Arterial Sampler Filling Time During Arterial and Venous Punctures, and Its Relationship with Mean Arterial Pressure in Human Subjects

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BACKGROUND: When obtaining an arterial blood sample via percutaneous puncture, there is a risk of accidentally obtaining venous blood. Conventional methods of confirming arterial blood at the bedside, such as blood color and pulsatile return, can be misleading in patients with low blood pressure or hypoxemia. OBJECTIVE: To determine if the arterial sampler filling time can be an accurate indicator of obtaining an arterial blood sample in subjects with various blood pressures. Our hypotheses were that there would be a statistically significant negative correlation between sampler filling time during arterial puncture and mean arterial blood pressure, and a statistically significant difference between venous and arterial filling times in human adults. METHODS: Prior to an arterial puncture, we measured and recorded arterial blood pressure noninvasively. During the arterial and venipuncture procedures we measured the amount of time it took to fill the sampler and the volume of blood obtained. A *t* test for independent samples was calculated to determine if mean arterial sampler filling times were significantly different between the arterial and venous groups. Pearson correlation coefficient was calculated to determine the relationship between mean arterial pressure and seconds of filling time per milliliter in the arterial group. RESULTS: This study included 38 human subjects; 22 were adult patients ordered for arterial blood gases by arterial puncture; 16 were normal, healthy, adult volunteers who had a venipuncture performed using an arterial blood sampler. The mean ± SD filling time was 15 ± 4 s/mL for the arterial group and 115 ± 48 s/mL for the venous group, and the difference was significant ($P < .001$). The range of mean arterial pressures was 69–125 mm Hg; the average mean arterial pressure was 91 ± 13 mm Hg, and the Pearson correlation coefficient for mean arterial pressures and sampler filling times was −0.49 ($P = .02$). CONCLUSION: Our results were consistent with a laboratory study showing a significant difference between arterial and venous filling times and a negative correlation between mean arterial pressure and sampler filling time, but our times in adult subjects were longer. Respiratory therapists may find arterial sampler filling time as a useful indicator of 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.* [Respir Care 2012;57(11):1945–1948. © 2012 Daedalus Enterprises]

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Introduction

Respiratory therapists and other clinicians frequently obtain arterial blood samples by percutaneous arterial puncture in ICUs, emergency departments, pulmonary function testing laboratories, and clinics. The results of arterial blood gas analysis often contribute to patient care decisions.[1] Results of arterial blood gas analysis enable clinicians to evaluate the adequacy of ventilation and oxygenation, to quantify the patient's response to therapeutic intervention, and to monitor the severity and progression of a documented disease process.[2] Risks associated with arterial punctures include hematoma, hemorrhage, trauma to the vessel, vasovagal response, and pain.[3] It is imperative that arterial punctures be performed correctly and competently and that unnecessary punctures be avoided, not only to provide timely and appropriate care but also to reduce complications and trauma associated with percutaneous punctures.

When obtaining an arterial blood sample there is a risk of accidentally obtaining venous blood. At the bedside it is important for clinicians to be able to verify that the blood drawn is truly arterial. Conventional methods of confirming arterial blood at the bedside, such as blood color and pulsatile return, can be misleading in some clinical situations. The blood of patients with hypoxemia can show a dark color similar to venous blood, and patients with low blood pressure may have very low pulsatile action.[2] Using the results of the blood gas analysis to verify that a sample is indeed arterial blood can be inefficient and potentially hazardous to the patient if venous blood is not recognized. If the sample is found to be venous, another sample must be obtained by an arterial puncture, producing a delay in making patient care decisions. There are currently no quantitative measures that can be taken during the percutaneous puncture to ensure that an arterial blood sample is truly arterial. A study using an extracorporeal circuit has shown a significant difference between arterial and venous filling times and a negative correlation between mean arterial blood pressure (MAP) and arterial sampler filling time in a laboratory setting.[4] In order to determine clinical validity, sampler filling times and variable blood pressures should be measured using real patients.[5]

The purpose of this study was to determine if the arterial sampler filling time can be an accurate predictor of obtaining a successful arterial blood sample in adults with various blood pressures. Our hypotheses were that there would be a statistically significant negative correlation between sampler filling time during arterial puncture and MAP, and a statistically significant difference between venous and arterial filling times in human adults.

QUICK LOOK

Current knowledge

During arterial blood sampling via a percutaneous puncture there is a risk of accidentally obtaining venous blood. Conventional observational methods of confirming arterial blood acquisition at the bedside, such as blood color and pulsatile return, can be misleading in patients with hypotension or hypoxemia.

What this paper contributes to our knowledge

There is a statistically significant difference between arterial and venous filling times using an arterial blood sampler in human subjects, and a moderate inverse relationship between mean arterial pressure and filling times in human subjects. Arterial sampler filling time is a useful indicator of successful arterial puncture at the bedside.

Methods

This study was comparative and correlational, using a sample of convenience. For the comparative part of the study, arterial sampler filling times for arterial and venous punctures were compared; for the correlational part of the study, the relationship between MAP and the amount of time it took to fill an arterial sampler with 1 mL of blood was determined. Our study was submitted to and approved by the institutional review board at The Ohio State University, via an expedited review. The protocol number was 2011H0017.

Our study included 2 groups: arterial and venous. The arterial group included patients at The Ohio State University Medical Center who were ordered for an arterial blood sample. For the arterial group, we recruited subjects who were scheduled for a prescribed arterial puncture; the majority of subjects were out-patients in our pulmonary function laboratories. Another group of volunteers had their venous blood drawn via the brachial vein, using an arterial blood sampler, performed by an experienced phlebotomist; they were faculty and students in respiratory therapy at The Ohio State University School of Allied Medical Professions. All subjects were informed of the procedures and signed consent forms before the procedures were started.

For the arterial group, we measured systemic arterial blood pressure noninvasively, using a hospital-approved, calibrated sphygmomanometer (Accutorr Plus, Datascope/Maquet, Bridgewater, New Jersey), and we timed the sampler filling time using a stopwatch for both groups. To ensure timer reliability, a training session was con-

Table. P_{aO_2} and Sampler Filling Times in Arterial and Venous Subjects

	Arterial (n = 22)	Venous (n = 16)	P
Filling time, s/mL	15 ± 4	115 ± 48	< .001
P_{aO_2}, mm Hg	89 ± 17	29 ± 9	< .001

Values are mean ± SD.

ducted; timers were consistent and within plus or minus 0.1 s. We recorded the amount of time to fill the sampler, from the initial blood flash in the needle hub until the blood flow stopped. We also recorded the volume of blood obtained in the sampler. The position of the subject was the same during the measurement of blood pressure and during the arterial blood gas procedure. The arterial blood sampling kits samplers (Pro-Vent, Portex - Smith Medical, Dublin, Ohio) had a 23 gauge, 1 inch needle attached for each sample. For the arterial group, the needle angle of entry was 45°, and 30° was used for the venous group. For the venous group, either no tourniquet was used or it was removed simultaneously with the blood flash in the needle hub. The blood samples obtained were verified as arterial or venous by measuring P_{aO_2}, using a blood gas analyzer (RapidLab 1200, Siemens, Berlin, Germany).

For the arterial group, we estimated[6] MAP using the equation:

$$\text{MAP} = (\text{systolic pressure} + 2 \times \text{diastolic pressure})/3$$

We used software (SPSS 17.0, SPSS, Chicago, Illinois) for statistical analysis. Pearson correlation coefficient was calculated to determine the relationship between MAP and seconds of filling time per milliliter in the arterial group. Following the Levene test for equality of variances, a one-tailed Student t test for independent samples was calculated to determine if arterial sampler filling times were significantly different between the arterial and venous groups. The alpha level was set a priori at .05.

Results

Our study included 38 adult subjects: 22 patients in the arterial group, and 16 volunteers in the venous group. The results of the P_{aO_2} measurements and the mean sampler filling times are presented in the Table. There was a statistically significant difference between the arterial and venous groups for both comparisons ($P < .001$). The mean ± SD filling time was 15 ± 4 s/mL for the arterial group and 115 ± 48 s/mL for the venous group. All blood pressures were recorded from our arterial sampler group and included in the data analysis. The range of MAPs was 69–125 mm Hg. The mean ± SD MAP was 91 ± 13 mm Hg. The Pearson correlation coefficient for MAPs and sampler filling times was –0.49 ($P = .02$). The negative correlation between MAP and sampler filling time indicates that MAP and sampler filling times vary inversely. The Figure shows the relationship between MAP and sampler filling time for the arterial group.

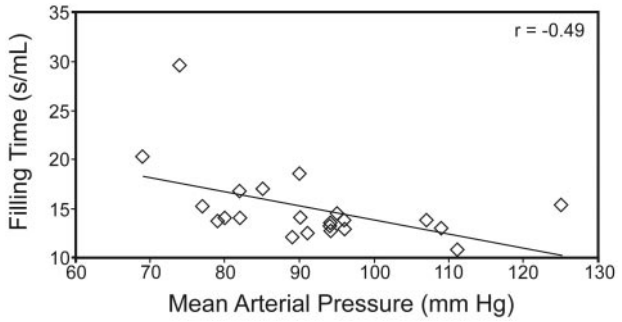

Figure. The relationship between mean arterial pressure and sampler filling time.

Discussion

That we found a statistically significant difference between arterial and venous sampler filling times and a statistically significant relationship between MAP and filling times was not surprising, and we believe the difference between arterial and venous sampler filling times to be clinically important. Our results are consistent with a previous laboratory study, although our times differed from theirs.[4] Our arterial group had a normal estimated MAP of 91 mm Hg and a mean filling time of 15 s/mL, whereas Johnson et al created a normal group using a simulation with a MAP of 93 mm Hg and measured a filling time of 16 s for a 2 mL sample. When filling time is converted to s/mL, the filling time equals 8 s/mL for the laboratory study, which is nearly twice as fast as our human group. This difference illustrates the importance of performing this study using human subjects. Some reasons for this difference may include various differences between human subjects and a laboratory simulation, such as blood viscosity, pulsatile blood flow, variable cardiac output, and partial needle occlusion, or incomplete arterial puncture in humans. The mean filling time for our venous group was also not equal to Johnson et al. Our mean venous sampler filling time was 115 s/mL, whereas Johnson reported a lower time, of approximately 25 s/mL. This difference is likely attributed to the venous pressure of 14 mm Hg in their laboratory model. Although venous pressure in human subjects is much lower, the filling time of 115 s/mL seems extremely prolonged. Regardless of the differences between studies, the differences between arterial and venous are clinically different. Measuring arterial

sampler filling time during arterial puncture may be a useful method of assuring the blood sample is truly arterial; a prolonged time may indicate the blood sample is venous. Having confidence that the sample is arterial may help reduce unnecessary repeated punctures and delays in patient care decisions.

We verified arterial and venous samples by measuring the blood P_{aO_2} with a blood gas analyzer. This method of confirmation is physiologically sound and consistent with Ak et al, who reported venous and P_{aO_2}, and oxygen saturation, and found a large difference, with very little correlation between them.[7] In some volunteers we could not use a 45° angle of needle entry for the venous group, because blood would not flow.

Limitations in our study include that we did not take into account hematocrit or hemoglobin concentration, which may affect blood viscosity and consequently blood flow through the needle and sampler filling time. Hypotensive and hypertensive patients were not well represented in this study. We used only one brand of arterial sampler; other brands may vent air from the sampler differently. Future studies should include a wider range of mean arterial pressures and a variety of samplers.

Conclusions

There is a statistically significant difference between arterial and venous filling times using an arterial blood sampler in human subjects, and there is a moderate inverse relationship between MAP and arterial sampler filling times in human subjects. Our arterial group had a normal estimated MAP of 91 mm Hg and a mean filling time of 15 s/mL, and our mean venous sampler filling time was 115 s/mL. Based on these results, respiratory therapists and other clinicians may find arterial sampler filling time as a useful indicator of successful arterial puncture at the bedside.

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