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Parameters for Validating a Hospital Pneumatic Tube System

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Guests: Dr. Ann Grownowski and Dr. Christopher Farnsworth from the Washington University School of Medicine in Saint Louis, Missouri.

Bob Barrett: This is a podcast from *Clinical Chemistry,* sponsored by the Department of Laboratory Medicine at Boston Children's Hospital. I am Bob Barrett.

Hospital pneumatic tube systems provide rapid transportation of patient samples to the laboratory. However, it is known that the physical movement through a pneumatic tube system can agitate blood samples and sometimes cause cells to break open and leak intracellular components. As a result, multiple laboratory results are susceptible to error.

Despite the known impact of pneumatic tube transportation on cellulolysis and numerous publications that urge hospitals to validate their system, there is no consensus on how to best evaluate a pneumatic tube system for its effects on clinical lab results. The May 2019 issue of *Clinical Chemistry* published a paper by Dr. Ann Gronowski and Dr. Christopher Farnsworth and their colleagues at the Washington University School of Medicine in St. Louis that describes parameters for evaluating a hospital pneumatic tube system. Today, we have Dr. Gronowski, Professor in the Departments of Pathology and Immunology and Obstetrics and Gynecology, who led this research study and her co-author, Dr. Chris Farnsworth, a fellow in the Department of Pathology and Immunology.

So Dr. Gronowski, let's start with you. There have been numerous studies examining the effects of the pneumatic tube system on the results of blood tests. What makes your study different?

Dr. Ann Gronowski: Well, that's a great question. You're right, previous studies have evaluated pneumatic tube systems by correlating the number and magnitude of accelerations measured by various three-axis accelerometers with changes in laboratory results. And these studies have shown that false elevations in lactate dehydrogenase, potassium, and hemolysis index are associated with prolonged time in the pneumatic tube.

While these studies have demonstrated the impact on patient samples, many questions remained with regard to how to actually validate your own pneumatic tube system to ensure accurate reporting of clinical test results. For example, what type of device should be used to measure the number and magnitude of shock forces, what physical parameters best correlate with clinically significant changes in test results, and what kind of day-to-day variability is there in a pneumatic tube system? And finally, what are the appropriate subjects to use for validation studies?

It's interesting when you think about it. The pneumatic tube system is probably the largest piece of equipment that a hospital owns and yet, repairs, maintenance, speed, and other factors that might affect blood most often fall outside of the laboratory's purview. Despite that, recent articles have called for laboratorians to "validate" their pneumatic tube system. So, we tried to come up with actual tools that laboratories could use to do just that.

Bob Barrett: One of your recommendations is the use of a three-axis accelerometer. Can you tell us about this device and why did you choose it?

Dr. Ann Gronowski: I really appreciate you asking this question because I think it illustrates the power of young minds. So first, let me take a step back to 2016 when Drs. David Bruns and Garrett Mullins from the University of Virginia published some great papers evaluating their pneumatic tube system using an iPhone. They even took a video of blood in the pneumatic tube using their phone to illustrate the significant agitation that a tube of blood endures during transport.

Their papers were sensational and really raised the visibility of this problem to the greater lab community. At the time that those studies were done, Dr. Mullins was a young trainee, and I don't know for a fact, but I suspect that it was he that brought to Dr. Bruns's attention the power of a simple cellphone.

Now fast forward to our study, we actually planned to copy Drs. Bruns and Mullins for our studies and use an iPhone. But I mentioned this to my son Zack, who is a high school senior, and he kind of scoffed at us. He said he thought that there would be much more robust devices to measure accelerations than a cellphone. Well, I didn't know if he was right or not, but we had one of Zack's classmates, Drew Krekeler, who is a co-author, working in the lab for the summer.

So, I asked him to look into it and Drew did some research online and came up with a number of choices, but we chose the PCE-VD3 three-axis accelerometer and we bought it

online on Amazon.com and it cost about $150.00. It turns out that Zack was right. We showed that while the iPhone captured more subtle accelerations between about 1 and 3G, much larger magnitude accelerations were detected using the accelerometer device. The maximum G-force that we recorded in our tube system was 10G for the iPhone and 22G for the accelerometer.

And it's actually similar in size, shape, and weight to a tube of blood. So, I really give credit to the ingenuity of these younger people who have really gotten us to where we are today in understanding the pneumatic tube system.

Bob Barrett: Now Dr. Farnsworth, let's switch over to you. Once you had the accelerometer selected, you started to send it to the lab from various locations around the hospital in the pneumatic tube. What did you find?

Dr. Farnsworth: It seems simple, but previous publications did not address the importance of testing multiple routes within a hospital. In our hospital, there are approximately 130 pneumatic tube stations, 150 transfer units, 45 traffic control units, 45 non-variable frequency drive blowers, and two multilinear transfer units, all of which can impact the number and magnitude of accelerations experienced by carriers.

To determine areas in our hospital that might be more susceptible to pneumatic tube-related hemolysis, we used the device to examine different pneumatic tube routes. The routes were selected for two reasons. First, we picked sites, like a cancer center, which closely monitor lactate dehydrogenase, and sites such as an ED for which hemolyzed samples can cause significant delay in patient treatment and diagnosis.

Second, we selected routes that were representative for a building. Most of the stations send pneumatic tube carriers to one of several transfer units in a building before redirecting them to the laboratory. Therefore, the forces from one tube station within a building generally reflect the whole building. In the paper, we published results from eight different routes although we tested far more than that. The parameters of pneumatic tube transport that have the greatest impact on patient sample is unknown.

It's likely a combination of the number of accelerations, magnitude of the force and duration of transport within the pneumatic tube system. So, we recorded all these parameters for each of the routes multiple times each over several days. We found that there is a great deal of variability in the number and magnitude of forces experienced by different routes.

In addition, we found that for some routes, there were significant within- and between-day variation.

Bob Barrett: How did you correlate what you found using the accelerometer with clinically significant changes in the lab test results?

Dr. Farnsworth: So, previous studies have shown that lactate dehydrogenase is the most sensitive to physical agitation, but we also looked at potassium and hemolysis index. To determine how much agitation causes a clinically relevant change, we collected blood from eight subjects and transported the samples in the accelerometers through the pneumatic tube up to four times. Then, we generated response curves based on the various parameters collected from the accelerometer.

Using a 20% change in lactate dehydrogenase as clinically significant, we were able to establish cutoffs to define parameters that should not be exceeded in order to avoid falsely elevated results. For instance, we were able to show that for our pneumatic tube system, there is a greater than 20% change in lactate dehydrogenase with approximately 198 accelerations exceeding 3G, or approximately 20 accelerations that exceed 15G.

We then applied this information to the previous study which defined forces from the various pneumatic tube station routes and were able to estimate which routes might have the greatest effect on lactate dehydrogenase.

Bob Barrett: Now, in your paper, you mentioned an astute physician from your cancer center who noticed a change in the lactate dehydrogenase concentrations from her patient after you closed a satellite lab in the same building. Can you tell us about that?

Dr. Farnsworth: That's right. One of our co-authors, Dr. Nancy Bartlett, contacted us because she perceived an increase in the number of samples with falsely elevated lactate dehydrogenase in her leukemia and lymphoma patients. She noticed that their results were not elevated when repeated in an outside laboratory. So, after we ruled out the difference due to different instrumentation in the new lab versus the old lab, we looked at historical data for a three-month period after the satellite laboratory closure in the same three-month period one year prior.

The data revealed a 14% increase in median lactate dehydrogenase concentrations when samples were transported via the new pneumatic tube route to the core lab compared to the previous route to the old satellite lab,

but this is just median lactate dehydrogenase concentrations for their whole patient population. Maybe they just saw sicker patients in the second three-month period, right?

However, interestingly, based on the data we generated from our study, we predicted that an increase in lactate dehydrogenase between those two routes would be 14%, exactly what we saw in the switch. Therefore, due to the potential impact on patient care, a courier was implemented to walk samples from the cancer center to the core laboratory. Lactate dehydrogenase results from the two-month period prior to courier were compared to two months after courier and we saw a decrease in lactate dehydrogenase concentrations by walking the samples, thereby confirming Dr. Bartlett's observation.

Bob Barrett: Okay, and Dr. Gronowski, let's go back to you, just to sum things up. What suggestions do you have for other laboratories wanting to evaluate their pneumatic tube system?

Dr. Ann Barnowski: I think that there's a number of things that laboratorians can take away from this study. First, I think the use of a simple, inexpensive accelerometer is useful to record accelerations in the pneumatic tube system. Second, hospitals need to evaluate many different routes and in particular, routes that may be especially affected lysed cells. Third, hospitals need to establish their own response curves.

We established curves for lactate dehydrogenase, potassium, and hemolysis index, but these curves may look different at different hospitals due to different instrumentation. And then finally there's so much more work to be done. There are many other lab test results that could be impacted by agitations. Also, there's concern that anemic patients or patients in the ED and ICU and patients with high cell counts are more susceptible to hemolysis. Therefore, what may seem to like a safe route in our study might not be safe for all samples. So, further studies addressing at-risk populations might be useful. So, the bottom line is, there are lots of opportunities for additional studies in this area.

Bob Barrett: That was Dr. Ann Gronowski from the Washington University School of Medicine in St. Louis. She was joined by her co-author, Dr. Christopher Farnsworth. They have both been our guests in this podcast on pneumatic tube systems and transport of patient samples to the laboratory. Their paper appears in the May 2019 issue of *Clinical Chemistry.* I'm Bob Barrett. Thanks for listening!