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Effects of one directional pneumatic tube system on routine hematology and chemistry parameters; A validation study at a tertiary care hospital

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ABSTRACT

Background: The validation of sample stability through pneumatic tube system (PTS) is essential. The objective of this study was to evaluate the effects of PTS transportation on laboratory results.
Methods: Paired EDTA and SST blood samples were collected from 56 randomly selected patients. Laboratory parameters were compared between PTS group and hand-delivered group.
Results: No statistical differences were observed for complete blood counts, white blood cell differential parameters, erythrocyte sedimentation rate and most chemistry parameters between PTS and hand-delivered transport procedures. Mean platelet volume results obtained from samples transported through PTS were lower than that obtained from samples transported through hand-delivered method ($P = 0.001$). The results of aspartate aminotransferase ($P = 0.000$), lactate dehydrogenase ($P = 0.000$), and hemolysis index ($P = 0.000$) from PTS group were higher than that from hand-delivered group.
Conclusions: All laboratories should validate the stability of the results from samples according to transportation method.

1. Introduction

Preanalytical phase of clinical laboratory testing is the most vulnerable part to errors. This phase includes test ordering, collection of diagnostic specimens, handling, transportation, and storage of the specimen [1]. It has been demonstrated that the great majority of laboratory errors in the total test process come from this preanalytical phase [2]. Inappropriate sample transportations can fail to obtain a valid and fast laboratory test result.

Modern pneumatic tube system (PTS) provides rapid and efficient transportation of blood samples to the laboratory [3] and has been widely adopted. It is widely used to reduce the expanding workloads and to lead to faster sample processing and decreased turnaround times. During transportation, however, samples are often exposed to fast acceleration and deceleration [3]. It has been demonstrated that these changes can alter the quality of samples and induce hemolysis by leading primarily to increase in lactate dehydrogenase (LDH) concentrations, and potassium concentration [3–5]. It can also affect the results of in vitro platelet function test [6]. Incorrect test results can affect the diagnosis and the treatment for patients.

The effects of specimen transport when using a new PTS on laboratory results should be validated. The aim of this study was to evaluate the effects of one directional PTS on hematology and chemistry laboratory results in blood samples.

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2. Materials and methods

2.1. Subjects

Fifty-six pairs of samples for hematology analysis and chemistry analysis were included. Paired blood samples from each patient who underwent preoperative workup were randomly selected from specimen collection room without consideration of diagnosis from November 2016 to December 2016. The median age (range) was 48 (22–87) years. Female/male were 37/19. The collections of blood specimens were performed by well-trained phlebotomists. Samples were collected into 2 vacutainer K_2EDTA plastic tubes (Ref no. 367,856; BD Medical Systems, Franklin Lakes, NJ, USA) and into 2 vacutainer plastic serum tube (Ref no. 367,955; BD Medical Systems, Franklin Lakes, NJ, USA), from the same venipuncture. Laboratory parameters were measured using residual blood samples that would have been discarded. This study has obtained approval from the Institutional Review Board at Daegu Catholic University Medical Center (DCUMC).

2.2. Sample transportation

The PTS installed at DCUMC is a computer-controlled, one directional system of 2.5-cm diameter pipelines (Tempus600®, TIMEDICO A/S, Denmark). Sample tubes (1 in a K_2EDTA tube and 1 in a serum tube) were sent via the PTS. The corresponding sample tubes were hand-delivered by our laboratory personnel. The clinical laboratory is located on the fifth floor and the specimen collection room is located on the first floor at DCUMC. The distance of the PTS between 2 stations is approximately 347 ft (106 m). The system functions at a speed of 7–10 m/s and uses transfer stations that accelerate and decelerate the samples during zone transfers.

2.3. Laboratory parameters

All paired samples were treated in parallel, and analyzed at the same time to reduce the bias originated from time and temperature. Laboratory parameters routinely and frequently ordered were included.

The whole blood specimens anticoagulated with EDTA were analyzed for complete blood counts (CBCs), and white cell differentials using DxH800 (Beckman Coulter, Fullerton, CA, USA) and for erythrocyte sedimentation rate (ESR) using Test 1 (Alifax S.p.A., Polverara, Italy). The DxH800 uses impedence, light scatter and VCS technology in measuring red blood cells (RBCs), platelets (PLTs), white blood cells (WBCs) counts and parameters [7]. The CBC parameters consisted of WBCs, RBCs, hemoglobin (Hb), hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red cell distribution width (RDW), and platelets (PLTs). The WBC differential included the percentages of neutrophils, lymphocytes, monocytes, eosinophils, and basophils. The platelet parameters consisted of mean platelet volume (MPV), and platelet distribution width (PDW). The Test 1 uses photometrical technique to detect RBC aggregation for the measurement of ESR [7,8].

The serum samples were analyzed for aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), LDH, γ -glutamyl transferase (GGT), total bilirubin (T-bil), cholesterol, triglyceride (TG), glucose, protein, albumin, blood urea nitrogen (BUN), creatinine, uric acid, sodium (Na), potassium (K), chloride (Cl), lipemia index, icterus index and hemolysis index using cobas 8000 (Roche Diagnostics System, Basel, Switzerland). The quality control and calibration of all instruments were performed using proprietary controls and standard material.

2.4. Statistical analysis

Statistical analysis was performed using R software, version 3.2.4 (R Development Core Team 2016; http://www.R-project.org/). Continuous parameters with normal distribution are presented as mean with SD. Laboratory data with non-normal distribution are presented as median [interquartile range]. The statistical difference was represented by paired Student's *t*-test or Wilcoxon signed rank test. Statistical significance was considered if $P < 0.05$. Data were plotted using Bland-Altman plot to show difference pattern between the Tempus and hand-delivered method.

3. Results

Hematology parameters and chemistry parameters were obtained from samples sent to the laboratory by the PTS and hand-delivered method. The CBC and ESR results are shown in Table 1. No statistical differences were observed for CBC and ESR between PTS and hand-delivered transport procedures. There were no statistical differences for WBC differential parameters (Table 2). PLT parameters are shown in Table 3. MPV results between PTS and hand-delivered method showed statistical difference ($P = 0.001$). Mean difference between PTS and hand-delivered method were lower than zero for MPV (Fig. 1). The biggest difference in MPV was 2.4 fL. Bland-Altman plot showed that differences in measurements were within the 95% confidence interval of the mean difference except two outliers.

As shown in Table 4, median values of chemistry parameters were not significantly different except for AST ($P = 0.000$), LDH ($P = 0.000$), and hemolysis index ($P = 0.000$). Bland-Altman plots of these parameters are shown in Fig. 1. These plots showed that differences in measurements were within the 95% confidence interval of the mean difference except one to three outliers. Means of differences between PTS and hand-delivered method (represented by the solid bold line in Fig. 2) were systematically higher than

Table 1
Complete blood count (CBC) parameters and erythrocyte sedimentation rate (ESR) in the paired samples delivered to the laboratory via the pneumatic tube system (PTS) or by the courier.

Parameter	Courier	PTS	*P* value
RBC, × 10^{12}/L	4.00 [3.50–4.50]	4.00 [3.50–4.50]	0.705
Hb, g/dL	13.0 [12.0–14.0]	13.0 [12.0–14.0]	0.782
Hct, %	40.0 [34.0–46.0]	40.0 [33.0–47.0]	0.298
MCV, fL	90.6 [87.1–94.1]	90.5 [87.6–93.4]	0.207
MCH, pg	30 [28.1–31.9]	30 [28.1–31.9]	0.481
MCHC, g/dL	33 [32.5–33.5]	33 [32–34]	0.215
RDW, %	13 [12.1–13.9]	13 [12.1–13.9]	0.344
WBC, × 10^9/L	6.5 [5.0–8.0]	6.0 [4.6–7.4]	0.510
PLT, × 10^9/L	244 [212.5–275.5]	236 [200.5–271.5]	0.598
ESR, mm/h	12 [4.5–19.5]	10 [4–16]	0.263

RBC, red blood cell count; Hb, hemoglobin; Hct, hematocrit; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; RDW, red cell distribution width; WBC, white blood cell count; PLT, platelet count; PTS, pneumatic tube system.

Table 2
White cell differential parameters in the paired samples delivered to the laboratory via the pneumatic tube system (PTS) or by the courier.

Parameter	Courier	PTS	*P* value
Percentages			
Neutrophils	62.8 ± 11.7	62.5 ± 11.3	0.450
Lymphocytes	27.5 ± 10.8	27.5 ± 10.4	0.905
Monocytes	7 [5.5–8.5]	7 [5.5–8.5]	0.382
Eosinophils	2 [1–3]	2 [1–3]	0.335
Basophils	1 [0.5–1.5]	1 [0.5–1.5]	0.835
Absolute neutrophil count, × 10^9/L	4 [2.5–5.5]	4 [2.5–5.5]	0.450

Table 3
Platelet parameters in the paired samples delivered to the laboratory via the pneumatic tube system (PTS) or by the courier.

Parameter	Courier	PTS	*P* value
MPV, fL	8 [7.5–8.5]	8 [7.5–8.5]	0.001
PDW, %	16.3 [15.8–16.8]	17 [16.5–17.5]	0.189

MPV, mean platelet volume; PDW, platelet volume distribution width.

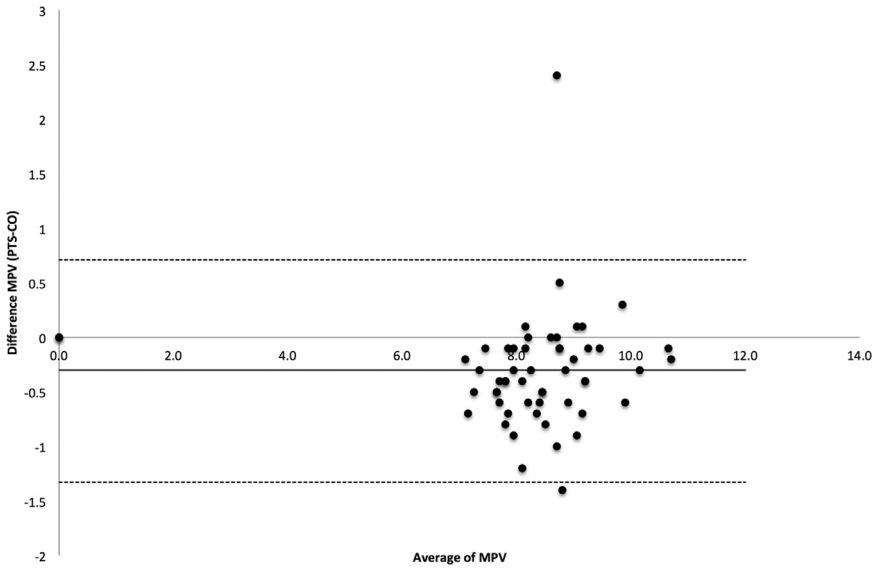

Fig. 1. Bland-Altman plot of MPV obtained from the paired samples transported through the pneumatic tube system (PTS) and the courier (CO) methods. Values on the x-axis show the result form the samples transported through PTS and CO methods. Values on the y-axis indicate the difference in the values from each paired samples.

Table 4
Chemistry parameters in the paired samples delivered to the laboratory via the pneumatic tube system (PTS) or by the courier.

Parameter	Courier	PTS	*P* value
AST, U/L	18.5 [13.5–23.5]	19 [14.5–23.5]	0.000
ALT, U/L	14.5 [9–20]	14.5 [8.5–20.5]	0.303
ALP, U/L	62 [41–83]	62.5 [40.5–84.5]	0.415
LDH, U/L	177.5 [156–199]	191.5 [169–214]	0.000
GGT, U/L	15 [10–20]	15 [10–20]	0.333
T-bil, mg/dL	0 [0–0.5]	0 [0–0.5]	0.180
Cholesterol, mg/dL	187.5 [156.5–218.5]	186.5 [152.5–220.5]	0.641
TG, mg/dL	105 [62–148]	105 [61.5–148.5]	0.641
Protein, g/dL	7 [6.5–7.5]	7 [6.5–7.5]	0.796
Albumin, g/dL	4 [3.5–4.5]	4 [3.5–4.5]	0.131
BUN, mg/dL	12.5 [8.9–16.2]	12.5 [8.9–16.2]	0.568
Creatinine, mg/dL	1 [0.5–1.5]	1 [0.5–1.5]	0.151
K, mEq/L	4 [3.8–4.2]	4[3.8–4.2]	0.366
Hemolysis index	7 [4–10]	8 [3–13]	0.000

AST, aspartate aminotransferase; ALT, alanine aminotransferase; ALP, alkaline phosphatase; LDH, lactate dehydrogenase; GGT, γ-glutamyl transferase; T-bil, total bilirubin; TG, triglyceride; Na, sodium; K, potassium; Cl, chloride.

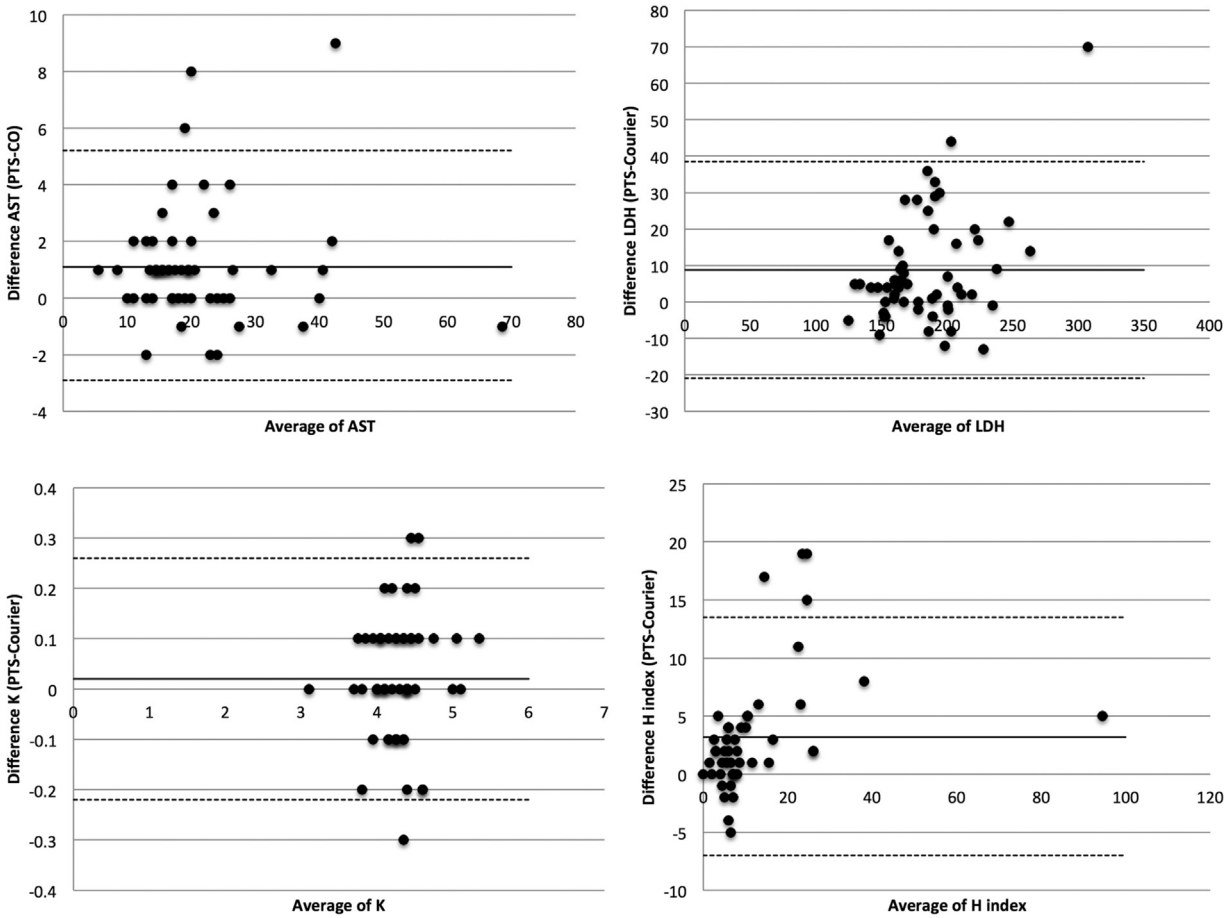

Fig. 2. Bland-Altman plot of AST, LDH, K, and hemolysis index obtained from the paired samples transported through the pneumatic tube system (PTS) and the courier (CO) methods. Values on the x-axis show the result form the samples transported through PTS and CO methods. Values on the y-axis indicate the difference in the values from each paired samples.

zero for AST, LDH, K, and hemolysis index indicating a very small but systematic bias.

4. Discussion

In the present study, we evaluate the effects of new PTS on hematology and chemistry results. During sample transport in the PTS,

blood samples are subjected to high speeds, rapid sample acceleration and deceleration [3]. It may increase the risk of hemolysis and affect the sample quality and test result. Therefore, the validation of sample stability through PTS is essential for correct analysis and reliable laboratory test results. In the current study, we evaluated the difference between the results obtained from the PTS transport procedure and the results obtained from hand-delivered procedure.

In this study, there were no statistical significant differences for CBC, WBC differential count, and ESR between both methods. Results of the present study correspond well with those of the earlier studies which reported that PTS does not affect hematology parameters [3,9–11]. A recent study found no statistical differences for CBC, and ESR between the PTS and hand-carried method [10]. In this study, CBC parameters and ESR were analyzed using the Beckman Coulter LH780 Gen-S system and Alifax-SPA Test 1 HDL system, respectively. Another study also showed no statistical significant differences for CBC, reticulocyte count, and ESR transported by both methods [11]. In this study, CBC parameters and ESR were analyzed using the ADVIA® 2120i hematology system and Test 1 YDL system. In the present study, CBC parameters were analyzed using the DxH 800 and ESR was measured using the Test 1.

There was statistical significant difference for MPV ($P = 0.001$) in this study. The mean difference was 0.3 fL, which was lower in samples transported via PTS than in samples transported via hand-delivered method. This difference was minimal and likely to be clinically acceptable. MPV is a measure of the platelet volume reflecting platelet size and has been thought a useful index of platelet activation [12]. It has also been demonstrated previously that clinically insignificant but statistically significant results on the mean platelet component were observed between PTS and manual transportation [3]. In another study, there was no effect on the mean platelet component [10]. Recent study found no statistically significant effects of PTS transport on platelet aggregation in patients with anti-platelet therapy [13].

Most chemistry parameters showed no statistically significant difference. Parameters relevant to hemolysis including LDH, hemolysis index, and AST showed statistically significant difference. The results obtained from samples transported through PTS tended to be higher than the results obtained from samples transported through hand-delivered method. Means of differences between PTS and courier method were higher than zero for AST, LDH, K, and hemolysis index. However, Bland Altman plots for these parameters shows few outliers in the reference range, which might be probably due to individual's condition. There was no significant outlier that would affect clinical judgement and action. These differences for AST, LDH, K, and hemolysis index could result in the systematic bias. It has been reported that acceleration and deceleration phase during PTS transport could affect the quality of samples and lead to hemolysis [14–16]. These changes can lead primarily to increase in LDH concentrations, and potassium concentration [3–5]. On the other hand, it has been demonstrated that the PTS did not affect samples and the K level did not show significant difference [9]. Although PTS transportation may seriously affect routine tests of non-centrifuged samples, the severity of hemolysis, plasma LDH and K levels were not significantly different in centrifuged samples transported by PTS and human carrier, regardless of rate and distance in the previous study [17]. These differences may be attributed to different manufacturers of PTS, different PTS lengths, different rates, and different methods of installation. In the present study, the transportation rates were 10 m/s, which is faster than the rates of previous study. The acceleration and deceleration phase through PTS system might result in hemolysis and lead to increase in chemistry parameters relevant to RBC damages. However, most values for AST, LDH, and hemolysis index were within the 95% confidence interval of the mean difference. These values could not have an impact on critical clinical decision. However, if the results are unexpectedly high, these differences might be originated from PTS transportation.

There are limitations in this study. This study has a limitation stemming from its small sample size. Another limitation is that the majority of test results were in the normal range.

In conclusion, blood sample transportation through PTS has no clinically significant effect on routine hematology parameters. Chemistry parameters including AST, LDH, and hemolysis index, which are interfered with hemolysis tended to show higher result in samples transported through PTS. All laboratories should validate the stability of the results from samples according to transportation method.

References

[1] G. Lippi, G. Banfi, S. Church, M. Cornes, G. De Carli, K. Grankvist, G.B. Kristensen, M. Ibarz, M. Panteghini, M. Plebani, M. Nybo, S. Smellie, M. Zaninotto, A.-M. Simundic, Preanalytical quality improvement. In pursuit of harmony, on behalf of European Federation for Clinical Chemistry and Laboratory Medicine (EFLM) Working group for Preanalytical Phase (WG-PRE), Clin. Chem. Lab. Med. 53 (2015) 357–370.
[2] A.-M. Simundic, G. Lippi, Preanalytical phase–a continuous challenge for laboratory professionals, Biochem. Med. 22 (2012) 145–149.
[3] A. Kratz, R.O. Salem, E.M. Van Cott, Effects of a pneumatic tube system on routine and novel hematology and coagulation parameters in healthy volunteers, Arch. Pathol. Lab. Med. 131 (2007) 293.
[4] H. Steige, J.D. Jones, Evaluation of pneumatic-tube system for delivery of blood specimens, Clin. Chem. 17 (1971) 1160–1164.
[5] R. Sodi, S.M. Darn, A. Stott, Pneumatic tube system induced haemolysis: assessing sample type susceptibility to haemolysis, Ann. Clin. Biochem. 41 (2004) 237–240.
[6] U. Hübner, N. Böckel-Frohnhöfer, B. Hummel, J. Geisel, The effect of a pneumatic tube transport system on platelet aggregation using optical aggregometry and the PFA-100, Clin. Lab. 56 (2010) 59–64.
[7] A.-J. Lee, S.-G. Kim, Mean cell volumes of neutrophils and monocytes are promising markers of sepsis in elderly patients, Blood Res. 48 (2013) 193–197.
[8] M.R. Hardeman, M. Levitus, A. Pelliccia, A.A. Bouman, Test 1 analyser for determination of ESR. 1. Practical evaluation and comparison with the Westergren technique, Scand. J. Clin. Lab. Investig. 70 (2010) 21–25.
[9] C.M.B. Fernandes, A. Worster, K. Eva, S. Hill, C. McCallum, Pneumatic tube delivery system for blood samples reduces turnaround times without affecting sample quality, J. Emerg. Nurs. 32 (2006) 139–143.
[10] F. Emel Koçak, M. Yöntem, Ö. Yücel, M. Çilo, Ö. Genç, A. Meral, The effects of transport by pneumatic tube system on blood cell count, erythrocyte sedimentation and coagulation tests, Biochem. Med. (2013) 206–210.
[11] G. Lima-Oliveira, G. Lippi, G.L. Salvagno, F. Dima, G. Brocco, G. Picheth, G.C. Guidi, Management of preanalytical phase for routine hematological testing: is the pneumatic tube system a source of laboratory variability or an important facility tool? Int. J. Lab. Hematol. 36 (2014) e37–e40.

[12] A.Y. Gasparyan, L. Ayvazyan, D.P. Mikhailidis, G.D. Kitas, Mean platelet volume: a link between thrombosis and inflammation? Curr. Pharm. Des. 17 (2011) 47–58.
[13] D. Enko, H. Mangge, A. Münch, T. Niedrist, E. Mahla, H. Metzler, F. Prüller, Pneumatic tube system transport does not alter platelet function in optical and whole blood aggregometry, prothrombin time, activated partial thromboplastin time, platelet count and fibrinogen in patients on anti-platelet drug therapy, Biochem. Med. 27 (2017) 217–224.
[14] G. Ellis, An episode of increased hemolysis due to a defective pneumatic air tube delivery system, Clin. Biochem. 42 (2009) 1265–1269.
[15] N.R. Chawla, J. Shapiro, R.L. Sham, Pneumatic tube “pseudo tumor lysis syndrome” in chronic lymphocytic leukemia, Am. J. Hematol. 84 (2009) 613–614.
[16] T. Streichert, B. Otto, C. Schnabel, G. Nordholt, M. Haddad, M. Maric, A. Petersmann, R. Jung, C. Wagener, Determination of hemolysis thresholds by the use of data loggers in pneumatic tube systems, Clin. Chem. 57 (2011) 1390–1397.
[17] O. Evliyaoğlu, G. Toprak, A. Tekin, M.K. Başarali, C. Kilinç, L. Çolpan, Effect of pneumatic tube delivery system rate and distance on hemolysis of blood specimens: pneumatic system rate and length on hemolysis, J. Clin. Lab. Anal. 26 (2012) 66–69.