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Original Research Article

Comparative Validation Study between Pneumatic Tube System and Hand Carried Blood Sample

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Abstract

Rapid delivery of specimens is crucial in today's clinical laboratories, and pneumatic tube systems are commonly utilized for this purpose. The validation of sample stability through pneumatic tube system (PTS) is essential. The use of Pneumatic Tube System can improve specimen turnaround time; allowing more effective time management of the porters by reducing the need to physically take specimens from one department to another. Prior to use, the Pneumatic tube system must be validated to ensure the reliability of laboratory test results, particularly those impacted by movement, such as lactate dehydrogenase (LDH), aspartate aminotransferase (AST), potassium (K+), complete blood count (CBC), particularly hemoglobin and coagulation tests. The most common way of validating pneumatic tube systems is to compare blood samples transported by pneumatic tube systems to blood samples transported by hand. High speeds and rapid acceleration of blood samples can increase the risk of hemolysis and negatively affect sample quality and test results. Moreover, the installation and design of each pneumatic tube system exhibit unique characteristics that are exclusive to each individual institution. The established protocol necessitated the use of either a human courier or pneumatic tube technology in order to transport a collection of replicated samples to the laboratory. Comparative research will be conducted on a sample size of twenty healthy adult volunteers to assess the integrity of the sample. The main objective of our study was to evaluate the effects of PTS transportation on laboratory results and whether is there any difference as compared to hand courier method.

Keywords: Pneumatic tube system; manual delivery system; validation study.

INTRODUCTION

This initial segment offers a thorough examination of the matter at hand and establishes the context for later deliberation. Significant advancements are continuously being achieved in the domain of laboratory sample processing, focusing primarily on the automation and expeditiousness of procedures. These advancements are aimed at alleviating the burden on healthcare professionals and improving the efficiency of result delivery, thus raising the quality of patient care. The rapid incorporation of emerging technologies is a challenge for regulatory frameworks to keep pace with innovation, especially when the absence of internal audits and quality assurance procedures for recently implemented protocols [2]. The significance of quality assurance during the preanalytical phase of clinical laboratory investigation accounts the transport of samples via pneumatic tube systems. Turnaround time (TAT), A key indicator of laboratory performance is worldwide accepted way of expressing the timeliness of laboratory services. This definition of TAT includes the preanalytical phase of the testing process, and therefore the time taken to transport samples to the laboratory. This has placed demands on clinical staff to reduce hospital length of stay and improvise early patient discharge.

MATERIALS AND METHODS

Samples, the Collection and Transportation of Blood Sample

Two methodologies were used to evaluate the impact on the six standard laboratory tests, which are recognized as the most sensitive parameters impacted.

The established protocol necessitated the use of either a human courier or pneumatic tube technology in order to transport a collection of replicated samples to the laboratory. Comparative research will be conducted on a sample size of twenty healthy adult volunteers to assess the integrity of the sample. Two methodologies were used to evaluate the impact on the six standard laboratory tests, which are recognized as the most sensitive parameters impacted. Six tubes of blood were drawn from 20 healthy people and placed in lithium heparin tube (for potassium (K+), Aspartate Aminotransferase (AST) and Lactate Dehydrogenase (LDH), EDTA tube (for CBC) and sodium citrate tube (for Coagulation) by a single experienced phlebotomist. After collecting the specimen, three samples for each individual was sent in PTS and at the same time the other three samples were sent manually to the laboratory. The speed of PTS was 7.5 meter/sec. The laboratory departments were provided with duplicate samples in a variety of unique ways, including delivery by a human courier and the use of the pneumatic tube system (Swisslog). The samples were placed in non-airtight, cushioned containers. When all of the samples arrived in the laboratory, they were all centrifuged at the same time. The chemistry samples were centrifuged at 5000 rpm (2500g) for 5 minutes while coagulation samples were centrifuged for 10 minutes. Then, Abbott Alinity C chemistry analyzer was used to measure LDH, AST and K. Abbott Alinity HQ was used for CBC and Stago R MAX was used for Coagulation samples. Then, the results were entered in the EP evaluator and were compared between PTS group and hand-delivered group. No significant difference was notice on both transportation methods (Tests transported via manual and tests transported via PTS). The test details are shown in Table 1.

Table 1

Number of samples	Test name	Test Tube	Quantity of tubes
20	AST	Lithium Heparin	2
20	LDH	Lithium Heparin	2
20	K	Lithium Heparin	2
20	PTT	Sodium Citrate	2
20	PT	Sodium Citrate	2
20	Hb	EDTA	2
Total samples per individual = 6			

Statistical Analysis:

The statistical analysis was conducted using IBM SPSS Statistics V29.0.1.0 software, developed by IBM Corporation in New York, USA. The normality of the sample data was assessed using the Shapiro-Wilk test. Samples that exhibited a p-value greater than 0.05 were derived from normally distributed populations. These samples were then represented using the mean and standard deviation, and their comparison was conducted using the paired t-test. In an alternative approach, analytes that did not follow a normal distribution were represented using the median value together with the interquartile range. The Wilcoxon signed rank test was employed to compare these cases. The threshold for statistical significance was established at a significance level of $p < 0.05$.

RESULTS

The results of the 20 healthy volunteers' samples for the manual and Pneumatic tube system, in terms of the tests that were performed for lactate dehydrogenase (LDH), aspartate aminotransferase (AST), potassium (K+), complete blood count (CBC), and most notably hemoglobin and coagulation, there were not any statistically significant differences found between the PTS and the hand-delivered transport techniques. This was determined by comparing the results of the tests. The significance level of the aspartate aminotransferase (AST) was found to be (P=0.739), whilst the significance level of the lactate dehydrogenase (LDH) was found to be (P=0.199). The significance level of the potassium levels was discovered to be (P=0.705). When compared with the levels of hemoglobin; however, the significance level found in the hemoglobin levels was found to be (P=0.751). It was discovered that the significance threshold for the partial thromboplastin time (PTT) was (P=0.082). As the cutoff point for statistical significance regarding the prothrombin time (PT), the value of (P=0.109) was used.

The following table shows the Cumulative results for PTS and manual transported samples in Table 2.

Table 2

Test Name	Cumulative results for PTS Transported samples	Cumulative results for Manual Transported samples	Result STATUS
AST	24.2 U/L	24.3 U/L	PASS
LDH	209.8 U/L	204.3 U/L	PASS
K	3.88 mmol/L	3.88 mmol/L	PASS
Hb	14.79 g/dl	14.70 g/dl	PASS
PTT	13.26 sec	13.36 sec	PASS
PT	33.73 sec	34.2 sec	PASS

The following tables a comparison of Pneumatic tube system and manual handing transportation with standard deviation and their respective P-value is shown in Table 3 and Table 4.

Table 3: Comparison of Pneumatic tube system and manual handing transportation for not normally distributed data

Analytes	Manual Handling			Pneumatic Tube System			Manual Handling to Pneumatic System	P-value (Wilcoxon signed rank test)
	Range	Median	Interquartile Range	Range	Median	Interquartile Range	Average Bias	
AST	14 to 42	22.5	14	15 to 41	23	15	0.02	0.739
K	3.5 to 4.6	3.8	0.4	3.4 to 4.6	3.8	0.3	0.01	0.705
PT	12.3 to 14.1	13.1	1	12.7 to 14.4	13.25	0.7	0.01	0.109
PTT	29.8 to 36.5	34.35	3.9	30.4 to 36.9	35.1	6.5	0.03	0.082

Table 4: Comparison of Pneumatic tube system and manual handing transportation for normally distributed data

Analytes	Manual Handling			Pneumatic Tube System			Manual Handling to Pneumatic System	P-value (Paired t-test)
	Range	Mean	Standard Deviation	Range	Mean	Standard Deviation	Average bias	
LDH	145 to 276	209.8	32.9	153 to 298	204.3	33.5	-0.12	0.199
HB	11.9 to 18.3	14.79	1.31	11.7 to 18.3	14.78	1.38	-0.01	0.751

DISCUSSION

The primary focus of ensuring adherence to proper procedures throughout the analytical phase mostly revolves on laboratory staff. In addition to the analytical techniques, clinical testing includes several activities such as handling and archiving, as well as conveying of samples, are often disregarded, so exerting a substantial influence on the occurrence of errors [3]. The potential use of some pre-analytical enhancements in laboratory testing might have adverse consequences if they priorities convenience above the preservation of sample integrity, hence amplifying the risks associated with sample manipulation [4].

Laboratory turnaround time is a performance quality metric that significantly incorporates the pre-analytical phase [5]. In a clinical setting, the term "turnaround time" refers to the duration between the initiation of a test request and the subsequent availability of the test results [6]. When turnaround time exceed the permitted limitations established by a particular institution, it serves as an indication for the evaluation and enhancement of all stages involved in the testing process [7].

The transportation of samples during post-traumatic stress involves directional changes that expose the sample to various factors, including the phenomenon of fluid mobility, mechanical stress, and heightened interactions between cells and their surrounding containers [8]. These parameters have been associated with the general integrity of the samples, including platelet depletion, elevated hemolysis, and subsequent elevations in potassium and the enzyme lactate dehydrogenase levels, among others [9].

Internal validation of the pneumatic tube system was the focus of this study, which compared the results of six laboratory experiments with those obtained using traditional methods of sample handling. The comparison was made between replicate specimens which were delivered either manually or via the pneumatic tube system. Validation refers to the comprehensive utilization of the pneumatic tube system for a diverse range of tests is required by the hospital clinics. This utilization aims to alleviate the workload of laboratory staff by cutting out the necessity for manually operated sample delivery. Additionally, it aims to meet the criteria set by specific regional laboratory accrediting

bodies and maintains adherence to the requirements to ensures compliance with the methods indicated in prior research on pneumatic tube systems. The ultimate goals of validation include reducing turnaround times and providing clinicians with promptly available, reliable laboratory test results to enhance patient care.

In recent times, sophisticated data recorders are used to record humidity, temperature, acceleration forces, and air pressure during the transportation of blood samples via pneumatic tube systems, examining their influence on the integrity of the samples [7].

Hospital pneumatic tube systems (PTS) provide rapid and efficient transport of samples [10]. Streichert and coworkers showed, fast and large acceleration changes and sudden deceleration or shock forces (three-axis acceleration) may contribute to hemolysis during PTS method [11]. Several studies have demonstrated that lactate dehydrogenase (LDH), potassium (K), and hemolysis index (HI) are prone to increases owing to PTS transport [12]. A number of studies have demonstrated that implementation of PTS and replacing human-courier transport of samples significantly reduces TAT [13]. In this study, one PTS route was used to deliver the samples rather than two routes used in Farnsworth *et al.*, (2018) study [14]. Although PTS method may affect routine tests of non-centrifuged samples, the severity of hemolysis and the rise in plasma LDH and K levels were not significantly different in centrifuged samples transported by PTS and hand carried [15]. Many studies have found that a falsely elevated serum concentration of K is observed in some hematological disorders like leukemia in which there is high amounts of WBCs and the leukemic cells are more susceptible to undergo lysis when exposed to even mild mechanical trauma [16]. Mullins and coworkers reported that plasma LDH had a positive linear relationship with the number of shock forces (>3 g) acquired during transport through the PTS [17].

CONCLUSIONS

All laboratories should validate the stability of the results from samples according to transportation method. Pneumatic Tube Delivery System for Blood Samples Reduces Turnaround Times Without Affecting Sample Quality.

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CONTRIBUTION

Data collection, design, analysis, interpretation, drafting, and critical revisions were done equally by the authors.

CONFLICT OF INTEREST

None of the authors have any conflict of interest with the material of this manuscript.

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