Bob Barrett: This is the podcast from *Clinical Chemistry.* I am Bob Barrett.

Although linear bar code technology allows clinical staff to significantly reduce identification and data entry error rates by instantly identifying the medications and specimens of patients, the identification methods are not fail-safe.

A report published in the October issue of *Clinical Chemistry* identified the sources of bar code decoding errors that generated incorrect patient identifiers when bar codes were scanned for point-of-care glucose testing and develop solutions to prevent their occurrence.

Dr. Corinne Fantz is co-author of the report and Associate Professor of Pathology and Laboratory Medicine at the Emory University School of Medicine. Dr. Charles Hawker is Scientific Director for Automation and Special Projects at ARUP, and Adjunct Professor of Pathology at the University of Utah. He is also the author of an editorial on the topic in the same issue. They are both our guests in this podcast.

Dr. Fantz, we all see bar codes everywhere—from the grocery store, to airline check-in—how are bar codes currently utilized in healthcare?

Dr. Corinne Fantz: Well, bar code technology is employed in every facet of health care, from pharmacy and point-of-care testing, to inventory and nutrition. Bar code labels are used in blood banks and laboratories to track blood products and specimens. And we use bar codes for identification purposes, and that has actually made healthcare processes more reliable and efficient.

We can perform more tasks in a shorter amount of time and with far fewer errors compared to traditional manual data entry systems.

Bob Barrett: Well, given this, do you think that bar codes are safe for use in this environment?

Dr. Corinne Fantz: Well, compared to manual identification processes, definitely. It's estimated that 1 in 300 manually entered characters are going to be entered incorrectly. So when you compare this to bar code error rate, say, for example, our laboratory standard, Code 128, with an estimated error rate of about 1 in 10 million, this is a major improvement. You are going to dramatically reduce errors and more importantly identification errors.

But what hospitals really need to realize is that bar codes are not failsafe and that how we implement and integrate them into our systems is going to be the key to our success and our patient safety.

So careful attention must be paid to set up specifications, such as minimum size requirements for bar codes, for each bar code scanner type. Unfortunately, when people are unaware of these requirements, bar code size specifications may be compromised, because of the size constraints on the wristband or a label.

You also want to consider how bar code printers are maintained. When printers begin to fail from normal wear and tear, they are unable to produce quality bar codes. It's important to recognize that Code 128 error rate estimations were made with the assumption that all conditions were ideal.

In a hostile environment, wristbands can be scratched or worn over time, and sometimes people make the mistake of writing on them. So to further complicate the matter, the quality of scanners reading the bar codes can also vary. And what we found is that, these real-world issues can drastically affect the scanning error rates. Using the Code 128 symbology, we found that the error rates were more than 10-15 times higher than the generally accepted estimates.

Bob Barrett: You have mentioned several times Code 128 as the laboratory standard. Now, in your opinion, are there some other bar code symbologies that might be safer?

Dr. Corinne Fantz: That's a great question. There are actually a number of different bar code symbologies, each with its own ideal requirements for minimum and maximum size, character types, the amount of data that can be stored, etcetera. So while the current standard is Code 128, it's certainly not the safest and most reliable symbology in use today.

There are 2-D bar codes, including matrix-type bar codes, that contain more sophisticated checking algorithms, such as the error correction and redundant data embedded in the bar code. So that approximately 30% or more of the bar code can be destroyed and still produce an accurate scan.

These symbologies are already in widespread use in a number of industries, including banks, the pharmaceutical industry, and mail delivery services. And I find it interesting that in healthcare, where the cost of an identification error could be life threatening, we haven't followed suit. We definitely need to adopt more robust technology that can withstand our less than ideal treatment and still maintain accuracy.

Bob Barrett: Okay. Well, what exactly are the most important considerations when implementing a bar code system?

Dr. Corinne Fantz: The implementation team—I think you do need a team approach—should seek to include all representatives from the groups intending to use the bar code, so that they have an overall idea of the needs for all of the various users.

Groups may have different size constraints. So maybe the tube is too small or the wristband orientation is limiting, for example. The team should become familiar with important bar code specifications, making sure that any generated bar code meets the minimum scanner requirement, with respect to bar code size and scanner resolutions. And this is true for all scanners in the healthcare system.

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So you might want to know what scanner models or types are even being used. And we discovered that in our own lab, we had more than ten different scanner models.

So from a technical perspective, if you are only using one type of bar code in your system, you should limit the scanner to read only that symbology. And in our study, we saw errors where the scanner interpreted the bar code as a different type of bar code altogether, such as Interleave 205 rather than Code 128.

Printer quality is another important consideration, and you need to have an error mitigation procedure in place. What happens when maintenance isn't performed? Is the operator notified or warned that there was a printer malfunction? And if not, how can you be sure that you haven't released a defective bar code to a patient care area? These are questions that we need to address.

Bob Barrett: And are there ways of checking or verifying bar codes before they are used for patient care?

Dr. Corinne Fantz: Yes, there are. Without more advanced barcoding technology in healthcare, and in order to make our systems safer, we have to include checks or alerts that notify the operator when we have a problem before the bar code is sent out for use.

And probably the most effective way of doing this is to purchase a bar code verification system. These devices can be used to scan and verify the bar codes before placing them into service. And they can be a good investment, especially in areas like admissions, where so many wristbands are being generated, that they are likely to have frequent printer failures.

A simple solution, however, is just to print a black bar under the bar code to detect white spaces that are indicative of printer malfunctions. This would then alert the operator that the bar code is defective and/or the printer is in need of maintenance.

Unfortunately, this system still requires a manual review and a printer failure can go undetected, and if it goes undetected, it can still result in a patient identification error.

So alternatively, there are some systems that have flexibility in the software, allowing you to change the orientation of the bar code, such that the printer failures can then be displayed perpendicular to the bars, and that won't interfere with the integrity of the bar code data.

However, none of these solutions will prevent the normal wear and tear that may ultimately result in an error at some later point in time, and for this, there is an option of manually checking bar codes, but this is not 100% reliable, as we have talked about before.

In the healthcare environment, implementing manual checks have been made policy in high-risk areas, such as labeling a blood bank specimen, but there is always a chance that someone gets busy and the manual check isn't done, and this kind of check requires constant vigilance. What we really need is just to move to an alternate, more robust technology.

Bob Barrett: Well, considering the limitations of bar codes then, what future technologies could be better or safer than bar codes?

Dr. Corinne Fantz: Bar codes enable us to represent the identification of patient's drugs and specimens in a way that a bar code scanner can instantly recognize and upload and process information.

As I mentioned before, newer bar code symbologies enable us to do that with much less error. And in addition to what I have previously discussed, they allow us to encode multiple pieces of data into a small area, such as a patient's first name, last name, date of birth, and medical record number.

While the current standard for bar codes in healthcare is Code 128, it only has room for one piece of data. Therefore, if that one piece of data is misread, there is a real chance that the computer could associate the data with the wrong patient or drug or specimen.

So back to your question, there are indeed technologies which improve our processes in healthcare which can be, and really should be, used in conjunction with more robust bar codes.

The best example of this is the RFID, or Radio Frequency Identification Technology. RFID tags are so small that they can fit on a tube or a label or wristband without disturbing any of the other information.

The main advantage to RFID is that unique Radio Frequency Signature applied to the person or item in question allows you to hone in on its location using an interrogator or reader.

Businesses use these tags on each item in their inventory to keep track of where each piece is located.

Similarly, RFID tags on specimen would allow us to precisely track the location of tube throughout the process, all the way from collection, to testing, to storage.

For both upgraded bar code technology and RFID tags, however, cost is a significant barrier to implementation, and especially when you have a lot of scanners in use. But I have to ask, what is a life worth? Relying on outdated technology to perform checks before a life threatening procedure, test or drugs are administered, when there are safer options available, seems like we are cheating our patients.

I have looked at, in my research in this area, we can learn from other industries in this regard. There are vendor incentives or cost motivators that some businesses have used to help push suppliers to provide robust systems and update their bar code technologies.

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For example, I read on one bar code verification website that Wal-Mart charges its vendors about $50,000 for producing bar codes that repeatedly miss scan. So ultimately, what we really need to do is define the standards, and they need to be updated and implemented to reduce this risk to patient safety.

Bob Barrett: Well, thank you Dr. Fantz. Now, going to Dr. Hawker. Doctor, you recently, as we mentioned before, wrote an editorial on the topic of bar code safety in the latest issue of *Clinical Chemistry.* Why is this such an important topic now?

Dr. Charles Hawker: Well, it's a really simple answer, and that's patient safety. If it was your specimen or my specimen that was misidentified because of a bar code error, and thus you got an incorrect laboratory result reported to your physician, and then that physician ordered a particular treatment that was not correct for you, that would be a pretty serious issue.

This report from Emory University showed a much higher error rate for incorrectly read bar codes than anyone might have reasonably expected, based on what most of us in the industry think is the expected rate of bar code errors.

So eliminating these kinds of errors actually has been a major focus of the healthcare industry ever since the well-known publication of the Institute of Medicine in 2000 entitled, *To Err is Human*.

What was totally surprising is that all of us in the clinical laboratory field are using a particular bar code symbology called Code 128. It's the actual bar code symbology that's been specified by standards organizations. And the error rate that we normally expect from this bar code symbology is somewhere on the order of 1 error per every 2.8 million bar codes, ranging up to as high as 1 error per every 37 million bar codes.

However, the Emory group had a much, much higher error rate of approximately 1 per 84,000, and to be frank, it was shocking.

So their report was an attempt, a really excellent attempt, to try to describe how that happened and what they did about that.

Bob Barrett: Where exactly do these bar code errors occur?

Dr. Charles Hawker: Well, when patients are admitted to the hospital, they are given an identification wristband and there is a bar code printed on that wristband at the time of admission. This bar code is an ID number for that patient. It's when those bar codes were being printed to put on the wristbands, that some of the printers had defects and caused the bar codes to be defective.

This wristband then is of course used throughout the hospital for various procedures. It depends on different hospitals' policies, but that wristband is going to be scanned by a person who is doing testing, laboratory testing, at the patient's bedside. They will scan the bar code to put that patient's ID into the device that's doing the laboratory test, and associate that patient's ID with the result that's determined by the test, and then that's transmitted into the laboratory's computer system to be reported to the patient's medical record.

The wristband bar code could also be used for identifying the patient, when they are going to receive their medications, or identifying the patient for some other procedures, such as an x-ray, or something or other. So this defectively printed bar code could misidentify the patient, and in fact, in the Emory report, did misidentify the patient, when they were doing these laboratory tests.

Now, fortunately, Emory caught those mistakes and there weren't any patients harmed, but it was because of their vigilance that they caught these errors that they had detected in the poor bar codes.

Bob Barrett: Were the authors of the article able to determine why they got the high error rates?

Dr. Charles Hawker: They reported on this. As the printers were being used to print the bar codes, what happens is, is that there are print heads, little tiny print heads, that generate heat, and the heat darkens the media. The media is not really paper in most cases, it's some other material, usually a plastic material, and it responds to the heat by darkening. That makes the letters in the patient's name, the age, sex, and the other information on the label, and it also makes the bar codes.

If the print heads, these little tiny print heads are defective, then they don't produce the heat, and instead of the media turning black in that particular part of the label, it stays white. What they were seeing was that defective print heads would cause white streaks, and while they were printing these labels, the white streaks would actually be parallel to the bars in the bar codes.

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So instead of there being a black bar of a certain width that made up the bar code, there was a white streak. So the number that the bar code represented would be changed, because the width of some of the black bars had changed. So it would give an incorrect number when interpreted by the computer. They simply discovered that this was going on, which was pretty outstanding on their part to identify these errors.

Bob Barrett: Don't bar code readers have some sort of error-checking capabilities?

Dr. Charles Hawker: Yes that's true, most of these do, some bar code readers are better than others. So what was really interesting to see in the article from the Emory group was that they compared a number of different bar code readers that were in use in their institution and they showed what the error rates were for these different bar code readers.

And, there was a range of results in the sense that one particular brand of bar code reader that they employed had no patient misidentifications, no so-called number substitutions, but in fact the bar code reader would say that there was an error and other bar code readers had a high number of substitution errors because they weren't showing that to be an error.

So there is error-checking capability and some readers are better than others.

Bob Barrett: Well *Clinical Chemistry's* readers tend to be more laboratory scientists than laboratory managers. How is this important to the scientist?

Dr. Charles Hawker: Well, interesting question. As a laboratory scientist we all share in the responsibility for the quality of what's going on in our laboratory. Most of us, as scientist, perceive that that has to do with the quality of a test that we report. It has to do with the quality of our analyzers and how all of that performs, and that's what as scientists, we are most often held accountable for and that's where we have focused attention.

But if, in fact, defective bar codes are being printed on the labels, on the specimens that are going into our analyzers and our analyzers, which are interfaced to our laboratory's computer systems, also were to read bar codes incorrectly and associate a result with a wrong patient identification number, we would then end up a unknowingly, because there wouldn't maybe anyway to really check this right away until somebody, a physician for example complained about an unexpected result, we would unknowingly report out an incorrect result.

So I think it's just important for laboratory scientists, *Clinical Chemistry* readers, to realize that in fact these analyzers that they are so vigilant about the quality control of the chemistry test or the amino chemistry test and so on, it could make an error and it's all because of the poor quality bar code on the tube that's going through that analyzer.

Bob Barrett: So what can laboratories do to minimize the risk for misidentifying patients due to bar code errors?

Dr. Charles Hawker: Well, I think the Emory grouped showed several things that they had done, and that's in their article. For the patient wristband issue and the defective bar code issue, they actually rotate it how the labels go through those bar code printers by 90 degrees and that put the white streaks that were caused by the defective print heads at a 90 degree angle to bars as opposed to being parallel to the bars and so they were immediately visible.

If there was a print head that was malfunctioning because it was dirty or clogged and didn't provide the correct amount of heat to the label there would be a white streak going across the bar code and that would be immediately visible.

The Emory group was also already using check digits so there is a numeric calculation, a mathematics calculation with the formula based upon whatever the ID number is that's embedded in the bar code, and then you add a couple of more bars to the bar code, which are a couple more digits, that are going to be calculated based on the other numbers according to a specific formula.

So if when the bar code is read those two check digits don't turn out to give the number that's expected by the computer, when it does that mathematics calculation it would show up as an error. So this is some thing that every laboratory should make sure that there are check digits setup with their bar codes.

And then in the editorial that I wrote I also provided a couple of other suggestions. A very simple one is to just simply purchase a device known as a bar code verifier. A bar code verifier is a device that actually can scan bar codes and provide a letter grade, A thorough F for the quality of that bar code.

The ANSI standard specify that only a grade A, B or C bar code is of good quality and should be used and so that's a simple thing that a laboratory could purchase, have on hand, and check their bar codes.

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And I think if the laboratories can do all of these different kinds of things it's going to turn out to be a major improvement for the quality of the bar codes that the laboratories are producing and using.

Bob Barrett: With that in mind, we've heard about newer concepts such as two-dimensional bar codes and radio frequency identification. Are these possibilities for laboratories in future?

Dr. Charles Hawker: Yes, very definitely. The only question is when these things might happen. Two-dimensional bar codes have actually been around for a couple of decades or more. The problem is that the equipment to read those bar codes is more expensive than standard linear bar code readers because they really are more in the order of a camera system.

So the vendors that make of all the analyzers that have bar codes readers in the analyzers have not been inclined to put more expensive camera systems that can read two-dimensional bar codes into their analyzers.

And, since laboratories are producing just linear bar codes they've not been asking the venders to put into two-dimensional systems into their analyzers. So it's a kind of a catch-22, and neither group is pushing the other to do this.

And so, probably the only way we'll ever see two-dimensional bar codes in the laboratory field is if an organization, such as the Clinical and Laboratory Standards Institute, CLSI, would go ahead and develop a standard for two-dimensional bar codes and try to push the industry to move into that direction.

The other technology that you mentioned is RFID, radio frequency identification, is still kind of in its infancy with regards to the laboratory field. The RFID chips are still quite expensive. The equipment to read the chips is still quite expensive and so even though this technology is much more mature for the retail industry and other industries.

And everybody listening to this podcast is familiar with RFID because it may be even in your ID batch with which you enter or exit your place of work or you may have purchased something, an article of clothing or an electronic item in a retail store and then that RFID chip has to be deactivated by the cashier before you can exit the store with the item that you just purchased.

A variety of things, and that deactivation of the RFID chip prevents you from setting off an alarm, but it also debits the inventory for that item in the store's inventory system and so there is a lot of things that a RFID is being used for in that sense.

But in the laboratory, because the chips cost roughly 15 to 30 cents yet that's much too expensive to put one on each specimen and so it's going to take a while for this RFID concept to mature and the prices to come down to make it affordable for laboratory specimens.

Bob Barrett: Dr. Corinne Fantz is Associate Professor of Pathology and Laboratory medicine at Emory University School of Medicine. Dr. Charles Hawker is Scientific Director for Automation and Special Projects for ARUP and adjunct Professor of Pathology at the University of Utah. They have been our guests in this podcast from *Clinical Chemistry*.

I am Bob Barrett. Thanks for listening.

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