The Effects of Abnormal Blood Pressure on Arterial Sampler Filling Times

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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 subjects with abnormal blood pressures. OBJECTIVE: To determine whether 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. We hypothesized that mean arterial pressure and arterial sampler filling time would have a negative correlation, and that venous sampler filling time would be significantly longer than arterial filling time. METHODS: We studied 40 subjects: 25 arterial subjects, and 15 venous subjects. The arterial subjects included 3 groups: hypertensive, hypotensive, or normal. During the arterial and venipuncture procedures, we measured sampler filling time and recorded blood volume. The P_{O_2} of the samples was measured. Additionally, blood pressure and S_{pO_2} were measured in the arterial group. RESULTS: The mean sampler filling time was 220.4 s/mL for the venous group, and 18.1 s/mL for all 3 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 rate between the arterial subgroups ($P > .99$). The correlation between mean arterial pressure and filling rates was 0.06 ($P = .38$). CONCLUSIONS: There is a significant difference between arterial and venous filling rates. There was no relationship between filling time and abnormal mean arterial pressure. Regardless of the arterial pressure, the 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.* [Respir Care 2013;58(11):1907–1910.

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_{aCO_2} is in the normal range, the agreement between the arterial and venous values is acceptable for pH, P_{CO_2}, and bicarbonate, but oxygenation status cannot be accurately assessed with venous blood.[2] During a COPD exacerbation, when P_{aCO_2} is higher than

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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.

The authors have disclosed no conflicts of interest.

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DOI: 10.4187/respcare.02339

normal, there is insufficient agreement between venous and arterial P_{CO_2} for a venous blood measurement to replace an arterial blood measurement in determining the degree of hypercarbia.[3] Therefore, it is crucial to be certain of obtaining an arterial sample, not a venous sample. Clinical practice guidelines recommend assessing the color and pulsatile flow of the blood during sampling.[4,5] Sampling errors may occur in some circumstances. In a patient with hypotension the pulse pressure may be decreased and pulsatile flow may be low or absent. Arterial blood will likely appear darker and be mistaken for venous blood if the patient is hypoxemic. Sampling errors can result in unnecessary repeated punctures, and can be hazardous to the patient if venous blood is mistaken for arterial blood, or arterial mistaken for venous. Arterial puncture is more painful than venous puncture, 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 et al initially described 3 vented arterial samplers when they were introduced in the 1980s.[7] Although they claimed that "All 3 greatly reduce or eliminate the error of venous sampling," they did not test the samplers under venous pressure. Since the samplers filled passively, their claim was based on eliminating the then common practice of sampling arterial blood with a syringe. Sampler filling time begins with the initial flash of blood in the needle hub and ends when the preset sampler blood volume is obtained. With vented arterial samplers, 2 studies found significant differences between arterial and venous sampler filling time. Johnson et al used an extracorporeal laboratory model to also compare the needle length and gauge to sampler filling time.[8] They concluded that there was no significant difference in filling time between 2 different needles, but the study was criticized for lack of clinical validity.[9] Bender et al's study[10] did include human subjects, but only a few subjects with abnormal blood pressure, which the investigators defined as a mean arterial pressure $<$ 80 mm Hg or $>$ 100 mm Hg, and the venous filling times were remarkably longer than those in Johnson et al.[8]

Since there have been no other studies of blood sampling time in subjects with abnormal blood pressure, we studied the effects of abnormal blood pressure on sampler filling time, to determine if filling time can be an accurate indicator of obtaining an arterial rather than a venous sample. Our research questions were: is there a difference between sampler filling time for venous versus arterial blood over the range of abnormal arterial blood pressure? and is there a relationship between filling time and mean arterial pressure over the range of abnormal arterial blood pressure? We hypothesized that there would be a significant difference between sampler filling times for venous and arterial samples over the range of abnormal arterial blood pressure, and a significant negative correlation between sampler filling time and mean arterial pressure in adults with abnormal blood pressure.

QUICK LOOK

Current knowledge

Percutaneous arterial puncture is common, and clinicians use blood color and pulsatile flow to confirm that they are obtaining arterial (not venous) blood. Hypoxia and hypotension can confound the use of color and pulsatile flow as indicators of arterial puncture.

What this paper contributes to our knowledge

There was a significant difference in sampler filling rate between arterial and venous blood. Sampler filling rate can be used as an indicator of arterial puncture, even in a patient with hypotension.

Methods

We conducted a comparative and correlational study, using a sample of convenience at the Wexner Medical Center at Ohio State University. This study was approved by our Office of Responsible Research Practices (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 sample. The venous subjects were healthy adult volunteers affiliated with the School of Health and Rehabilitation Sciences. Our subjects were divided into 4 groups: hypotensive (mean arterial pressure $<$ 80 mm Hg), normal (mean arterial pressure 80–100 mm Hg), hypertensive (mean arterial pressure $>$ 100 mm Hg), and venous.

In the venous group a critical care nurse used an arterial sampler (Pro-Vent, Portex-Smith Medical, Dublin, Ohio) with a 23 gauge needle, and took 0.5–2 mL of blood from the antecubital vein. The antecubital vein was identified with a tourniquet, which was removed before the puncture. In the arterial group we measured S_{pO_2} 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 subject for an arterial puncture. All therapists used an arterial sampler (Pro-Vent, Portex-Smith Medical, Dublin, Ohio) with a 23 gauge needle, and took 0.5–2 mL of blood from the radial artery. Sampler filling time was defined as the time from when

Table. Sampler Filling Rates and P_{O_2} for Arterial and Venous Sampling

	Arterial			Venous	
	Hypotensive (< 80 mm Hg) $n = 13$	Normotensive (80–100 mm Hg) $n = 6$	Hypertensive (> 100 mm Hg) $n = 6$	$n = 15$	P
Filling rate, s/mL	19.8 ± 5.8	13.3 ± 4.0	21.1 ± 10.3	220.4 ± 102.2	< .001
P_{O_2}, mm Hg	120.9 ± 65.5	87.3 ± 30.3	201.1 ± 188.4	37.4 ± 10.6	< .001

Values are mean ± SD.

blood first entered the needle hub until the preset volume was reached. We measured sampler filling time with a stopwatch and recorded the volume of blood drawn. If the sampler did not fill to the set volume, any air was evacuated immediately. P_{O_2} 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 mean arterial pressure using the equation:

$$\text{Mean arterial pressure} = (\text{systolic} + [2 \times \text{diastolic}])/3$$

We calculated the sampler filling rate by dividing the filling time by the blood volume. We used analysis of variance with repeated measures to compare the sampler filling rates between the 4 groups, and applied the Tukey post hoc comparison to identify significant differences. We used the Pearson product-moment correlation coefficient to determine the relationship between mean arterial pressure and the sampler filling rate in the arterial groups. The alpha level was set a priori at .05.

Results

The sampler filling rates and P_{O_2} values are presented in the Table. The P_{O_2} values confirmed blood samples as arterial or venous. The mean arterial sampler filling time was 220.4 s/mL for the venous group, and 18.1 s/mL for all 3 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 the arterial subgroups ($P > .99$). The correlation between mean arterial pressure and fillings rate was 0.06 ($P = .38$).

Discussion

Some of our results are consistent with those of Johnson et al,[8] who used an extracorporeal laboratory model, and Bender et al,[10] who studied primarily normotensive human subjects. Consistent with our results, both previous studies also showed a significant difference between arterial and venous sampler filling rate. Johnson et al used a 23 gauge, 2.5 cm needle and found a mean sampler filling rate range of 11.5–20.5 s/mL in 6 arterial groups, with mean arterial pressure range of 57–133 mm Hg; the filling rate was 49.2 s/mL for the venous group. Bender et al found a mean sampler filling rate of 15.1 s/mL in their arterial group, and 114.5 s/mL in their venous group. All 3 studies found that venous filling time is significantly longer than arterial filling time, and that the filling rate is an accurate indicator of a successful arterial puncture, regardless of mean arterial blood pressure, even in hypotensive or hypertensive subjects.

The mean filling rate for our hypertensive group, defined as a mean arterial pressure > 100 mm Hg, was surprisingly longer than our normotensive and hypotensive groups. Contrary to the results in Johnson et al and Bender et al, showing significant negative Pearson correlation coefficients between mean arterial pressure and sampler filling rate, our results show very little correlation with hypertension. In the laboratory, using constant blood flow in a circuit, Johnson et al found a strong negative correlation of −0.86. Bender et al's results, which included primarily adults with normal mean arterial pressure, 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 pressure, we no longer observed a significant correlation between mean arterial pressure and sampler filling time. This inconsistency was largely due to the longer filling time 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 would not in the laboratory model.

Johnson et al's venous filling rate was 49.2 s/mL, but they admitted it could be underestimated, because the lowest pressure in the circuit exceeded normal venous pressure. As well, we thought that Bender et al's longer mean venous filling rate (114.5 s/mL) required further investigation. As a result, we repeated the venous group punctures in our study. Unexpectedly, our venous filling times were longer than Bender et al's, with a mean filling rate of 220.4 s/mL. This discrepancy is thought to be attributed to

the difference in methods between the 2 studies. The phlebotomist in the Bender et al study did not remove the tourniquet until after the initial blood flash. Our nurse used the tourniquet only to identify the vein, then removed it before the puncture. The difference in methods could have led to the venous group in the Bender et al study to have shorter filling time, because the tourniquet release may have caused an initial burst of pressure. Our results better mimicked 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 observed punctures using only 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.

Conclusions

In adults, regardless of mean arterial pressure, there is a significant difference between arterial and venous sampler filling time with a vented sampler. Respiratory therapists and other clinicians performing arterial punctures can use arterial sampler filling time to identify successful arterial puncture during the procedure. Successful arterial puncture has a sampler filling time range of 13.3–21.1 s/mL, or approximately 18 s/mL.

REFERENCES

1. Siobal MS. Analysis and monitoring of gas exchange. In: Kacmarek RM, Stollar JK, Heuer AJ, editors. Egan's fundamentals of respiratory care, 10th edition. St Louis: Mosby/Elsevier; 2013:381-395.
2. Malatesha G, Singh NK, Bharija A, Rehani B, Goel A. Comparison of arterial and venous pH, bicarbonate, P_{CO_2} and P_{O_2} in initial emergency department assessment Emerg Med J 2007;24(8): 569-571.
3. McCanny P, Bennett K, Staunton P, McMahon G. Venous vs arterial blood gases in the assessment of patients presenting with an exacerbation of chronic obstructive pulmonary disease. Am J Emerg Med 2012;(30):896-900.
4. American Association for Respiratory Care. AARC Clinical Practice Guidelines. Sampling for arterial blood gas analysis. Respir Care 1992;37(8):891-897.
5. Blonshine S, Fallon KD, Lehman CM, Sittig S; Clinical and Laboratory Standards Institute (formerly NCCLS). Procedures for the collection of arterial blood specimens: approved standard, 4th edition. 2004.
6. Giner J, Casan P, Belda J, Gonzalez M, Miralda RM, Sanchis J. Pain during arterial puncture. Chest 1996;110(6):1443-5.
7. Hutchison AS, Dryburgh FJ, Ralston SH. Sampling errors in pH and blood gas analysis: an evaluation of three new arterial blood samplers. Ann Clin Biochem 1986;23(5):329-33.
8. Johnson KL, Johnson AJ, Barnes KA, Douce FH. Effects of mean arterial pressure and needle size on arterial sampler filling time. Respir Care 2011;56(4):456-459.
9. Hess DR. Editor's commentary on the April 2011 issue. Respir Care 2011;56(4):393.
10. Bender JJ, Allison JR, Goehring JJ, Patel MD, Niederst SM, Douce FH. Arterial sampler filling times during percutaneous puncture in human subjects. Respir Care 2012;57(11):1945-1948.