Effect of Pneumatic Tube Delivery System Rate and Distance on Hemolysis of Blood Specimens

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Background: We evaluated the effects of pneumatic tube system (PTS) transport rates and distances on routine hematology and coagulation analysis. PTS effects on centrifuged blood samples were also examined. **Method:** The study was completed at Dicle University Hospital, which has the longest pneumatic tube system in Turkey. Blood samples were collected at three different locations within the hospital and an emergency department, and delivered to the central laboratory by the PTS or a human carrier. Samples were transported at different rates and over varying distances. Each specimen's potassium (K) and lactic dehydrogenase (LDH) levels, in both the serum and plasma, were tracked

to monitor hemolysis. Measurements of LDH and K were obtained using heparin or citrate. **Result:** A positive correlation was observed between distance and hemolysis in serum samples transported at 4.2 m/sec, and at 3.1 m/sec for more than 2200 m ($r = 0.774$ and $r = 0.766$, respectively). Distance and hemolysis were also correlated in non-centrifuged samples ($r = 0.871$). The alterations in plasma LDH and K levels at different rates and PTS lengths were not statistically significant. **Conclusion:** The rate of hemolysis in PTS transported samples, dependent on PTS length and rate, may seriously affect routine tests of non-centrifuged samples. J. Clin. Lab. Anal. 26:66–69, 2012. © 2012 Wiley Periodicals, Inc.

Key words: tube system; rate; length; hemolysis

INTRODUCTION

Pneumatic tube systems (PTSs) are widely used in hospitals for convenience and reduced turnaround times, but they have also been implicated in hemolysis in transported blood specimens (1). During transport in a PTS, blood samples are often subjected to high speeds and rapid acceleration and deceleration, which can lead to hemolysis. Hemolysis, in turn, potentially affects laboratory parameters, such as lactate dehydrogenase (LDH) and potassium (K) levels (2, 3). Using gel in collection test tubes may provide protection against hemolysis (4), and, therefore, centrifuged sera are likely less prone to hemolysis during PTS transport. Several studies have assessed the level of hemolysis observed in blood samples transported through a PTS, but none have evaluated the role of transport distance and rate. In our study, we report the effects of different PTS rates and distances on routine hematology and coagulation test samples obtained from healthy volunteers. We also evaluate PTS effects on centrifuged samples.

MATERIALS AND METHODS

Tube System Design

The PTS installed at Dicle University Hospital is a computer-controlled, branched system of 11-cm diameter tubes supplied by Swisslog Healthcare Solutions Division, Germany (trading under the name Simeks in Turkey). Three hospitals—the children's hospital, the cardiology institute, and the oncology hospital—are connected to the central laboratory via the pneumatic tube delivery system, which is the longest system in Turkey. System specifications are detailed in Table 1. The system is capable of running at multiple speeds and requires several transfer stations. The force of the PTS is provided by

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TABLE 1. Descriptive Properties of the Pneumatic Tube Delivery System

	Emergency service	Oncology hospital	Cardiology institute	Children hospital
Distance to central laboratory (m)	500	1,380	1,450	1,100
Monthly volume of visit (<i>n</i>)	2,170	2,080	1,100	740
Transport duration (min)	6	12	10	11
Transfer station (<i>n</i>)	1	2	1	2

positive and negative air pressure. Samples are placed in plastic containers, or “tube carriers,” made of high-impact resistant polycarbonate. The tube carriers contain removable padded liners and the sample carriers (“pods”) have protective circular felt or “O” rings on the outside.

Specimens and Transport

In this study, we used blood samples from 40 healthy volunteers. Each volunteer gave ten vacutainer tubes of blood obtained from a single venipuncture performed by a phlebotomist. These samples were sent to the central laboratory from four different locations, three hospitals and an emergency department, via the PTS and a porter. Blood tubes contained separating gel without anticoagulant, heparin, K₂EDTA, or citrate (BD Medical Systems, Franklin Lakes, NJ). The first group, containing all sample types, was immediately transported by a porter. K and LDH levels were measured and accepted as reference values. The second group of samples, containing separating gel without anticoagulant, was divided into two subgroups—one was sent to the central laboratory via the PTS before centrifugation and one after. The third group of samples, with anticoagulant, was sent to the central laboratory via the PTS. All samples were transported via the PTS at two different rates, 3.1 m/sec and 4.2 m/sec.

Sample Analysis

Assays were performed within 1 hr of collection, after centrifugation of the paired specimens at 1500 g for 10 min. Hemolysis was monitored by tracking K concentration and LDH activity. K and LDH levels were determined in both the serum and the plasma using heparin and citrate and an autoanalyzer, Architect 1600c (Abbott Laboratories, Irving, TX). Only LDH levels were measured in tubes with K₂EDTA. Hemogram parameters—including white blood cell counts, hemoglobin, red blood cell counts, and platelets—were measured using Cell-Dyn

3700 (Abbott Labs, Dallas, TX). Assays for prothrombin time (PT), activated partial thromboplastin time (PTT), and fibrinogen were measured on a SysmexCA-7000 coagulation analyzer (Sysmex, Kobe, Japan) using Thromborel S, actin, and thrombin reagent (Dade Behring, Marburg, Germany), respectively.

Statistical Analysis

The nonparametric Mann–Whitney U test was used to evaluate the significance of differences between groups. Results were considered statistically significant given a *P*-value of < 0.05. Correlations were computed using Spearman's test.

RESULTS

K and LDH levels increased significantly in samples transported at a rate of 4.2 m/sec. At a rate of 3.1 m/sec, the increase was not significantly different for those delivered by the PTS and those delivered by hand. However, when sample transportation was repeated twice at 3.1 m/sec, for a total distance of more than 2200 m, a positive correlation between distance and hemolysis ($r = 0.716$, $r = 0.628$, respectively) was observed. K and LDH increases were then also significantly higher for PTS samples than for hand-delivered samples (Fig. 1). A positive correlation between distance and levels of K and LDH was also found in noncentrifuged serum samples ($r = 0.871$ and $r = 0.774$, respectively) transported at a rate of 4.2 m/sec.

No statistically significant differences between PTS samples and samples delivered by hand were observed in routine complete blood cell counts, white cell differential parameters, or markers of platelet activation. There were also no statistically significant differences in PT, activated PTT, and fibrinogen levels between samples delivered by PTS and by hand. Plasma LDH and K levels did not significantly change, given different PTS rates and lengths. The severity of hemolysis (determined by levels of LDH and K) was not significantly different in centrifuged samples transported by PTS and human carrier, regardless of rate and distance (Tables 2 and 3).

DISCUSSION

Using a PTS system to transport blood samples can significantly reduce turn around times for test results without reducing sample quality (5). Laboratories should be aware that defects may arise in tube systems, which could cause rapid sample deceleration and excessive hemolysis (6). The pressure applied to samples during transport should also be considered, as it plays a pivotal role in hemolysis. The

Fig. 1. Serum lactic dehydrogenase (LDH) (U/L) and potassium (K) (mEq/L) values in different rates and lengths transports by PTS before centrifugation.

length of the PTS and the rate of transport increase the pressure on the erythrocytes, resulting in hemolysis (7). These considerations must be taken into account when designing new PTSs. Different hospitals will have varying system configurations and use different sample types. Sodi et al. recommended that each hospital investigate their own system to assess whether hemolysis is a recurring problem in any of the transported sample types (8).

In our hospitals, the longest transport distance is 1,450 m to the central laboratory. The manufacturer warned us about the possibility of PTS-related hemolysis. According to the literature, the mean PTS rate is approximately 7.6 m/sec, but the optimal length is unknown (9). When

we increased the rate of tube transport, hemolysis rates also increased. The optimum rate, calculated from the Figure 1, is 3.1 m/sec, assuming a travel distance below 2200 m. We were not satisfied with these results, as samples that are processed incorrectly (for example, without barcodes or with incorrect barcodes), or whose carriers are sent to wrong locations in the PTS, may elongate the transport distance. After centrifugation of gel containing tubes, hemolysis rates were the same as the reference values, independent of the length of the PTS.

Interestingly, the hemolysis rate of plasma samples increased very slowly as the PTS transport rate and distance increased (Table 2). In nonclotting samples, the

TABLE 2. Mean values of Hemogram, Coagulation, and Hemolysis Parameters in Different Rates and Lengths of the Pneumatic Tube Delivery System

Rate of PTS		3.1 (m/sec)				4.2 (m/sec)			
Length of PTS (m)	§	500	1,100	1,450	2,900	500	1,100	1,450	2,900
WBC (K/ μ l)	6.31	6.45	6.62	5.92	6.33	6.25	6.20	6.04	6.14
RBC (M/ μ l)	5.03	4.99	5.01	5.04	4.98	4.81	4.90	5.04	4.85
HGB (g/dl)	12.9	12.7	12.7	12.9	13.0	12.8	12.7	12.9	12.8
PLT (K/ μ l)	219	212	225	205	207	218	213	222	227
PTT (sec)	11.5	11.5	11.6	11.7	11.3	11.2	11.2	11.4	11.3
aPTT (sec)	28.7	28.4	30.9	27.3	28.6	29.1	29.3	27.8	28.4
K* (mEq/L)	3.8	3.8	3.8	3.9	3.9	3.8	3.9	3.9	4.0
K† (mEq/L)	3.8	3.8	3.9	3.9	3.9	3.8	3.9	4.0	4.0
K‡ (mEq/L)	3.8	3.8	3.8	3.8	3.9	3.8	3.8	3.9	3.9
LDH* (U/L)	215	217	222	221	228	218	225	232	245
LDH† (U/L)	217	223	229	232	237	219	231	235	248
LDH‡ (U/L)	213	216	224	221	218	217	226	228	223

*Plasma obtained by heparin.

†Plasma obtained by citrate.

‡Serum obtained by centrifugation before PTS.

§Transported by a carrier.

TABLE 3. Mean Values of K and LDH in Different Rates and Lengths of the Pneumatic Tube Delivery System

Rate of PTS	‡	3.1 (m/sec)				4.2 (m/sec)			
		500	1,100	1,450	2,900	500	1,100	1,450	2,900
Length of PTS (m)									
K* (mEq/L)	3.8	3.8	3.8	3.8	3.9	3.8	3.8	3.9	3.9
K† (mEq/L)	3.8	3.9	4.0	4.0	4.3§	4.0	4.1	4.2§	4.7§
LDH* (U/L)	213	216	224	221	218	217	226	228	223
LDH† (U/L)	221	235	241	253	352§	259§	289§	372§	406§

*Serum obtained by centrifugation before PTS.

†Serum obtained by centrifugation after PTS.

‡Transported by a carrier.

§ $P < 0.05$ compared with samples transported by a carrier.

hydrodynamic structure of blood may compensate for the pressure of environmental factors, but when clotting occurs in blood without gel separation, the hemolysis rate increases as clots hit the tube wall during transport.

Some researchers found that pneumatic tube sample transport impairs platelet aggregation (10), aspirin responsiveness (11), and spectrophotometric analysis of cerebrospinal fluid samples (12). The rate and length of the PTS may be affecting test reliability; more detailed studies are required.

In conclusion, transport through a PTS has no clinically significant effect on hematology and coagulation results when serum is centrifuged prior to transport. Each hospital should investigate their own system to assess whether hemolysis is a problem for any of their sample types under PTS conditions.

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