SmartMed Case Development Project

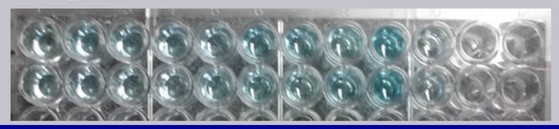
Alexandre Plastow, Hussah Alaseed, Alexander Fox
Advisor: Melanie G. Watson, Ph.D.
Trine University
One University Avenue, Angola, Indiana 46703

Trine University
Biomedical Engineering

Introduction:

- The ability to determine and record blood potassium levels is an important part of medicine. Many diseases and disorders can be diagnosed through evaluating the level of potassium in a patient. These readings can be required multiple times a week. This can leave copious stress on both a patient and their loved ones who may need to take the patient to the hospital. The SmartMed case is designed to circumvent this issue and will ideally provide accurate readings from the patient's home with minimal technical knowledge.
- The specific mechanism for potassium detection uses guanine-rich DNA strands, which can form a chair-like structure around potassium ions. We explored two potassium detection methods. The first is a colorimetric assay to differentiate potassium concentrations (shown in Figure 1). The second is to time a solution that is traveling through a paper-based pathway to compare to a standardized time. That is, faster solutions will have more potassium.
- To analyze the potassium stain, qualitative data needs to be converted to quantitative measurements by a MATLAB program, which will give a different value for varying potassium levels corresponding to the different shades of blue.

Figure 1: Image of an assay trial. The different blue colors may indicate potassium concentration or some other modified variable. This one is influenced by increasing concentrations of hemin, not potassium.



Materials and Methods:

- PS5.M DNA oligonucleotide
- KCl (Solutions)
- Hemin
- TMB solution/blue ink solution

The DNA is heated first, afterward KCl is added and the G-quadruplex should form. Hemin is added to form DNAzymes. This solution is added to a TMB solution and left to oxidize and turn blue (Figure 2). For the paper based assay, the DNAzyme is added with a Blue ink solution and allowed to travel a distance. The speed is a function of potassium concentration.

Image analysis:

Is intended to Identify distinct stains to determine potassium concentration. Darker stains correspond to lower RBC matrix ensembles, which may be used to assign concentration.

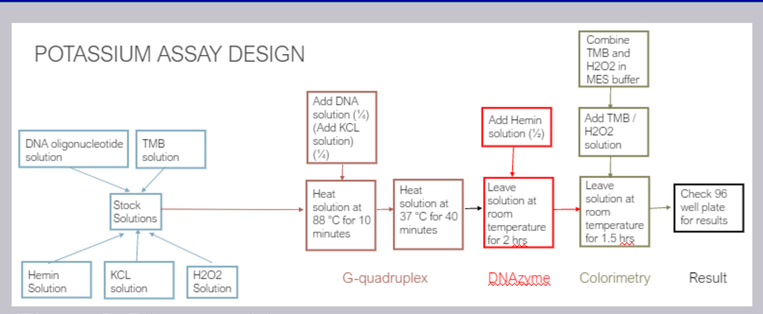


Figure 2: Diagram of the assay process

Results and Discussion:

During the semester, 31 different assay tests were run. 6 were completed in the first semester, 25 in the second.

The first semester was focused on understanding the assay process

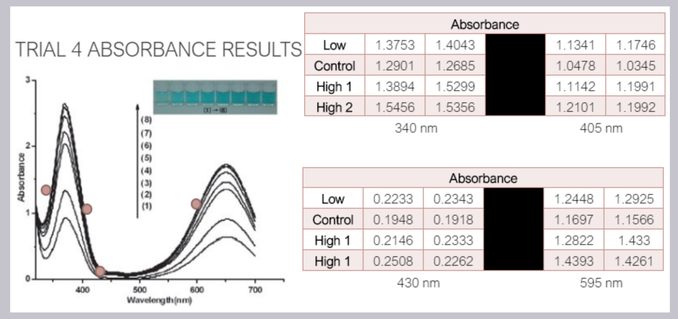
- It was shown that the assay could be replicated and have similar results to peer-reviewed literature (figure 3)

The second semester was focused on improving the assay and understanding specific components of the assay.

- Many components were varied, especially specific chemical concentrations (Hemin, DNA, TMB)
- Some varied chemicals caused issues with the assay, such as one trial with high Hemin concentrations which caused the solutions to become a dark shade of green
- Processes were also varied though multiple modalities, such as heating times, the number of heating periods, or the ink based method, which used a poly-TMB product to determine potassium concentration.

Image analysis:

- To find the best method to analyze the potassium stain, four techniques were tested, which include: the edge detection function, image crop, segmentation App, and Color-Based Segmentation. The Color-Based Segmentation was found to function well, and may identify a stain and analyze that stain to deduce potassium concentrations.



Absorbance					
Low	1.3753	1.4043		1.1341	1.1746
Control	1.2901	1.2685		1.0478	1.0345
High 1	1.3894	1.5299		1.1142	1.1991
High 2	1.5456	1.5356		1.2101	1.1992
		340 nm		405 nm	

Absorbance					
Low	0.2233	0.2343		1.2448	1.2925
Control	0.1948	0.1918		1.1697	1.1566
High 1	0.2146	0.2333		1.2822	1.433
High 1	0.2508	0.2262		1.4393	1.4261
		430 nm		595 nm	

Figure 3: Image of one trial's data. This data is then matched to a standard wavelength (red circles) to show the integrity of the data.

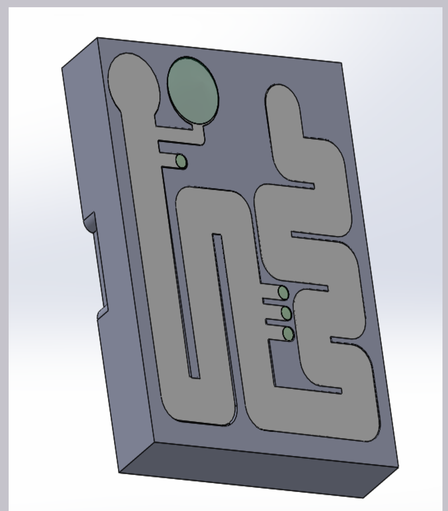


Figure 4: Microcartridge redesign. The design is simplified and spaced to work over a specific period of time.

Conclusion:

The SmartMed case is a device with multiple functionalities and can help a lot of people. Finishing this device could reduce hospital visits. There are similar, but varied way the potassium assay can be completed, but devising an affordable technique requires ingenuity. New techniques for potassium detection have been investigated, though the assay process remains inconsistent. Hopefully, future SmartMed case teams can continue where we stopped and see this project to its end.

Future Work:

The following are ideas to further improve the SmartMed Case project:

- Experiment more with paper-based assays which rely on the hydrophobicity of a poly-TMB product
- Continue to improve the MATLAB program for color detection to more effectively isolate blue stains for analysis
- Integrate the assay process into the new microcartridge by distributing the components among the blister packs (Figure 4)

Acknowledgements:

The Biomedical Engineering Senior Design Team would like to thank the following for their contributions, facilities, and resources:

- Trine University
- Innovation One
- Cameron Hospital