

The Effects of Abnormal Blood Pressure on Arterial Sampler Filling Times

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The study was performed at The Wexner Medical Center at The Ohio State University.

Mr. Cortes presented a version of this paper at the Open Forum of the AARC Congress 2012, held November 10-13, 2012, in New Orleans, Louisiana.

There were no sources of financial support.

All authors claim no conflicts of interest.

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BACKGROUND: Sampler filling time begins with the initial flash of blood in the needle hub until the preset sampler volume is obtained. Previous studies have shown statistically significant differences between arterial and venous sampler filling times but included only a few patients with abnormal blood pressures. **Purpose:** To determine if the time required to fill a vented arterial sampler is an accurate indication of a successful arterial blood sample in adults with abnormal blood pressure. **Hypotheses:** MAP and arterial sampler filling time will have a negative correlation; venous sampler filling time will be significantly longer than arterial filling time. **METHODS:** We studied 40 subjects, 25 arterial subjects and 15 venous subjects. The arterial subjects included three groups: hypertensive, hypotensive or normal. During the arterial and venipuncture procedures, we measured sampler filling time and recorded blood volume; the PO₂ of the samples was measured. Additionally, BP and SpO₂ were measured for the arterial groups. We used a Pearson correlation coefficient to determine the relationship between MAP and sampler filling rate. We determined if there was a significant difference between arterial and venous groups using ANOVA with an alpha level of .05 and Tukey's post hoc. **RESULTS:** The mean sampler filling times were 220.4 sec/mL for venous and 18.1sec/mL for all three arterial groups combined. There were significant differences between each mean arterial sampler filling rate and mean venous filling rate ($P < .001$). There were no significant differences in mean sampler filling rates between arterial subgroups ($P = .997$). The correlation between MAP and filling rates was 0.062 ($P = .384$). **CONCLUSION:** There is a significant difference between arterial and venous filling rates. There was no relationship between filling times and abnormal

MAPs. Regardless of arterial blood pressure, arterial sampler filling time can be used as an indicator of a successful arterial puncture at the bedside. *Key words: arterial blood sampling; percutaneous puncture; venous blood; low blood pressure; hypoxemia; arterial sampler; filling time; arterial blood pressure.*

Introduction

Percutaneous punctures to obtain arterial blood samples are frequently performed in the clinical setting to assess a patient's oxygenation and ventilation status, as well as the presence of acid-base disturbances. The information obtained from these samples is used to monitor the severity and progression of a disease, to make decisions on treatment, or to assess the effectiveness of current respiratory therapy for patients.¹ Venous blood is not a valid substitute for arterial blood. When $P_a\text{CO}_2$ is in the normal range, the agreements between arterial and venous values are acceptable for pH, $p\text{CO}_2$, and bicarbonate, but the oxygenation status of the patient cannot be accurately assessed with venous blood.² During acute exacerbations of COPD when $P_a\text{CO}_2$ is higher than normal, there is insufficient agreement between venous and arterial $P_a\text{CO}_2$ for venous blood gas to replace arterial blood gas in determining the degree of hypercarbia.³ Therefore, when performing a percutaneous puncture, it is important for clinicians to know they have obtained a valid arterial sample at the bedside. Clinical practice standards recommend the assessment of color and pulsatile flow of the blood during sampling.^{4,5} Sampling errors may occur in special circumstances. In cases of hypotension, pulse pressure may be decreased and pulsatile flow low or absent. Arterial blood will likely appear darker and be mistaken for venous, if a patient is hypoxemic. Sampling errors can result in unnecessary

repeated punctures and be hazardous to the patient,⁵ if venous blood is mistaken for arterial or arterial mistaken for venous. Arterial punctures are more painful than venous punctures and can cause complications such as arterial damage, median nerve damage, hemorrhage, and vasovagal response.⁶ Therefore, having an additional method for distinguishing arterial from venous blood at the bedside would be advantageous.

Hutchinson initially described three vented arterial samplers when they were introduced in the 1980s.⁷ Although he claimed that “All three greatly reduce or eliminate the error of venous sampling,” he did not test the samplers under venous pressures. Since the samplers filled passively, his claim was based upon eliminating the then common practice of aspirating arterial blood using a syringe. Sampler filling time begins with the initial flash of blood in the needle hub until the preset sampler blood volume is obtained. Using vented arterial samplers, two studies have shown statistically significant differences between arterial and venous sampler filling times. Johnson’s study utilized an extracorporeal lab model to also compare the length and gauge of the needle to sampler filling time.⁸ Johnson concluded that there was not a statistically significant difference in filling time between the two different needles, but the study was criticized for lack of clinical validity.⁹ Bender’s study did include human subjects, but that study included only a few patients with abnormal blood pressures which the investigators defined as a mean arterial blood pressure (MAP) less than 80 or greater than 100 mmHg, and their venous filling times were remarkably longer than Johnson’s.¹⁰ Since there have been no other studies done to compare abnormal blood pressures in this way, our study focuses on patients with blood pressures outside of the normal range and examines the effects of abnormal blood pressure on arterial sampler filling times.

The purpose of this study was to determine if the time required to fill a vented arterial sampler can be an accurate indicator of obtaining a successful arterial blood sample in adults with abnormal blood pressure. Our research questions were: Is there a difference between sampler filling times for venous and arterial samples over the range of abnormal arterial blood pressures, and is there a relationship between filling times and MAP over the range of abnormal arterial blood pressures? We hypothesized that there would be a statistically significant difference between sampler filling times for venous and arterial samples over the range of abnormal arterial blood pressures. We also hypothesized that there would be a statistically significant negative correlation between sampler filling time and MAP in human adults with abnormal blood pressure.

Methods

We conducted a comparative and correlational study, using a sample of convenience taken from The Wexner Medical Center at The Ohio State University. This study was approved by the Office of Responsible Research Practices (IRB#2011H0017). We studied 40 subjects, 25 arterial subjects and 15 venous subjects. The arterial subjects were adults chosen based on the location of their hospital admission (ICU, The James Cancer Hospital and/or the Emergency Department) and an order for an arterial blood gas puncture. The venous subjects were healthy adult volunteers affiliated with the School of Health and Rehabilitation Sciences. Our subjects were divided into four groups: 1) hypotensive subjects (MAP<80 mm Hg), 2) subjects with normal blood pressure (MAP 80-100 mm Hg, 3) hypertensive subjects (MAP>100 mm Hg) and 4) venous subjects.

For the venous group, a critical care nurse used an arterial sampler (Pro-Vent, Portex - Smith Medical, Dublin, Ohio) with a 23 gauge needle attached to withdraw 0.5-2 mL of blood from the antecubital vein. The antecubital vein was identified with a tourniquet, but it was removed before the puncture began. For the arterial group, we measured SpO₂ and systemic arterial blood pressure noninvasively, using a hospital-approved, calibrated sphygmomanometer (Accutorr Plus, Datascope/Maquet, Bridgewater, New Jersey), while a respiratory therapist prepped the patient for an arterial puncture. All therapists used an arterial sampler (Pro-Vent, Portex - Smith Medical, Dublin, Ohio) with a 23 gauge needle attached to withdraw 0.5-2 mL of blood from the radial artery. Sampler filling time was defined as the time when blood first entered the needle hub until the preset volume was reached. We measured sampler filling time with a stopwatch, and we recorded the volume (mL) of blood drawn. If the sampler did not fill to the set volume, any air was evacuated immediately. The PO₂ of the blood samples was measured using a blood gas analyzer (RapidLab 1200, Siemens, Berlin, Germany).

We used statistics software (SPSS 17.0, SPSS, Chicago, Illinois) for statistical analysis. We calculated MAP using the equation: $MAP = (systolic + 2 \times diastolic) / 3$. We also calculated the sampler filling rate (sec/mL) by dividing the filling time by the blood volume. We used ANOVA with repeated measures to compare sampler filling rates (sec/mL) among our four groups and applied Tukey's post hoc comparison to identify where significant differences were present among the groups. We used Pearson product-moment correlation coefficient to determine the relationship between MAP and the sampler filling time rate (sec/mL) among the arterial groups. The alpha levels were set a priori at $p < 0.05$.

Results

The results of sampler filling rates and PO₂ values are presented in Table 1 for all four groups. The PO₂ values confirmed blood samples as arterial or venous. The mean arterial sampler filling times were 220.4 sec/mL for venous and 18.1 sec/mL for all three arterial groups combined. There were significant differences between each mean arterial sampler filling rate and mean venous filling rate ($P < .001$). There were no significant differences in mean sampler filling rates among arterial subgroups ($P = .997$). The correlation between MAP and fillings rates was 0.062 ($P = .384$).

Discussion

Some of our results are consistent with those of Johnson⁷ who used an extracorporeal lab model and Bender⁹ who studied primarily normotensive human subjects. Consistent with our results, both previous studies also showed a significant difference between arterial and venous sampler filling rates (sec/mL). Johnson's results using a 23 gauge one inch needle showed mean sampler filling rates of 11.5 – 20.5 sec/mL for six arterial groups with MAPs ranging from 57 mm Hg to 133 mm Hg; the filling rate was 49.2 sec/mL for the venous group. Bender's results showed a mean sampler filling rate of 15.1 sec/mL for the arterial group and 114.5 sec/mL for the venous group. The results of all three studies have confirmed that venous filling time is significantly longer than arterial filling time and arterial sampler filling time or rate (sec/mL) can be used as an accurate indicator of a successful arterial puncture regardless of mean arterial blood pressure, even in hypotensive or hypertensive patients.

The mean filling rate for our hypertensive group, defined as a MAP > 100 mm Hg, was surprisingly longer than our normotensive and hypotensive groups. Contrary to Johnson's and

Bender's results showing significant negative Pearson correlation coefficients between MAP and sampler filling rate, our results showed very little correlation due to the inclusion of subjects with hypertension. In the laboratory using constant blood flow in the circuit, Johnson demonstrated a strong negative correlation of -0.86. Bender's results, which included primarily normal MAPs in adults, showed a moderate negative correlation of -0.487; whereas, our results show a Pearson correlation coefficient of 0.062. Once we expanded our subject groups to include abnormal blood pressures, we no longer observed a significant correlation between MAP and sampler filling time. This inconsistency was largely due to the longer filling rates of the hypertensive group. Factors such as reduced peripheral blood flow may be associated with hypertension and could have affected the arterial sampler filling time in adults but not in the laboratory model.

Johnson's venous filling rate was 49.2 sec/mL, but Johnson admitted it could be underestimated because the lowest pressure in the circuit exceeded normal venous pressure, and we thought that Bender's longer mean venous filling rate (114.5 sec/mL) required further investigation. As a result, we repeated the venous group punctures for our study. Unexpectedly, our venous filling times were longer than Bender's with a mean filling rate of 220.4 sec/mL. This discrepancy is thought to be attributed to the difference of methods between the two studies. The phlebotomist in Bender's study did not remove the tourniquet until after the initial blood flash. Our nurse only used the tourniquet to identify the vein then removed it before the puncture occurred. The difference in methods could have led to the venous group in Bender's study having shorter filling times because of the effects of the tourniquet may have caused an initial

burst of pressure upon initial puncture. Our results better mimic true clinical conditions since tourniquets are not used during arterial punctures.

There were several limitations of our study, including the small sample size due to limited orders for arterial punctures during our study period. We only observed punctures using one brand of arterial sampler; other brands may vent air differently. We were unable to control for possible confounding variables such as cardiac output, blood viscosity, or peripheral blood flow. These limitations provide for future study.

Conclusion

For adults and regardless of MAP, there is a significant difference between arterial and venous filling times or rates (sec/mL) using a vented arterial sampler. Respiratory therapists and other clinicians performing arterial punctures can use arterial sampler filling time or rate (sec/mL) to identify successful arterial punctures at the bedside during the puncture procedure. Successful arterial punctures have arterial sampler filling time or rates between 13.3 – 21.1 sec/mL or approximately 18 sec/mL.

Products Used

Sphygmomanometer: Accutorr Plus, Datascope/Maquet, Bridgewater, New Jersey

Arterial blood sampling kits: Pro-Vent, Portex - Smith Medical, Dublin, Ohio

Blood gas analyzer: RapidLab 1200, Siemens, Berlin, Germany

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Table. Sampler filling rates and PO₂ in arterial and venous subjects.

	Hypotensive MAP < 80 (n = 13)	Normotensive MAP 80-100 (n = 6)	Hypertensive MAP > 100 (n = 6)	Venous (n = 15)	<i>P</i>
Filling Rate, s/mL	19.8 ± 5.8	13.3 ± 4.0	21.1 ± 10.3	220.4 ± 102.2	< 0.0001
PO ₂ , mmHg	120.9 ± 65.5	87.3 ± 30.3	201.1 ± 188.4	37.4 ± 10.6	< 0.0001

Values are mean ± SD.