverts all tubes for required inversions(8-10)* → packages specimens in yellow Biohazard zip lock bag.		
17. Ensures p-VAD is secured and dressed. Answer Patient Questions		
18. Properly disposes of all materials & exits room.		
19. Transports Specimens to the laboratory→ *applies appropriate cushioning for tubes placed in the pneumatic tube transport system.*		

*****This is your personal reference sheet for the duration of this project. Thank you for keeping on your person when not in use.*****

References

Becan-McBride, K. (1999). Laboratory sampling: Does the process affect the outcome? *Journal of Intravenous Nursing, 22,* 137- 146. Retrieved from http://journals.lww.com/journalofinfusionnursing

Boone, D. J. (2004). Is it safe to have a laboratory test? *Accreditation and Quality Assurance: Journal for Quality, Comparability and Reliability in Chemical Measurement, 10*, 5-9. doi:10.1007/s00769-004-0855-5

Burns, E. R., & Yoshikawa, N. (2002). Hemolysis in serum samples drawn by emergency department personnel versus laboratory phlebotomists. *Laboratory Medicine, 33,* 378-380. Retrieved from http://labmed.ascpjournals.org

Bush, V., & Mangan, L. (2003). The hemolyzed specimen: Causes, effects and reduction. *LabNotes*, *13*, 1-5. Retrieved from http://www.bd.com/vacutainer/labnotes

Carraro, P., & Plebani, M. (2007). Errors in a stat laboratory: Types and frequencies 10 years later. *Clinical Chemistry, 53*, 1338-1342. doi:10.1737/clinchem.2007.088344

Clinical and Laboratory Standards Institute (2007). Procedures for the collection of diagnostic blood specimens by venipuncture: Approved standard – Sixth Edition (CLSI Document H3-A6). Wayne, PA: Author.

Corbo, J., Fu, L., Silver, M., Atallah, H., & Bijur, P. (2007). Comparison of laboratory values obtained by phlebotomy versus saline lock devices. Academic Emergency Medicine, 14, 23-28. doi:10.1197/j.aem.2006.06.053

Dale, J.C., & Novis, D. A. (2002). Outpatient phlebotomy success and reasons for specimen rejection. *Archives of Pathology and Laboratory Medicine, 126*, 416-419. Retrieved from http://www.archivesofpathology.org

Dugan, L., Leech, L., Speroni, K. G., & Corriher, J. (2005). Factors affecting hemolysis rates in blood samples drawn from newly placed IV sites in the emergency room. *Journal of Emergency Nursing, 31,* 338-345. doi:10.1016/j.jen.2005.05.004

Ernst, D. J. & Calam, R. (2004). NCCLS simplifies the order of draw: A brief history. Medical Laboratory Observer, May 2004, 26-27. Retrieved from http://www.mlo-online.com

Fernandes, C. M. B., Walker, R., Price, A., Marsden, J., & Haley, L. (1997). Root cause analysis of laboratory delays in an emergency department. *Journal of Emergency Medicine, 15,* 735-739. Retrieved from http://www.jem-journal.com

Fernandes, M., Worster, A., Eva, K., Hill, S., & McCallum, C. (2006). Pneumatic tube delivery system for blood samples reduces turnaround times without affecting sample quality. *Journal of Emergency Nursing, 32,* 139-143. doi:10.1016/j.jen.2005.11.013

Grant, M. S. (2003). The effect of blood drawing techniques and equipment of the hemolysis of ED laboratory blood samples. *Journal of Emergency Nursing, 29,* 116-121. doi:10.1067/men.2003.66

Halm, M. A., & Gleaves, M. (2009). Obtaining blood samples from peripheral intravenous catheters: Best practice? *American Journal of Critical Care, 18,* 474-478. doi:10.4037/ajcc2009686

Heyer, N. J., Derzon, J. H., Winges, L., Shaw, C., Mass, D., Snyder, S. R., ... & Liebow, E. B. (2012). Effectiveness of practices to reduce blood sample hemolysis in EDs: A laboratory medicine best practices systematic review and meta-analysis. *Clinical Biochemistry, 45,* 1012-1023. doi.org/10.1016/j.clinbiochem.2012.08.002

Himberger, J. R., & Himberger, L. C. (2001). Accuracy of drawing blood through infusing intravenous lines. *Heart & Lung, 30,* 66-73. doi:10.1067/mhl.2001.110535

Institute of Medicine (2000). In L. T. Kohn, J. M. Corrigan & M. S. Donaldson (Eds.). *To err is human: Building a safer health system.* Washington DC: National Academy Press.

International Federation of Clinical Chemistry and Laboratory Medicine (IFCC), Education and Management Division, Working Group: Laboratory Errors and Patient Safety (n.d.). Model of Quality Indicator 9.3.8. Laboratory Errors and Patient Safety (WG-LEPS). Retrieved from http://www2.csinet.it/mqiweb/

Kennedy, C., Angermuller, S., King, R., Noviello, S., Walker, J., Warden, J., & Van, S. (1996). A comparison of hemolysis rates using intravenous catheters versus venipuncture for obtaining blood samples. *Journal of Emergency Nursing, 22,* 566-569. Retrieved from http://www.jenonline.org

Lehman, B. & Goldstein, L. (Eds.) (2012). *HCAHPS Executive Insight Letter*, (2012, Summer). Retrieved from http://www.hcahpsonline.org/executive_insight/

Lippi, G., Guidi, G. C., Mattiuzzi, C., & Plebani, M. (2006). Preanalytical variability: The dark side of the moon in laboratory testing. *Clinical Chemistry and Laboratory Medicine, 44,* 358-365. doi:10.1515/CCLM.2006.07

Lippi, G., Salvagno, G. L., Montagnana, M., Brocco, G., & Guidi, G. C. (2006). Influence of hemolysis on routine clinical chemistry testing. *Clinical Chemistry and Laboratory Medicine, 44,* 311-316. doi:10.1515/CCLM.2006.054

Lippi, G., Salvagno, G. L., Montagnana, M., Franchini, M., & Guidi, G. C. (2006). Phlebotomy issues and quality improvement in results of laboratory testing. *Clinical Laboratory, 52,* 217-230. Retrieved from http://www.clin-lab-publications.com

Lowe, G., Stike, R., Pollack, M., Bosley, J., O'Brien, P., Hake, A., …& Stover, T. (2008). Nursing blood collection techniques and hemolysis rates in an emergency department: Analysis of venipuncture versus intravenous catheter collection techniques. *Journal of Emergency Nursing, 34,* 26-32. doi:10.1016/j.jen.2007.02.006

Melnyk, B. M. & Fineout-Overholt, E. (2005). *Evidence-based practice in nursing and healthcare*. Philadelphia, PA: Lippincott Williams & Wilkins.

Ong, M. E., Chan, Y. H. & Lim, C. S. (2008). Observational study to determine factors associated with blood sample haemolysis in the emergency department. *Annals of Academic Medicine Singapore*, 37, 745-748. Retrieved from http://www.annals.edu.sg/pdf/37volno9sep2008/v37n9p745.pdf

Plebani, M. (2006). Errors in clinical laboratories or errors in laboratory medicine? *Clinical Chemistry and Laboratory Medicine, 44,* 750-759. doi:10.1515/CCLM.2006.123

Plebani, M. (2007). Laboratory medicine: Value for patients is the goal [Letter to the Editor]. *Clinical Chemistry, 53,* 1873-1874. doi:10.1373/clinchem.2007.090563

Plebani, M., & Carraro, P. (1997). Mistakes made in a stat laboratory: Types and frequency. *Clinical Chemistry, 43,* 1348-1351. Retrieved from http://www.clinchem.org

Sharp, M. K., & Mohammad, S. F. (1998). Scaling hemolysis in needles and catheters. *Annals of Biomedical Engineering, 26*, 788-797. doi:10.1114/1.65

Shahangian, S., & Snyder, S. R. (2009). Laboratory medicine quality indicators A Review of the literature. *American Journal of Clinical Pathology*, *131*, 418-431. doi: 10.1309/AJCPJF8JI4ZLDQU

Smith, B. (2007). Preanalytical errors in the emergency department. *BD LabNotes*, *17*(1), 1-7. Retrieved from http://www.bd.com/vacutainer/labnotes

Stark, A., Jones, B. A., Chapman, D., Well, K., Krajenta, R., Meier, F. A., & Zarbo, R. J. (2007). Clinical laboratory specimen rejection: Association with the site of patient care and patient's characteristics: Findings from a single health care organization. *Archives of Pathology and Laboratory Medicine*, *131,* 588-592. Retrieved from http://www.archivesofpathology.org/doi/pdf/10.1043/1543-2165%282007%29131%5B588%3ACLSRWT%5D2.0.CO%3B2

Strauss, M., Sherman, B., Pugh, L., Prone, D., Lobby-Rodriquez, K., Bell, A., & Reed, C. (2012). Hemolysis of coagulation specimens: A comparative study of intravenous draw methods. *Journal of Emergency Nursing, 38,* 15-21. doi:10.1016/j.jen.2010.08.011

Steindel, S., & Howanitz, P. (2001). Physician satisfaction and emergency department laboratory test turnaround time. *Archives of Pathology and Laboratory Medicine, 125,* 863-872. Retrieved from http://www.archivesofpathology.org

Wagar, E. A., Tamashiro, L., Bushra, Y., Lilborne, L., & Bruckner, D. A. (2006). Patient safety in the clinical laboratory: A longitudinal analysis of specimen identification errors. *Archives of Pathology and Laboratory Medicine, 130,* 1662-1668. Retrieved from http://www.archivesofpathology.org

Wallin, O., Soderberg, J., Grankvist, K., Jonsson, P. A., & Hultdin, J. (2008). Preanalytical effects of pneumatic tube transport on routine haematology, coagulation parameters, platelet function and global coagulation. *Clinical Chemistry and Laboratory Medicine, 46,* 1443-1449. doi:10.1515/CCLM.2008.288

Zarbo, R. J., Jones, B. A., Friedberg, R. C., Wallenstein, P. N., Renner, S. W., Schuman, R. B., ... & Howanitz, P. J. (2002). Q-Tracks: A College of American Pathologists program of continuous laboratory monitoring and longitudinal performance tracking. *Archives of Pathology and Laboratory Medicine*, *126*(9), 1036-1044. Retrieved from http://www.archivesofpathology.org

Vita

Barbara Klos Vernoski was born . She was awarded a bachelors of science in nursing from Niagara University and earned a masters of science in trauma and critical care nursing from the University of Maryland in 1989.

The first part of her healthcare career was spent in the United States Navy as a Nurse Corps officer stationed throughout America and Europe. Beginning her military career as a critical care nurse, she expanded her practice to ambulatory care and healthcare administration and became the first nurse corps officer to serve as the commanding officer of a naval hospital with a graduate medical education program. Additional assignments included the Casualty Reception Division Officer aboard the hospital ship USNS Comfort during Desert Shield and Desert Storm, commanding officer of a1000-bed Fleet Hospital, Deputy Director of TRICARE Europe, and leader of a Department of Defense/Veterans Affairs healthcare delegation to Romania.

Upon her transition from the military, she settled in Jacksonville, Florida and worked for The Joint Commission as a hospital accreditation program surveyor. She is currently employed at the Shands Jacksonville Medical Center as the Vice President for Specialty Care Services and the Division Director for Ancillary and Clinical Services.

Chernow, B., Vernoski, B. K., Zaloga, G. P., Cook, D., D'Angona, D. Jr., VanNess, M., and Fletcher, J. R. (1984). Dexamethasone causes less steroid-induced alkalemia than methlyprednisilone or hydrocortisone. *Critical Care Medicine*, *12*(4), 384-386.

Vernoski, B. K. and Chernow, B. (1983). Steroids: Use and abuse. *Critical Care Quarterly*, *6*(3), 28-38.