

EVALUATING THE EFFECTS OF A PNEUMATIC TUBE DELIVERY SYSTEM ON THE PATIENT'S LENGTH OF STAY IN AN EMERGENCY DEPARTMENT BY USING A SIMULATION MODEL

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Abstract

Collaboration between emergency departments and clinical laboratories is not as effective as it could be. At this moment the specimens are delivered to the laboratory mostly by a nurse who has to walk constantly between an emergency department and a laboratory. It slows down the turnaround time of results and thereby increases the total throughput time of patients in the ED. In this study, which is a part of approved doctoral thesis, the main objective was to study the effects of a pneumatic tube delivery system on the patient's average throughput time in the Emergency Department. Simulation was used as a research method. A pneumatic tube delivery system scenario was developed and compared the results of the scenario to the results of the simulation model of present operation. The results showed that the average throughput time of patients decreased significantly (13,4 %) when the specimens were delivered to the laboratory by a pneumatic tube delivery system. The use of a pneumatic tube delivery system can significantly reduce the total throughput time of patients in the Emergency Department. It also eliminates tiring back and forth trips for nurses and makes it possible to take more blood tests and see more patients in the Emergency Department.

Keywords: Tube delivery, health care, simulation, clinical laboratory.

Presenting Author's biography

Toni Ruohonen is a senior researcher at the University of Jyväskylä. Mr. Ruohonen holds a bachelor's degree in Information Technology (telecommunication) from Satakunta University of Applied Sciences, Finland. He has successfully defended his doctoral thesis on simulation in health care as well and currently holds a PhD degree (University of Jyväskylä).



1 Introduction

Clinical laboratories are an important part of the patient process in the Emergency Departments. In most cases, the final diagnosis for the patient can not be made before results of the tests are received from the Clinical Laboratory. The longer it takes to process the blood tests samples, the longer the patient has to wait for final diagnosis in the ED. Usually the importance of a clinical laboratory operation and collaboration is undervalued when improving the operation of the ED. It is true that there are many phases which can not be quickened (for example analyzing phases) but there are also many manual phases which can be done differently. A good example of this is the delivery system of the specimens.

At this moment the specimens are delivered to the laboratory by a nurse who first has to walk to the ED, then take the blood samples from the patients and finally deliver them to the laboratory on foot. This is very time-consuming mode of operation and requires a lot of back and forth trips for the nurses. It has been calculated that during a one-shift period, a nurse may have to walk altogether 12-16 kilometers. In the other words, a lot of time goes into transporting the specimens.

There are few studies where the alternative specimen transportation systems have been tested. Rossetti et al. (1) studied the possibility to use a fleet of mobile robot for clinical laboratory deliveries within mid-size hospital facilities. Bruner and Kissling (2) on their behalf evaluated the suitability of a pneumatic-tube system for delivering patient blood specimens to the blood bank. Fernandes et al. (3) concentrated also on the pneumatic tube delivery system. They observed the turnaround times of serum hemoglobin and potassium from the time that the tests were ordered by a physician to the time the results were ready and available.

Although a pneumatic tube delivery system has been under examination before, its effect on the patients average throughput time in the Emergency Department has not been studied. Also only a few specimen types have been under evaluation.

In this study, which is a part of approved doctoral thesis (4), we are testing a method where all specimens of the Emergency Department are delivered to the laboratory by using a pneumatic tube delivery system instead of delivering them manually by a nurse. The main objective is to examine its effects on the patients' average throughout time and evaluate its potential to decrease patients' length of stay in the Emergency Department.

2 Description of the pneumatic tube delivery system

One of the problems found in the emergency department was in its co-operation with the clinical laboratory. The patients' length of stay was increased particularly by the time-consuming back and forth trips of nurses when delivering blood test samples from the emergency department to the laboratory. In this chapter a solution to that problem is presented. First the current operation is described and then a new solution for the problem is presented.

2.1 The operation of the present specimen delivery process

A tube delivery process starts from the ED when the tests for patients are ordered. Test requests are sent via the hospital information system to the laboratory where a nurse acknowledges receipt of the request. After receiving the requests, a nurse takes the sampling equipment, walks to the ED and locates all the patients whose orders had been received. All patients are examined one by one and the blood samples are taken from them. Once all the patients have been examined, the nurse walks to the laboratory with a cart to deliver the blood samples. The initial process flow is shown in Figure 1.

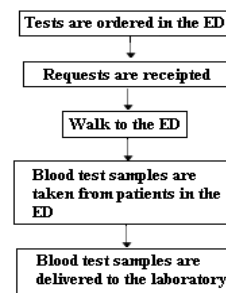


FIGURE 1: Present sampling action process in the ED

2.2 The operation after the implementation of the pneumatic tube delivery system

A pneumatic tube delivery system will change and automate the process as follows. A nurse, currently effecting the delivery of the specimens to the laboratory by walking, can be situated permanently in the ED for the sampling action. This means that the nurse

no longer need search for patients, who are instead guided to the room where the sampling action takes place. Once the patient has entered the room, the blood test samples are taken and then placed into the duct. There is a direct connection between the laboratory and the sampling room. The transportation time in tubes is approximately 30 seconds. After the samples have arrived at the laboratory, the process continues in the same way as in present operation. The process flow of a pneumatic tube delivery system is shown in Figure 2.

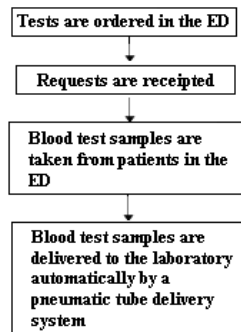


FIGURE 2: A blood test sample delivery process after installation of a pneumatic tube delivery system

3 Evaluating the effects of a pneumatic tube delivery system by using simulation

The simulation model of the Emergency Department of Special Health Care at the Central Hospital of Jyväskylä, Finland was used in evaluation. The model was developed by using the simulation software Medmodel (www.promodel.com). The operation of a pneumatic tube delivery system was configured into the model and the results of the scenario developed were then compared to the validated simulation model of the present operation.

The operation of the pneumatic tube delivery system was defined and examined as follows. First a certain area for the sampling action was configured into the model. Earlier, the blood samples were taken where the patient happened to be at the moment (waiting area, etc.); in this new scenario the sampling action was centralized. After the location definition, a certain resource for the sampling action was defined: the nurse, who earlier took the blood samples and delivered them to the laboratory, was placed permanently in the sampling room instead of the laboratory. These were the structural definitions of the pneumatic tube delivery system scenario.

Because the structure of the process was changed, process logic needed to be changed as well. In this new scenario, patients were routed directly to the waiting area of the sampling action room after the lab tests were ordered. There they waited for their turn and

then entered the room where the blood samples were taken. After the blood test, the samples were delivered directly to the laboratory through the pneumatic tube delivery system, and the patients were routed normally to the next phase of the process.

The duration of operation for each phase of action was obtained partially from the information system and partially by observing the process. Data was analyzed with the Stat:Fit statistical software and the defined distributions were then entered into the model. Time definitions for the present operation and the pneumatic tube delivery system scenario are shown in Tables 1 and 2.

Table 1: Time definitions for the present operation (E= Exponential distribution, U= Uniform Distribution, W= Weibull distribution).

Activity	Duration (min)
Walking to the ED	E(3,7.74)
Sampling action	U(3,1)
Walking back and analysis	W(1.89,58.5)

Table 2: Time definitions for the pneumatic tube delivery system (E= Exponential distribution, U= Uniform distribution, W= Weibull distribution).

Activity	Duration (min)
Walking to the ED	E(3,7.74)
Sampling action	U(3,1)
Transportation of samples	0.5
Analysis of samples	W(1.78,47.1)

3.1 Results

The scenario of a pneumatic tube delivery system was tested and the results were compared with the present operation. The focus was on the patient's average length of stay (throughput time), which was the main target variable in our research. The simulation time was one week and a one week's warm-up period was used. The warm-up time was needed to reach steady state for the parameters in the system being modeled. To get appropriate results, the pneumatic tube delivery system scenario was replicated 30 times. The results show that the pneumatic tube delivery system will reduce the patients' length of stay 13,4 %. The results are shown graphically in Figure 3 and numerically in Figure 4.

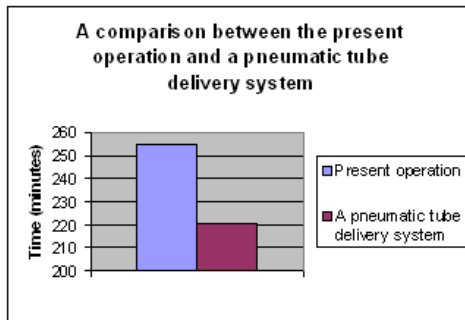


FIGURE 3: The effect of a pneumatic tube delivery system on patients' average length of stay in the ED compared with the present operation in a graphical form.

REPLICATION ANALYSIS (Sample size 30)

Statistic	Avg	Median	Min	Max	Std Dev	Std Err
Length of stay - Average Value	221.31	224.46	161.17	312.40	35.15	6.41
Length of stay - Maximum Value	739.93	708.50	579.00	983.00	106.14	19.37
Length of stay - Minimum Value	11.96	11.50	5.00	17.00	2.80	0.51
Length of stay - Number Of Observations	544.63	545	538	549	2.93	0.53

FIGURE 4: The results of a simulation run in a numerical form

Just as in the other scenarios, the confidence interval examination was performed in order to define where the true mean falls with a certain probability. The confidence level was selected to be 95 %, which was the same as in the other scenario testings and was calculated as follows:

95 % CI = $p \pm 1,96 * S$, where p = the average value of the patient's length of stay, S = standard error of the mean.

The values for the average value of the patient's length of stay and the standard error of the mean were obtained from the results of the simulation run. As can be seen in Figure 51, the patient's average length of stay was 221,31 minutes and the standard error of the mean was 6,41

Once all the parameters needed in the equation were known, the upper and lower limits were calculated. The limits for 95 % confidence interval were:

$$95 \% \text{ CI} = 221,31 \pm 1,96 * 6,41 = 221,31 \pm 12,56 = 208,75 - 233,87$$

The result shows that the true mean falls between 208,75 – 233,87 with a probability of 95 %.

As shown above, the collaboration between the ED and the clinical laboratory has a significant effect on the patient process and it should be taken into account when improving the operations in the ED. The use of a pneumatic tube delivery system can significantly reduce the total throughput time of patients. It also eliminates the tiring back and forth trips for nurses

and makes it possible to take more blood tests and see more patients in the ED.

4 Discussion

Nowadays, a lot of work is been done for improving the operations of the Emergency Departments. The solutions for the problems found are sought in many different ways. Resources are reallocated, processes are changed and technological solutions are used as well. Although there are many possibilities where the answers can be sought from, it is very difficult to validate their effects on the whole operation without implementing them first or risking the everyday activities. If the decisions are made without using any tools and they are based only on managers' own experience, it can be very costly. In order to avoid all these risk factors, an appropriate tool should be used.

Simulation is this kind of a tool. By using a simulation, it is possible to validate the effects of the alternative solution proposals on the whole operation of the ED. After the present operation has been modeled, it is very easy to configure the alternative scenarios into the model and examine their effects on the selected target variables without any risks and without disturbing everyday work in the ED.

In this study we used a simulation model of the ED of Special Health Care to evaluate the effects of a pneumatic tube delivery system on the patient's average length of stay. The collaboration between the ED and a clinical laboratory is very important part of the patient process but very often ignored when improving the operations in the ED.

As shown in this study, the collaboration between the ED and a clinical laboratory has a significant effect on the patient process and it should be taken into account when improving the operations in the ED. The use of a pneumatic tube delivery system can significantly reduce the total throughput time of patients. It also eliminates tiring back and forth trips for nurses and makes it possible to take more blood test and see more patients in the ED.

5 References

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