Mohs Turnaround Time Tracking: Preliminary Report

Biomedical Engineering Design 200 - 300
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Abstract

Mohs surgery is a dermographic procedure that involves removing and analyzing cancerous skin lesions. Before a specimen from a given lesion site can be analyzed, the specimen must undergo a time-consuming preparation. The time to return a sample for analysis, turnaround time (TAT), is a direct measure of efficiency and accuracy within a point-of-care lab. At the University of Wisconsin School of Public Health and Medicine, the Mohs Laboratory team is looking to improve their TAT system, which is currently using physical time cards to track important steps of site preparation. This system has several issues that make it infeasible to measure TAT accurately and reliably. In addition, there are no other solutions on the market with enough flexibility to fit the structure that is the Mohs Laboratory. For these reasons, a proposed TAT tracking system will utilize two multi-purpose scanners to integrate the barcodes and QR codes associated with each site to take accurate and reliable time stamps. The time stamps will be stored on a computer within the lab and analyzed through custom programming. This system will provide a more efficient and accurate way of tracking TAT in order to define time standards for site preparation, increase lab efficiency, and decrease wait times for patients and physicians.

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I. Introduction

Turn Around Time (TAT) is a very important and prevalent aspect in modern point-of-care laboratories. As clinicians seek faster test results, TAT can be directly measured and becomes a focal point in lab quality [1]. In order to improve lab efficiency, a serious amount of planning, educating, and investing must be done by all members involved[1]. However, the efforts are exponentially beneficial, as highlighted by Howanitz and Howanitz, "Small investments in the clinical laboratory resources may improve TAT and greatly improve clinicians' efficiency, as well as help reduce required days of hospitalization for patients. [1]" There are various areas where laboratories can focus on improving TAT, decreasing the time for intake and analysis of a specimen is crucial [2].

The Mohs Laboratory at the University of Wisconsin School of Public Health and Medicine is focused on improving their TAT through this specific area. The Mohs team specializes in dermatology surgery, removing and analyzing possible cancerous skin lesions. The Mohs lab takes these removed sites, prepares, and returns them to a physician for microscope analysis. It is this process that the Mohs Laboratory is looking to improve upon.

However, applying any time tracking system will not work, as there are some recommended guidelines highlighted by R.C. Hawkins in his research *Laboratory Turnaround Times* [2]:

1. Choice of appropriate analytes for monitoring,
2. Clear definition of TAT in terms of start points and end points,
3. Clear definition of measures to be measured.

4. Clear definitions of acceptable and unacceptable performance based on clinical evidence, benchmarking data and local expectations.
5. Establishment of a system for long term monitoring of performance using available data.

Currently, the Mohs Laboratory is using a time card system to track their TAT. Various problems have arisen with their system, such as skipped timestamps, limited time card supply, and need for human time-stamp recording. These issues put this system out of the recommended guidelines, making it impractical for long term use.

A solution on the market is Sunquest Laboratory™ Specimen Management Routing and Tracking (SMART) system [3]. Their technology is not well described on the website and seems better implemented in large-scale laboratories. In addition, their system would likely be over the Mohs Laboratory budget. In this light, designing a more efficient, accurate, and autonomous system to improve the TAT of the Mohs Laboratory is needed.

II. Background

Mohs Research

Mohs surgery is a procedure in which skin cancer is removed from the outer layer of the skin. At first, the surgeon will take a sample of the skin (called a site), and then the tissue site is taken by a lab technician and split up into smaller sections called specimens. These specimens are then mapped using dye in order to locate which section of the site has skin cancer in it and which do not. Going through every section the specimen includes (the amount of specimens

ranges on the size of the site), each and every specimen is tested in order to figure out the location of the cancer's possible “roots” and how deep a cancerous spot goes. [4] The first site’s results will determine if another sample is necessary. If the cancerous spot ends within the first site with every section being cleared, the surgery is done. However, if the cancer remains in any of the sections, the surgeon will go into that section again and repeat the process until all of the cancer is cleared, as depicted in Figure 1 [5]. This process is fairly simple, with the procedure and analysis all happening within a single visit in only a few hours.

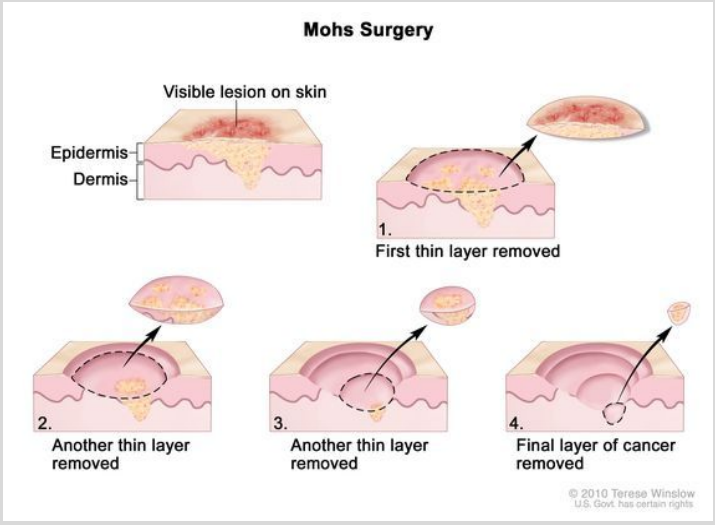

Figure 1: Example of the Mohs Surgery procedure with various extractions of the same site to remove cancerous layers. This is an iterative process that will create a unique time stamp in the laboratory for each layer. [5]

UW Hospital Lab Diagram

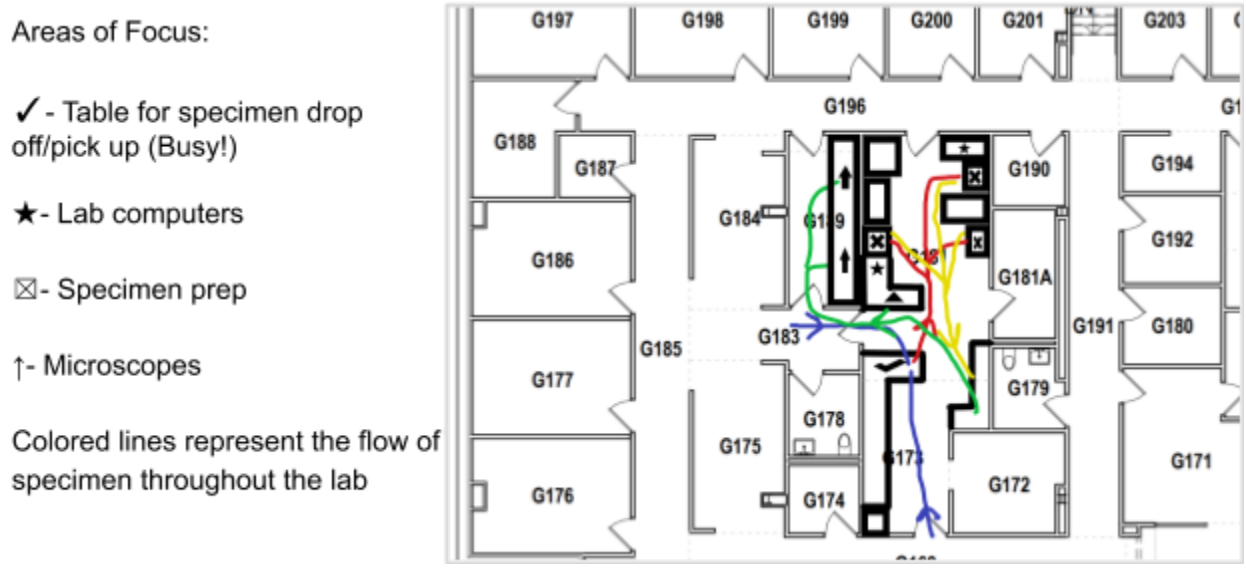

Figure 2: Layout of Current Lab at UW Hospital as depicted by Mr. Ryan Dauman. This map provides the basic workflow Mohs team members go through while processing a site. Colored lines are the movement of the specimen and the various shapes (defined in the key) represent important lab equipment and processing areas.

As most of Mohs surgery deals with the analysis of the tissue specimen, there is a lot of activity in the lab itself. Specifically, at UW Hospital they follow a path that includes three checkpoints within a small space. The first checkpoint is when the physician delivers the specimen to the technicians in the lab and inks the specimen at the table marked with the checkmark [Figure 2]. The second time point is taken when the lab technician picks up and begins work on the specimen. During the time of analysis, the lab technicians take the path of the red and yellow lines in which they inspect and cure the specimen at the tables with the X's on them [Figure 2].

Following the inspection and cutting of the specimen, the slide is cover-slipped and the third time stamp is recorded. Next, the slide is delivered to the physician, following the green arrow [Figure 2], to the microscope room where the specimen is inspected by the physician for cancer.

It is at this point the specimen is read and cleared by the physician for the procedure to be considered done. If the specimen is not considered clear (containing cancer), another stage will need to be taken and the process is repeated again, using another site from that same location. When the specimen is cleared, no matter the number of stages needed, the physician will declare the site is finished and signs it off with the last time point.

Client Information

The client is Mr. Ryan Dauman, a supervisor at UW Health who has been working with the lab technicians and the Mohs surgeon to find a time tracking system to measure TAT.

Design Specifications

The major design specifications that need to be taken into consideration are efficiency, accuracy, and safety, all while remaining under budget. The lab is consistently processing sites, with the busy days being Monday, Wednesday, and Thursday, in which seven or more unique sites could be in processing simultaneously. Due to this schedule, a system must be created to differentiate between many test sites while also being time-efficient and easy to integrate into the lab flow (Appendix A). As technology is becoming ever more prevalent in medicine, the system will track all of its time points virtually, on a data program such as excel or google sheets,

requiring technology in the workspace. For example, barcode scanners or QR scanners must be in reach of any computer or tablet required to interface these different technologies.

With the addition of extra equipment to the laboratory, there must be an areas with enough space to cause minimal disruption and maintain safety to the laboratory flow. In addition, technology brings concerns to shelf life, as needing to charge batteries or offloading data will require human intervention. For these reasons, the shelf life should last at least one week without outside assistance to ensure that the system will be up and running during the days the lab is open (Appendix A). The biggest safety factor with this system involves the protection of confidential patient information. With technology, there is a larger risk for HIPPA violations, and in order to account for this, the program setup must be able to protect all patient information from any possible breaches.

Finally, the system needs to be constructed for under $200 with the ability to use any existing lab equipment to minimize cost. Overall, the system for the UW Hospital must be more advanced in terms of efficiency, whether it be time-wise or integration into the workflow, while maintaining patient confidentiality.

III. Preliminary Designs

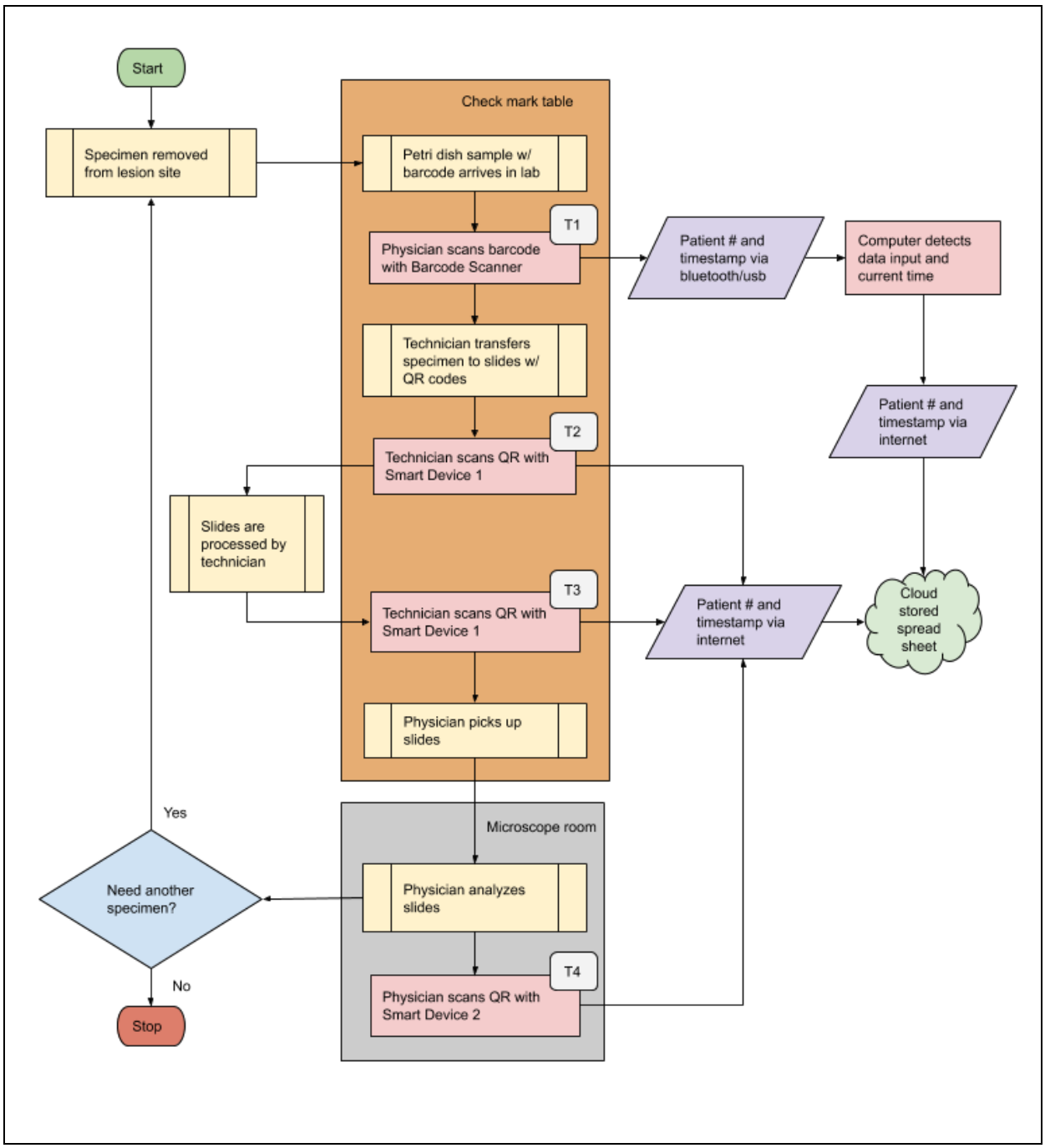

Figure 3. Flow diagram for the "Mixed" design. Note the two separate paths that data takes to the spreadsheet. T1, T2, T3 and T4 indicate the four times that the TAT system must track.

The Mixed design involves the use of the existing barcode scanner in the lab. The scanner would connect to a computer that uploads patient identification and a timestamp to the cloud. For the remaining timestamps, smart devices will use a scanner app that can read QR codes and upload a timestamp and patient identification directly to the cloud.

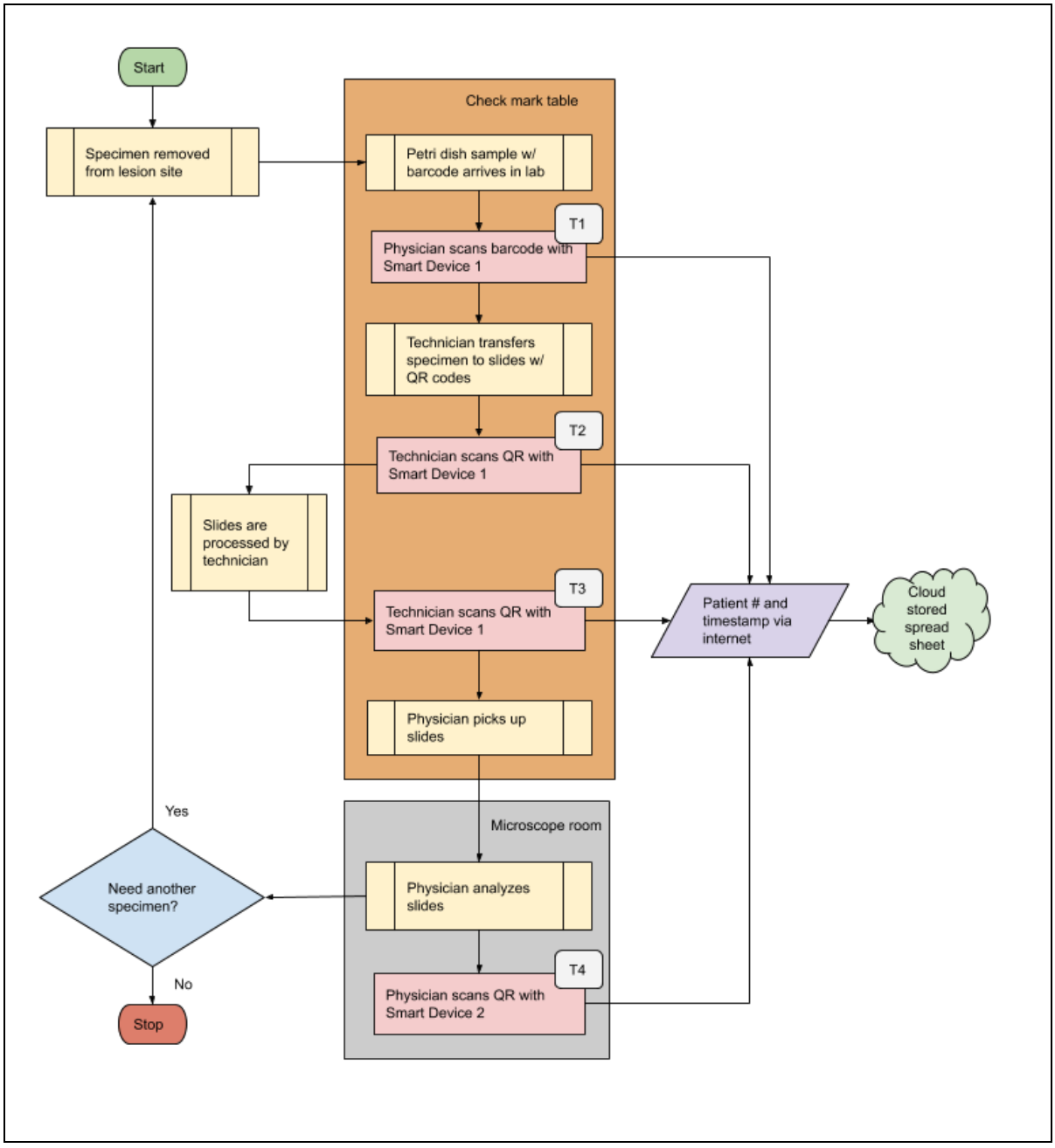

Figure 4. Flow diagram for the "Smart" design. Note how smart devices can directly transfer data to the cloud. T1, T2, T3 and T4 indicate the four times that the TAT system must track.

The Smart design employs the use of just two smart devices, be that old phones or tablets. The devices will use an app that can scan both barcodes and QR codes and upload this data to the cloud.

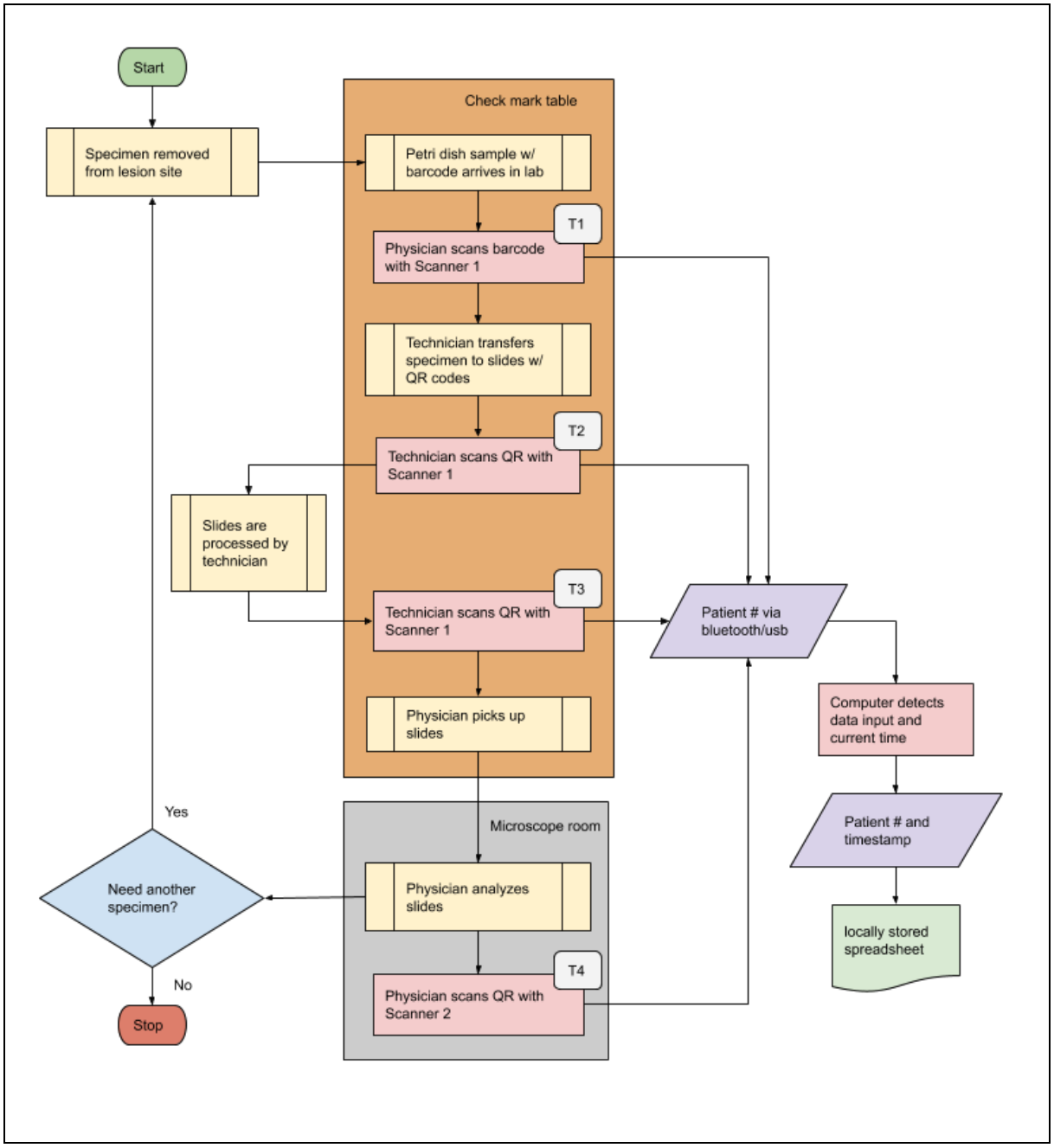

Figure 5. Flow diagram for the "Scanner" design. Note the use of scanners at each step and the locally stored data. T1, T2, T3 and T4 indicate the four times that the TAT system must track.

The Scanner design uses two wireless scanners, the first which can scan both barcodes and QR codes, and the second which may be the same kind of scanner but does not need barcode capabilities. The barcode/QR data gets transmitted via Bluetooth and a computer records the patient identification as well as the current time into a spreadsheet.

IV. Preliminary Design Evaluations

Criteria	Weighted Factor	Mixed	Weighted Score #1	Smart	Weighted Score #2	Scanner	Weighted Score #3
Efficiency	20.0	4.0	16.0	4.0	16.0	5.0	20.0
Accuracy	20.0	3.0	12.0	3.0	12.0	4.0	16.0
Ease of use	15.0	3.0	9.0	4.0	12.0	4.0	12.0
System Integration	15.0	3.0	9.0	4.0	12.0	4.0	12.0
Maintence Requireme	12.0	4.0	9.6	5.0	12.0	2.0	4.8
Safety	10.0	4.0	8.0	3.0	6.0	5.0	10.0
Cost	8.0	4.0	6.4	5.0	8.0	2.0	3.2
Total	100.0		63.6		70.0		74.8

Figure 6: Design Matrix with Proposed Final Design

1 - Efficiency

Efficiency is intended to evaluate each design's ability to minimize the time that the lab staff must spend to operate the system. It was also intended to evaluate how readily the data is collected and available for reading and analysis. A high score in efficiency indicates that design most effectively created an efficient system for the lab.

Both the Mixed and Smart designs received 4/5 since they both involved having the first three time-stamp stations at the same spot in the lab, resulting in the possibility for crowding and traffic jams if all lab technicians needed to scan samples at the same time. The Scanner design

rated a 5/5 because of the fact that it separated the location of the time-stamps in the lab more than the other two designs.

2 - Accuracy

Accuracy is intended to evaluate each design's ability to minimize human error (ie: skipping a step in the process). Additionally, it also evaluates a design's ability to accurately record the time-stamps in the tracking system. A high score in this category indicates that the design was both able to minimize the possibility for error and accurately records the time data.

The Mixed and Smart designs both received a 3/5 because they both relied on a smartphone or tablet at some point in the process, which are less reliable in terms of connectivity to wifi. The Scanner design was ranked a 5/5 because it does not have the need to be connected to wifi, which removes the chance of disconnection during work hours.

3 - Ease of Use

Ease of use is intended to evaluate each design's simplicity and how easily the lab staff is able to operate the system. A high rating in ease of use indicates an easy to use system that is not super complicated for the lab staff to use.

The Mixed design received a 3/5 in this category because it would require the lab staff to become trained in using both scanner and smartphone technologies to operate the system. Both the Smart and Scanner designs received a 4/5 because they only require one type of technology, but both were different from the current system, so some training would be required.

4 - System Integration

System integration is intended to evaluate each design's ability to minimize additional clutter in the workspace and the amount of changes in the work environment required for the implementation of the system. A high score in this category reflects a design that does not take up a lot of counter space and one that does not drastically alter the workflow of the lab.

The Mixed design received a 3/5 in this category because the complexity of two different technologies requires many changes needed to both the workspace and workflow of the lab. The Smart and Scanner designs received a 4/5 due to the fact that they require minimal counter space for implementation, but also require changes to the technology currently used in the lab.

5 - Maintenance Requirements

Maintenance requirements are intended to evaluate each design's need to be charged, updated, or repaired in order to maintain function and durability. A high score in maintenance requirements indicates a design's minimal need to be charged, updated, and repaired.

The Mixed design received a 4/5 due to its inclusion of a smartphone or tablet, which has minimal charging and repair requirements. The Smart design scored a 5/5 in this category because it solely relies on smartphones or tablets, meaning that charging and repair requirements are low. The Scanner design received a 2/5 because the wireless scanners need to be charged much more frequently than smartphones/tablets or require the batteries to be changed.

6 - Safety

Safety is intended to evaluate each design's ability to minimize the amount of physical contact needed to operate the system in order to minimize possible contamination to the tissue samples. It also takes into account the risk level of confidential patient information being compromised. A high ranking in this category reflects safety in contamination minimization and patient information leaks.

The Mixed design received a 4/5 in safety due to its use of a scanner, but also the need for a smartphone or tablet, which can be hacked for patient information. The Smart design received a 3/5 because it only involved smartphones or tablets, which require higher levels of contact and patient confidentiality concerns. The Scanner design received a 5/5 because it eliminates the need for contact and also most effectively minimizes the risk of patient information being compromised.

7 - Cost

Cost is intended to evaluate each design's monetary requirements. A high score in the cost category indicates that a design has a low-cost requirement for implementation.

The Mixed design received a 4/5 because it combined the low cost of a smartphone/tablet with a slightly higher cost of a wireless scanner. The Smart design received a 5/5 because it was the cheapest of the three designs. The Scanner design received a 2/5 due to the fact that reliable, wireless scanners can get quite expensive comparatively.

Proposed Final Design

Based on the team's evaluation of each of the three designs, the Scanner design was decided to be the best fit to move forward with the proposed final design. This design was rated the highest in the following categories: efficiency, system integration, and safety. The Scanner design was best able to be integrated into the existing system in the Mohs Lab, mainly due to the fact that it removed the need for the first three scans to be done at the same station in the lab that was associated with both the Mixed and Smart designs. Additionally, patient information would be the safest due to the absence of the tablet/smartphones.

V. Fabrication/Development Process

Materials:

The materials for the design must be able to withstand laboratory conditions including sterilization. Materials chosen should be durable and non-toxic. For the scanner design, the team will need to purchase two wireless scanners that can scan both barcodes and QR codes. The scanners chosen must be able to hold a charge and be easily recharged. In addition to scanners, the team will need to develop or find software that will input data that is received from the scanners into a spreadsheet. The software should avoid inhibiting the use of the lab computer that is collecting data. This is because the lab may need to use the computer for other tasks other than recording time stamps. Possible software development platforms that the team may use include Java, Python and C++.

Methods:

Fabrication of the design will require obtaining and testing the scanners to understand how they can interface with the computer. For example, scanners may have specific drivers involved which may help with the transferral of data. Next, based on this information, the team will begin to develop software that works well with the scanner and the current lab computer. It is possible that development of such adequate software is outside the scope of the team's abilities. In this event, it may be necessary for the team to outsource the required software.

VI. Discussion

The implications of the team's future results could allow for greater efficiency inside of the lab which could lead to better reviews and higher revenue. If more patients are able to be processed each day the clinic can continue to increase the amount of patients they can take in each day until they reach a new maximum. The shorter wait times most likely would result in raised patient satisfaction. This may lead to more promotion from patients to others who also have skin cancer in an attempt to push them towards the clinic. This in turn creates a cycle of requiring higher efficiency from the lab in order to continue to decrease processing times of the specimens.

The ultimate goal for the product is to produce a system that can still issue a standard expected time for turnaround with minimal user input. In regards to the ethical considerations, a major complaint has been presented about such a system in a laboratory setting: It could result in unanalyzable specimens due to the laboratories being rushed to provide results.[2] Only by

providing a standard that can be upheld, rather than simply pushing the laboratory to achieve the lowest average time possible, can a beneficial result be acquired. There is also the ethical concern that the turnaround times could become inflated due to factors that are outside of the laboratory's control. An example of this was shown in a study at the clinical laboratory of the Kathmandu University Hospital in Nepal, where issues with patient billing caused 48.4% of delays for patients' reports.[6] This means that there has to be some method included to discount or correct erroneous data when creating the standard mentioned earlier.

In future testing, methods will be used to account for sources of error to create the most accurate system possible. For recording time stamps, scan errors to the computer will need to be addressed along with connectivity range. In data analysis, double scanning a specimen, missing a timestamp, scanning out of order, and other errors will need to be accounted for in the testing of our program.

VII. Conclusion

The Mohs Laboratory is looking to improve upon their current TAT tracking system, a physical paper punch card system, with a more reliable, efficient, and accurate technology-integrated solution. "Scanner," the chosen design as highlighted by the design matrix, will excel in efficiency and laboratory integration by using two multipurpose barcode/QR code scanners connected to a laboratory computer. One scanner will track the first three time stamps (intake, begin preparation, finished preparation) and will be located at the checkmark table. Another scanner will be located in the microscope room to track the final reading time by the physician.

The future of this project will mainly consist of research, purchasing the proper devices, and testing the system. Further research will be needed in the connectivity of the scanners and programs that interface with the recorded data. Once the scanners are obtained, testing will be done to determine the coding needed to account for errors, allow for site iterations, and display data in a human-friendly manner. The testing will attempt to replicate the Mohs laboratory workflow and account for possible system errors. If the scanner solution does not seem feasible as it is further developed, the team will return to the design matrix and pursue other options.

VIII. References

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IX. Appendices

Appendix A: **Project Design Specifications (PDS)**

Function:

The goal of this project is to modify and update the existing Turnaround Time Tracking system used in the Mohs surgery laboratory. Mohs surgery involves the removal of tissue specimens from the patient and subsequent laboratory work on each specimen. To ensure the quality and efficiency of this procedure, the laboratory has adopted a time tracking system. Currently, the physician or lab technicians are tasked with punching paper time cards at each transition in the laboratory process. Physical time cards are inefficient and may lead to misplaced or incomplete data. Thus the team is tasked with creating a more automated turnaround time tracking system that utilizes the existing barcode on each tissue specimen.

Client requirements:

- The timestamps that must be recorded are:
    - when the tissue specimen arrives at the lab
    - when a technician begins to work on the tissue specimen
    - when the finished slide is returned to the physician
    - when the slide has been read by the physician

- The barcode contains 2 patient identifiers and will be used to assign individual specimens to the time at which they were scanned at each stage. All of this information must be recorded on a computer in ideally Excel format.
- The system must be able to handle cases in which a specimen needs additional work in the laboratory. Additional timestamps must be recorded.
- Eliminate human error from the system and minimize the manual work done to produce the timestamp data

Design requirements:

1. Physical and Operational Characteristics
    a. *Performance requirements*:
        i. The system will be used every week day, with busier days on Monday, Tuesday, and Thursday.
        ii. It should increase efficiency and decrease timing errors
    b. *Safety*:
        i. Wires should be organized to minimize tripping hazard.
        ii. General laboratory equipment safety requirements should be met
    c. *Accuracy and Reliability:*
        i. The system should be able to record the time between each station to the nearest second for time less than 24 hours.

d. *Life in Service*:

    i. The system should be able to track time upwards of 10 hours but not over 24 hours (sites enter the lab and are completed in the same day) of all active sites in the laboratory.

    ii. The maximum anticipated volume is 20 sites per day, however, it may increase if a site needs additional stages.

    iii. There are approximately five sites being read in the laboratory at the same time (may fluctuate depending on schedule).

e. *Shelf Life*:

    i. System should last a minimum of 1 week without charging or the offloading of data

    ii. The overall life span of the system should be upwards of 3 years

f. *Operating Environment*:

    i. System will experience minimal disruption in the setting it is intended to be used.

g. *Ergonomics*:

    i. Lab physician and lab technicians must be able to use the system with relative ease

h. *Size*:

    i. Should be portable in order to be moved around the lab when needed

    ii. Should fit within the available space within the lab - quantitative values to come once the virtual lab tour occurs

i. *Weight*:

i. Should be no more than 15 lbs (tentative value) - must be able to be easily moved by lab members as needed

j. *Materials*:

i. Products included in the system need to be steralizable as they are a part of a laboratory and should be antimicrobial.

k. *Aesthetics, Appearance, and Finish*:

i. No specific requirements for the appearance of the system have been identified

2. Production Characteristics

a. *Quantity*:

i. One unit

b. *Target Product Cost*:

i. The ideal budget is $200 with the ability to use already existing equipment in the lab with it.

3. Miscellaneous:

a. *Standards and Specifications*:

i. No FDA approval required

b. *Customer*:

i. Digitize the system as much as possible

ii. Maintain barcode/patient label system already in use

c. *Patient-related concerns*:

i. The data from the time tracking will have to be confidential as well as any patient information that goes along with it due to HIPAA.

d. *Competition*:

i. The current time card system at the Mohs lab is the only identified competition