

Effects of Pneumatic Tube Transport on Blood Gas and Supplemental Analytes

Phillip R Jensen, Ryan L Aramaki, Steve C Mannebach, and Boaz A Markewitz

BACKGROUND: Pneumatic tube transport of blood gas samples is a common method of delivery within a facility. The effects of pneumatic tube transport on blood gas analysis has been studied. However, other analytes that are often assessed in blood gas analysis (eg, electrolytes, metabolites, and oximetry) are not typically included in these studies. We sought to investigate the impact of pneumatic tube transport on some of these other analytes. **METHODS:** The study was conducted at the blood gas laboratory at the University of Utah Hospital. A split sample comparison was performed. Both samples were walked to a pneumatic tube station, where one sample was sent via tube to the blood gas laboratory, while the other sample was walked back to blood gas laboratory. We examined 2 samples from each of the 27 different pneumatic tube stations in this hospital. Results were graphed with upper and lower control limits set to conform to acceptable College of American Pathologists proficiency testing evaluation criteria. Data were compared using the Student *t* test. **RESULTS:** Differences between walked and tubed specimens were neither clinically nor statistically significant. **CONCLUSIONS:** Pneumatic tube transport of blood gas specimens is acceptable for blood gas and supplementary analytes, as evidenced by multiple points of evaluation, including statistical analysis, clinical judgment, and concordance with regulatory guidelines. *Key words:* pneumatic tube; blood gas; quality improvement; pulmonary laboratory. [Respir Care 2021;66(10):1567–1571. © 2021 Daedalus Enterprises]

Introduction

Pneumatic tube transport of blood gas samples is a common method of delivery to a blood gas laboratory. Prior studies have shown acceptable levels of impact on pH and P_{CO}₂ analysis, but results for P_O₂ vary based on the study, with the consensus being that latent air bubbles or pneumatic tube carriers that are not pressure sealed may be potential sources of error.^{1,2}

What is typically unaccounted for in these studies are the other analytes that are often assessed in blood gas laboratories (eg, electrolytes, metabolites, and oximetry), even though there are studies that highlight a potential for hemolysis in samples sent via pneumatic tube.^{3,4} Cakirca and

Erdal⁵ and Tiwari et al⁶ reported that the use of the foam padding and lower transport speeds may eliminate hemolysis due to pneumatic tube transport.

Most of the related studies in the literature only include a single pathway through the pneumatic tube system, such as the pathway from an emergency department or operating room to the blood gas laboratory or clinical laboratory. The elevation differences within these facilities range from 15 m to 1,020 m above sea level.

This study evaluates blood gas values and the concomitant analytes generally reported across a > 500-bed academic medical center with multiple pneumatic tube stations. The aim of the study was to determine the effect of pneumatic tube transport on all reported values as assessed with our blood gas analyzers.

Mr Jensen, Mr Aramaki, and Mr Mannebach are affiliated with the Pulmonary Laboratory, University of Utah Health Sciences, Salt Lake City, Utah. Dr Markewitz is affiliated with the Department of Internal Medicine, Section of Respiratory, Critical Care, Occupation (Pulmonary) Medicine, University of Utah Health Sciences, Salt Lake City, Utah.

The authors have disclosed no conflicts of interest.

Correspondence: Phillip R Jensen MBA RPFT DLM(ASCP). E-mail: phillip.jensen@hsc.utah.edu.

DOI: 10.4187/respcare.07974

Methods

Specimen Processing

This study was conducted by the Pulmonary Laboratory at the University of Utah Hospital from April 14–16, 2019. The Pulmonary Laboratory is in the basement of the University of Utah Hospital at an elevation of approximately 1,500 m above sea level. Barometric pressure ranged from 629.4 to 634.0 mm Hg and averaged 631.0 mm Hg. Blood samples were received through normal care processes. The institutional review board categorized the project as health care improvement and waived the need for consent.

A split sample comparison was performed on blood left over after patient blood gas results were reported. In 8 cases, the remaining blood sample was large enough to split immediately. In 46 cases, the samples were pooled, tonometered for 20 min, and then split. Once a sample was split into 2 separate syringes, both were walked to one of 27 pneumatic tube stations throughout the hospital, at which time one sample was sent via pneumatic tube (SwissLog, Buchs, Switzerland) to the blood gas laboratory, while the other sample was walked back to the blood gas laboratory. The average pneumatic tube system speed is 6.1 m/s. Appropriate padding and carriers were used during transport. After both samples had returned to the blood gas laboratory, they were analyzed serially on the same blood gas analyzer (Radiometer 835, Copenhagen, Denmark).

Statistical Analysis

Two samples were sent from each of 27 different pneumatic tube stations throughout the hospital, for a total of 54 comparison samples. Results were graphed on a difference plot with upper and lower control limits set to conform to acceptable College of American Pathologists proficiency testing evaluation criteria (Table 1).

Table 1. College of American Pathologists Proficiency Testing Evaluation Criteria

Analyte	Criteria
pH	± .04
P _{CO} ₂ , mm Hg	± 8% or 5 mm Hg
P _O ₂ , mm Hg	± 3 SD
Na ⁺ , mmol/L	± 4
K ⁺ , mmol/L	± 0.5
Ca ⁺⁺ , mmol/L	± 3 SD
Lactate, mmol/L	± 0.4 or 3 SD
Glucose, mg/dL	± 6.0 or 10%
Total hemoglobin, g/dL	± 7%
Oxyhemoglobin, %	± 3 or 3 SD
Carboxyhemoglobin, %	± 3 or 3 SD
Methemoglobin, %	± 2

QUICK LOOK

Current knowledge

Pneumatic tube transport of blood gas specimens can be useful and acceptable if all air bubbles are expelled prior to transport, proper padding is used to insulate the specimen from jarring vibrations, and pneumatic tube speed is regulated. Blood gas laboratories often report chemistry analytes in addition to blood gas values that can be influenced by similar issues in pneumatic tube transport, such as hemolysis.

What this paper contributes to our knowledge

With the same safeguards in place for protecting primary blood gas values, pneumatic tube transport of blood gas specimens was safe for other analytes reported by blood gas laboratories. Multiple pathways throughout an institution's pneumatic tube system can be utilized so long as the characteristics of those pathways and sample preparations are standardized and align with best practice.

Average bias was determined, and data were compared using the Student *t* test. Analytes evaluated were pH, P_O₂, P_{CO}₂, total hemoglobin, percent oxyhemoglobin, percent carboxyhemoglobin, percent methemoglobin, sodium (Na⁺), potassium (K⁺), ionized calcium (Ca⁺⁺), glucose, and lactate.

Results

Figure 1 illustrates the differences for each analyte between the walked and tubed samples. Upper and lower control limits are drawn at the proficiency testing evaluation criteria. Visually, the data points for all of the analytes appear to be evenly distributed around the zero point of

Table 2. Average Bias

	Average Bias (walked vs tubed)	Standard Deviation
pH	0	0.007
P _{CO} ₂ , mm Hg	0.1	1.214
P _O ₂ , mm Hg	-0.531	1.584
Total hemoglobin, g/dL	0.043	0.269
Oxyhemoglobin	-0.178	0.613
Carboxyhemoglobin	-0.004	0.095
Methemoglobin	-0.011	0.092
K ⁺ , mmol/L	0.033	0.091
Na ⁺ , mmol/L	-0.185	1.083
Ca ⁺⁺ , mmol/L	-0.002	0.018
Glucose, mg/dL	0.352	4.775
Lactate, mmol/L	0.109	0.434

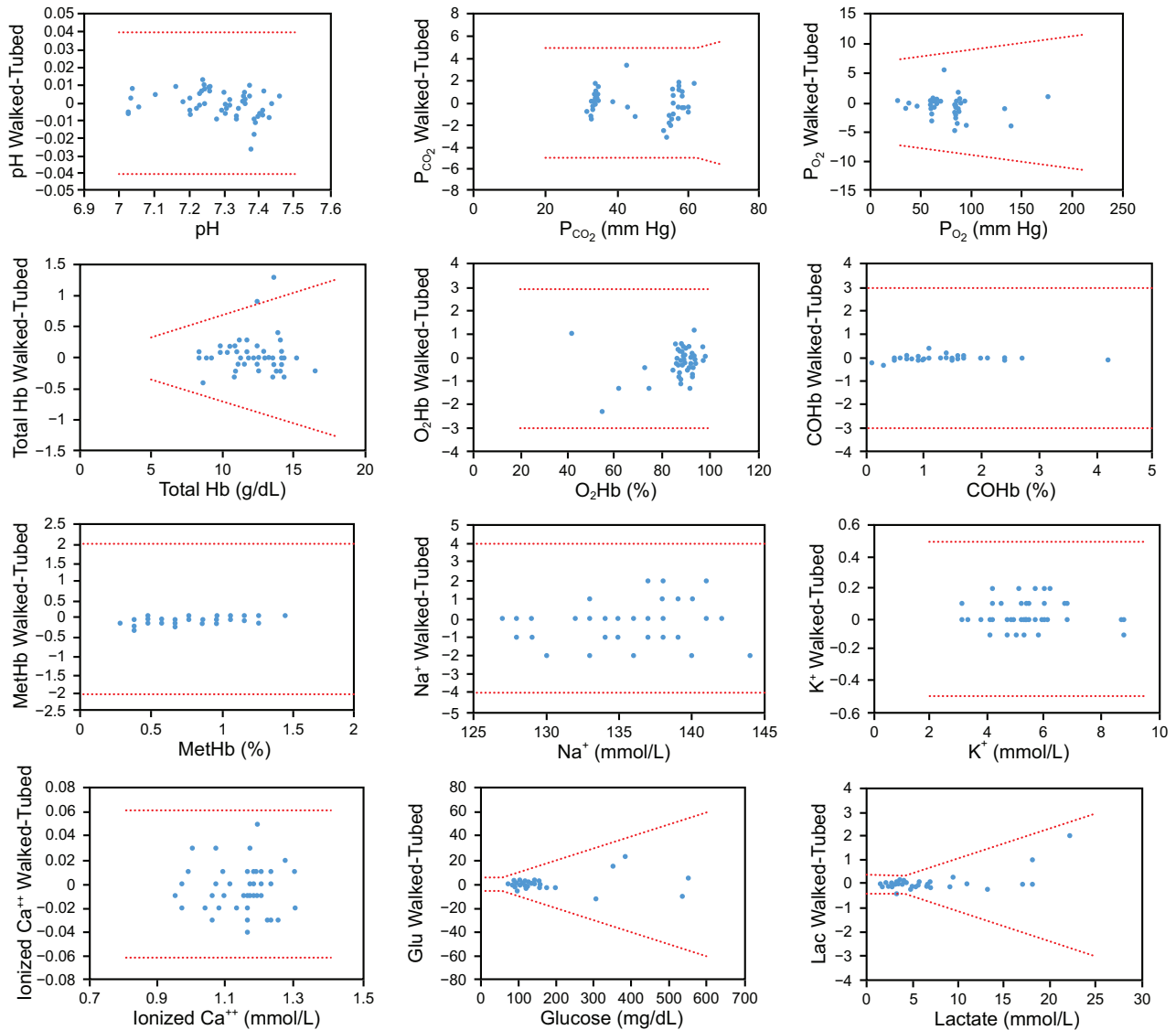


Fig. 1. Differences for each analyte between walked and tubed samples. Upper and lower control limits (dotted lines) are drawn at College of American Pathologists proficiency testing evaluation criteria.

difference without any obvious positive or negative trending across the ranges tested.

Two data points for total hemoglobin fell outside the defined tolerance. All other data points for all remaining analytes fell within range. Total hemoglobin values can be subject to settling and may elicit erroneous values if they are not mixed sufficiently prior to analysis. Inadequate mixing is suspected to be the cause of the 2 total hemoglobin data points that fell outside the acceptability criteria. Each outlier is surrounded by similar data points that were in-range, and the difference is not clinically important.

The average bias for each analyte is not clinically meaningful (Table 2). P_{O_2} and glucose exhibited the largest standard deviations, as might be expected given that the samples were

run serially on the same analyzer. The method employed required one of the samples to sit at the bench-side up to 3 min longer than the first sample analyzed, during which time cellular metabolism continues to consume oxygen and glucose. Use of Student *t* tests showed no statistically significant difference between walked and tubed samples (Table 3).

Discussion

This study provides novel information comparing the results of blood gas analysis (ie, oximetry, electrolytes, and metabolites) of samples transported via pneumatic tube with those of samples transported on foot. Our results indicate that these analytes are not affected by pneumatic tube

PNEUMATIC TUBE TRANSPORT AND BLOOD GAS RESULTS

Table 3. Two-Sample *t* Test Assuming Unequal Variances

	Transport Mode	Mean	Variance	<i>P</i> (1-tail)	<i>P</i> (2 tail)
pH	Walk	7.29	0.01	.49	.98
	Tube	7.29	0.01		
P _{CO₂}	Walk	45	128.9	.48	.96
	Tube	44	134.1		
P _{O₂}	Walk	76	589.0	.46	.91
	Tube	77	603.2		
Total hemoglobin	Walk	11.8	4.4	.46	.92
	Tube	11.7	4.4		
Oxyhemoglobin	Walk	87.7	97.5	.46	.93
	Tube	87.9	94.9		
Carboxyhemoglobin	Walk	1.2	0.5	.49	.98
	Tube	1.2	0.5		
Methemoglobin	Walk	0.8	0.1	.42	.84
	Tube	0.8	0.1		
Na ⁺	Walk	136	17.3	.41	.82
	Tube	136	18.1		
K ⁺	Walk	5.5	1.7	.45	.89
	Tube	5.5	1.7		
Ca ⁺⁺	Walk	1.1	0.01	.45	.9
	Tube	1.1	0.01		
Glucose	Walk	141	10,022.4	.49	.99
	Tube	140	9,865.9		
Lactate	Walk	6.2	27.1	.46	.91
	Tube	6.2	24		

Number of observations = 54. For each analyte, the hypothesized mean difference is 0.

transport. Our results align with previous research findings from traditional blood gas analysis, providing additional support for best-practice packaging and transportation with a pneumatic tube system. Based on the prior referenced studies, it should be recognized that the success of this study is likely due to the set speed of the pneumatic tube system, the use of appropriate padding, and the consistency of sample preparation by trained laboratorians.

The effect of time delay is a factor for concern when considering how well results from a blood gas analysis represent a patient's condition at the time of the blood draw.⁷ Changes in blood gas values over time is well established in the literature beyond the research referenced here. An alternative to eliminate time delay as a source of error, such as point-of-care analysis, could be considered; this would also eliminate the need for pneumatic tube transport. While pneumatic tube transport is a fast and efficient means of transporting samples to a central location for analysis, doing so almost certainly adds time compared to point-of-care analysis, assuming a trained operator is available at the bedside at the time of draw.

Our study has some limitations. Samples were obtained during normal business processes and appear to have a representative range for hospitalized patients; however, because samples were picked randomly from the remainders of

previously processed specimens, and in many cases pooled, not all extreme or critical values are represented. Further study of these extremes is warranted. Furthermore, the steps noted above are not always practiced consistently among non-laboratory staff in real-world scenarios. Indeed, at our facility, nearly 90% of the samples processed in the blood gas lab are drawn from indwelling lines by the nursing staff. Varying use of padding and the presence of minute air bubbles do not always lead to specimen rejection. While this study indicates that pneumatic tube transport itself does not contribute to meaningful sample alterations, real-world sample acquisition and packaging by non-laboratory staff prior to pneumatic tube transport is a potential source of error.

Conclusions

Pneumatic tube transport of blood gas specimens with the described conditions (ie, padding, speed regulation, and optimal sample preparation) is acceptable for blood gas and supplementary analytes as evidenced by multiple points of evaluation, including statistical analysis, clinical judgment, and concordance with regulatory guidelines.

REFERENCES

1. Collinson PO, John CM, Gaze DC, Ferrigan LF, Cramp DG. Changes in blood gas samples produced by a pneumatic tube system. *J Clin Pathol* 2002;55(2):105-107.
2. Carabini LM, Nouriel J, Milian RD, Glogovsky ER, McCarthy RJ, Handler TG, et al. The clinical significance of patient specimen transport modality: pneumatic tube system impact on blood gas analytes. *Respir Care* 2016;61(10):1311-1315.
3. Kara H, Bayir A, Ak A, Degirmenci S, Akinci M, Agacayak A, et al. Hemolysis associated with pneumatic tube system transport for blood samples. *Pak J Med Sci* 2014;30(1):50-53.
4. Ellis G. An episode of increased hemolysis due to a defective pneumatic air tube delivery system. *Clin Biochem* 2009;42(12):1265-1269.
5. Cakirca G, Erdal H. The effect of pneumatic tube systems on the hemolysis of biochemistry blood samples. *J Emerg Nurs* 2017;43(3):255-258.
6. Tiwari AK, Pandey P, Dixit S, Raina V. Speed of sample transportation by a pneumatic tube system can influence the degree of hemolysis. *Clin Chem Lab Med* 2012;50(3):471-474.
7. Knowles TP, Mullin RA, Hunter JA, Douce FH. Effects of syringe material, sample storage time, and temperature on blood gases and oxygen saturation in arterialized human blood samples. *Respir Care* 2006;51(7):732-736.