THE CANADIAN SCIENCE FAIR JOURNAL

ARTICLE

Tube-y or Not Tube-y: Traditional vs. Modern Insulin Pumps

Riley Last

Age 15 | Gold River, British Columbia

Canada-Wide Science Fair 2019 Finalist

Just like any disease or condition a person might be diagnosed with, diabetes has become a huge part of my life, therefore becoming a huge part of the lives of my family and friends. If I am one person with diabetes, affecting so many people around me, I can only imagine how many people the other millions of diabetics around the world affect, and broadly speaking, none of us want diabetes management to be a burden. In an effort to ease the challenges that come with managing such a thing, scientists like Dr. Arnold Kadish (1960), and engineer Dean Kamen, developed the first insulin pumps (1976).

INTRODUCTION

In June of 2015, my Omnipod brand insulin pump came in the mail. At the time I wasn't aware that I was one of the first people on the west coast of British Columbia to have a modern, tubeless insulin pump. In July of 2018, I attended a camp designed for young diabetics to connect with each other. At this camp, I observed the different types of insulin pumps the individuals used - most of which were traditional and tubed.

This prompted the question I would later use for my science fair study: is a traditional insulin pump better or more reliable than a modern insulin pump and what are the differences? Though the thought had never crossed my mind before, I started to question the integrity of my own diabetes management system. A science fair project provided the perfect opportunity to look deeper into the types of insulin pumps, with the intention of discovering if one insulin pump is superior to the other. To be able to come to a sophisticated conclusion, I was going to need to do some thorough research. Starting research on traditional insulin pumps, I came across a website called Open APS (Dana Lewis, 2015) (artificial pancreas system). Through research, I found out it is a developing project in which an attempt is made to manage diabetes more effectively using existing medical equipment. This artificial pancreas system allows insulin pumps and CGMs (continuous glucose monitor) to communicate so that insulin is administered in corrective doses, according to the CGM readings, and without being manually entered. Unfortunately, Open APS (Dana Lewis, 2015) algorithms are only compatible with traditional insulin pumps. Initially I was disappointed about this because I thought I'd have to wait for someone else to make it compatible with my modern insulin pump. This disappointment lasted a few minutes until I realized I could always try to do it on my own.

When science fair season started approaching, I made the decision to spread out a project about insulin pumps and artificial pancreas systems over two years. The first year (this year), I would research insulin pumps in a study, and the second year I would utilize that information when programming the modern insulin pump for the artificial pancreas system modification.

PROCEDURE

The first thing I did after deciding what this project was going to be about and where I would take it, is to begin gathering background information necessary to continue research. This information included the following basic questions: what is an insulin pump, what is insulin and why do we need it, and who needs an insulin pump?

After I collected the background information, it was time to research the types of pumps. I started with a summary of the types of insulin pumps and moved onto choosing specific models to study. Though there are many brands of traditional pumps, I chose to study the most common brand, Medtronic. This pump company has many different styles and versions, so to make it easy, I decided to use the generic pump layout from one of the older models (Figure 1). This would be used as the traditional insulin pump studied in the project.

Next, I chose a modern insulin pump. There are only two types of modern insulin pumps and one is significantly more

Figure 1. Generic traditional insulin pump.

doi: 10.18192/csfj.v2i32020110114

Figure 2. Omnipod modern insulin pump.

common than the other. This made the decision to study Omnipod brand modern insulin pumps (Figure 2) very easy.

With both the traditional and modern insulin pumps chosen, I proceeded to gather information on the main components of both. After learning what the necessary physical parts of each pump are, I dove into the pump program features. In this research, I found that the traditional and modern pumps generally have the same features when it comes to insulin delivery factors and blood sugar counting. Though the pumps have similar calculation settings, they still have a few different attributes including style, wear time, waterproof capabilities, and more. I also collected information regarding the future of insulin pumps and diabetes management technology, catching a glimpse of next year's project. I looked at the forms of existing artificial pancreas systems and how both types of insulin pumps are implemented in them. With an enhanced curiosity, I opened up a modern insulin pump patch/pod and discovered something that will be important for next year's project.

COLLECTED INFORMATION

What Is an Insulin Pump?

An insulin pump is a small, battery operated medical device that resembles a pager. They allow diabetic people to avoid multiple daily injections of insulin and promote a more convenient lifestyle by releasing insulin into the user's body. An insulin pump uses programming set by the user and health professional so it knows when to administer the insulin. Insulin pumps give users the opportunity to have better maintained blood glucose levels, resulting in an overall higher quality of life.

Who Needs an Insulin Pump?

An insulin pump is a medical device used by diabetic patients. Diabetes is caused by the pancreas being unable to produce enough or any insulin. This is due to many reasons including heritage, environment, or lifestyle. There are different types of diabetes, the main two being type 2 diabetes and type 1 diabetes. An insulin pump is more commonly worn by a type 1 diabetic as type 1 diabetics have no insulin production and type 2 still have some insulin production but the insulin isn't used properly. Type 2 diabetes can be managed with different medications, but in more severe cases, an insulin pump may be used.

What Is Insulin & Why Do We Need It?

Insulin is a hormone produced by beta cells in the pancreas or,in the case of a diabetic, synthetically produced. Manufactured insulin was initially derived from cows and pigs - this changed in 1983, when biosynthetic insulin became available. Insulin allows the body to ingest and properly use the sugar (or glucose) that is found in carbohydrates. Insulin regulates the metabolism of carbohydrates by absorbing glucose from the bloodstream, causing it to be stored instead of immediately being used for energy. Therefore, when you eat carbs and glucose from it makes your blood sugar rise, which will signal the beta cells to release insulin. The released insulin attaches to blood cells and absorbs the sugar from the bloodstream. Thus, the purpose of insulin is to keep blood glucose levels in range and promote a healthy life.

Insulin Pump Components

When an insulin pump is shipped to someone, they will receive all the components to the respective pump. Each brand and style of pump will have different parts but each have basic components that are generally all found with each insulin pump.

Types of Insulin Pumps

Many different types of insulin pumps exist and a user's preferred system may different from another user. There are generally two main types of insulin pumps, these are traditional and modern (insulin patch) pumps. With a traditional insulin pump, the insulin is held in a reservoir inside the pump and is delivered through an infusion set. A modern insulin pump patch holds insulin in a reservoir directly on the skin, and is delivered via a small cannula inserted above the insulin reservoir. This type of insulin delivery is also controlled by a handheld pumping mechanism, although the modern pumping mechanism is detached from the rest of the system. A lot of pumps are able to connect wirelessly to blood glucose meters, which measure the level of glucose in your bloodstream. Blood glucose levels help to determine the amount of insulin given to a patient through a pump. Another blood glucose (BG) monitor is a continuous glucose monitor (CGM.) A CGM is a device in which a tiny wire is inserted under the skin and transmits BG levels to a meter. Some insulin pumps have their own CGM systems that connect to the pump and help determine insulin delivery without the user having to input numbers.

Omnipod

The omnipod is an insulin pump patch. This is a new type of pump that sticks directly onto the skin and does not require tubes. The patch part of this pumping system is called a pod. The pumping mechanism of an omnipod is handheld and it does not have to be held on the body of the user, like the pump for a traditional pump. Insulin delivery is determined by the programmed settings in the pump. Omnipod features include customizable reminders, carb count calculator, alarms in the event of pod failure, and insulin sensitivity factor calculator. The pod is waterproof and it continues to deliver insulin in the water. The insulin reservoir also holds up to 200 units of insulin, and each pod lasts about 72 hours.

Traditional Pump

Traditional pumps have been around for over 20 years, though more portable insulin pumps have only been around for only 20. Traditional insulin pumps have infusion sets that stick to the person. This is called a site. The site is attached to the pump by tube and the insulin flows through the tube and into the body. The pump is clipped onto the person so that insulin flow can go through the day. Insulin delivery is determined by the programmed setting in the pump, just like the omnipod. There are different brands and styles of traditional insulin pumps, therefore they do not have all of the same features. Generally speaking, a traditional insulin pump will also have a carb count calculator, alerts, and an insulin sensitivity factor calculator. There is one style of traditional insulin pump that is waterproof, meaning you can swim and shower with the pump remaining attached to your person. The insulin reservoir also typically hold up to 200 units of insulin, and the sites last about 72 hours as well.

Shared Pump Features

A carb count calculator is essentially a feature that takes the programmed insulin to carb ratio (1:10) and determines how much insulin is needed according to how many carbs the user is consuming. Insulin sensitivity factor is the amount of insulin needed to correct a high blood sugar. It is the number of units of blood sugar that 1 unit of insulin drops the glucose. The type of insulin delivery that carb count calculator and insulin sensitivity factors use is called a bolus dose because it is given according to a BG number. The other type of insulin delivery is called a basal rate. This is a background rate of insulin that runs 24/7 to keep stable blood sugar numbers overnight and when your not eating. Basal insulin is a key feature in all insulin pumps.

Artificial Pancreas Technology

Diabetes management technology seems to always be developing and sometimes it's hard to keep up with. As of right now, it seems like diabetes management technology is going in the direction of APS (artificial pancreas systems) which use manufactured mechanics to mimic the way a pancreas delivers insulin. There are three major forms of APS right now.

Closed Loop APS

A closed loop artificial pancreas system uses existing traditional insulin pumps and CGMs (continuous glucose monitor) to deliver more or less insulin every few minutes. The system makes these decisions depending on the blood glucose level readings from the CGM and preset insulin sensitivity factors on the pump. They are able to communicate because of an algorithm that connects them. Closed loop artificial pancreas systems are considered hybrids still due to the fact that most insulin peaks at 60 - 90 minutes after delivery, and carbs hit at 15 minutes, leaving a large gap of time to catch up. This is also why most people who use closed loop systems still administer bolus doses for large corrections and food consumption.

Bionic Pancreas

A bionic pancreas system works like a closed loop, but instead of using existing technology, a bionic pancreas is its own program/system. As of right now there is only one bionic pancreas program in the making. This is iLet created by Dr. Edward Damiano. There are three components to iLet - these include: a CGM system, the iLet pump, and the infusion set. It works by sending CGM readings right to the iLet set which then automatically delivers insulin or glucagon according to the reading. This bionic pancreas was enrolled in bionic pancreas clinical trials in 2017. The brand is using 600 patients aged 13 and up, who have type one diabetes. Their goal was to have the insulin only version FDA approved by 2018, though that turned out unsuccessful. Bionic pancreas systems are currently in trial stages.

Implanted Artificial Pancreas

The implanted artificial pancreas systems are in testing and developing stages, with researchers from De Montfort University studying a gel that could be injected into a patient. When the gel reads high blood sugars, it automatically releases insulin. When it reads low blood sugars it decreases insulin delivery. Currently, there isn't a lot of information on implanted artificial pancreas systems but they are in testing and developmental stages. Keep your eyes open.

Traditional Insulin Pumps & Artificial Pancreas Systems

Currently, old model traditional insulin pumps used in the closed loop artificial pancreas systems are widespread. The only type of artificial pancreas systems that uses existing technology, is exclusively compatible with traditional pumps. This is due to the fact that the closed loop algorithm is only programmed to communicate with a single system. The traditional pump will generally come with a USB to transfer the data onto a computer. The USB connects with the circuit board for the loop therefore connecting the programmed circuit board to the pump. The CGM (continuous glucose monitor) is connected with a computer cord. The pump is told what to do based on the CGM readings and pump settings, and it delivers insulin automatically through the tube, making a closed loop with a traditional pump simpler to create.

As of right now, there are multiple websites open to the public with instructions on how to programmed the circuit board and create your own closed loop artificial pancreas system. The website/project that first caught my attention is "OpenAPS." This project website has an easy-to-follow layout and PDF instruction booklets. It also includes a diagram exhibiting the model of insulin pumps in which the closed loop APS is effective.

Modern Insulin Pumps & Artificial Pancreas Systems

At this point in time, there are no artificial pancreas systems using existing modern insulin pump technology. The only APS that even uses existing pump technology is closed loop systems which are exclusive to traditional pumps. OpenAPS (one of the project websites involved with APS tech) has opened a forum up to every individual interested in a closed loop with modern insulin pumps.

Currently, there has been no new headway in discovering an algorithm suitable for a modern insulin pump. Next year, I intend to look deeper into the inner workings of the Omnipod pump and finding a way to efficiently link a modern pump, CGM, and circuit board to complete a closed loop.

OBSERVATIONS

The traditional and modern insulin pumps proved that even though they are different in some ways, they customarily do the same thing. The styles and specific features of the respective pumps don't interfere with insulin administration and calculation functions or reliability of pump operation of either, meaning they are both equally effective. Opening up the patches/pods, I saw the microcontroller chips (Figure 3) which read the same chip name for each pod regardless of the lot it came from. The reason a traditional pump connects to a closed-loop APS is because the program only has to go through one system to deliver insulin, whereas for a modern insulin pump the program has to go through the pump and then the separate pod.

CONCLUSION

This study brought my attention to the fact that diabetes management technology is developing swiftly. My knowledge of traditional and modern insulin pumps has broadened and I no longer doubt the integrity of the type of insulin pump I use to manage diabetes. Ultimately, I think the decision to use a traditional or modern pump, in Canada, comes down to comfort zones. A lot of people I know are so used to traditional pumps that the change scares them, but I think projects like this are a good way to open their eyes to new, reliable technology. Afterall, it is the future of our health.

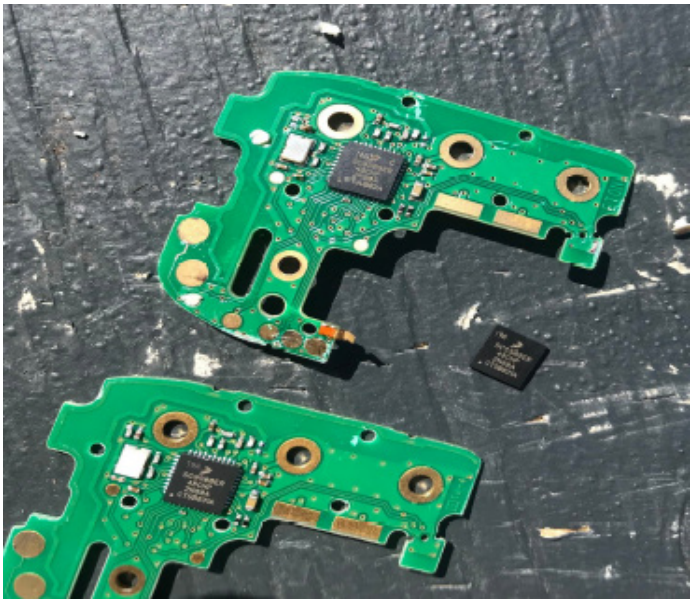

Figure 3. Microcontroller chips.

ACKNOWLEDGEMENTS

I would like to express my special thanks of gratitude to; my science teacher, Mrs. Katrina Kornylo; my mother, Stacy Last; and my father, Adrian Last for their support through the entire development and completion of my project. I'd also like to recognize and thank my English teacher, Ms. Happ for her time spent proofreading. Lastly, I wish to acknowledge my endocrinologist, Dr. Henderson; pediatrician, Dr. Lund; and all the amazing people at the diabetes clinic in Campbell River for inspiring me to learn about diabetes and managing it.

REFERENCES

"OpenAPS.org – #WeAreNotWaiting to Reduce the Burden of Type 1 Diabetes." OpenAPS.org, Dana Lewis, 2015, www.openaps.org/.

"Insulin Pumps." Diabète Québec, 15 Aug. 2018, www.diabete.qc.ca/en/living-with-diabetes/care-and-treatment/drugs-and-insulin/insulin-pumps .

"Insulin Pump Overview." EndocrineWeb, www.endocrineweb.com/guides/insulin/insulin-pump-overview .

Canada, Health. "Insulin Pumps." Canada.ca, 2 Oct. 2012, www.canada.ca/en/health-canada/services/healthy-living/your-health/medical-information/insuli n-pumps.html .

Medtronic. "Medtronic Diabetes Canada." Medtronic Diabetes Canada, www.medtronic.com/ca-en/diabetes/home.html .

"Everything That You Need to Know About Insulin Pumps." Diabetes Advocacy, 4 Feb. 2019, www.diabetesadvocacy.com/diabetes-care/everything-that-you-need-to-know-about-insulin-pump/ .

"Home | The Omnipod® Insulin Management System." Home | The Omnipod® Insulin Management System, www.myomnipod.com/home .

Butler, Deborah, and Licsw. "To Pump, or Not to Pump? - Diabetes Self." Management, www.diabetesselfmanagement.com/about-diabetes/kids-diabetes/to-pump-or-not-to-pump/ .

"OpenAPS.org – #WeAreNotWaiting to Reduce the Burden of Type 1 Diabetes." OpenAPS.org, Dana Lewis, 2015, www.openaps.org/ .

U.S. National Library of Medicine, National Institutes of Health, www.openi.nlm.nih.gov/detailedresult?img=PMC3118276_13300_2010_4_Fig2_HTML&req=4

"What Is Insulin?" EndocrineWeb, www.endocrineweb.com/conditions/type-1-diabetes/what-insulin

"Diabetes Treatment: Using Insulin to Manage Blood Sugar." Mayo Clinic, Mayo Foundation for Medical Education and Research, 29 Apr. 2016, www.mayoclinic.org/diseases-conditions/diabetes/in-depth/diabetes-treatment/art-20044084 .

"Glossary." DiabetesCanadaWebsite, www.diabetes.ca/about-diabetes-canada/glossary .

"Diabetes, Heart Disease, and Stroke," National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK). Retrieved: https://www.niddk.nih.gov/health-information/diabetes/overview/preventing-problems/heart-disease-stroke

"Glucose oxidase An overview" Science Direct. https://www.sciencedirect.com/science/article/pii/S0734975009000536

"Find a Supplier," Medicare.gov. Retrieved: http://www.medicare.gov/supplier

RILEY LAST

I'm Riley Last, a grade nine student at Gold River Secondary School, located in a small village on the west coast of British Columbia. I enjoy being a part of Junior Canadian Rangers and I represent my school as the Vice President and Secretary of the Student Council. I've had a passion for medical sciences since 2015 when I decided I wanted to go to university and obtain a bachelor's degree in science. I later decided to major in microbiology and pursue a career in pediatric endocrinology. This choice was made based on my desire to work in the medical field and to help other children understand diseases and conditions they have to manage. In my personal experience, managing the endocrine disease, diabetes, is a lot easier with the right technology. This is what gave me inspiration to study insulin pumps and diabetes management equipment. My advice to other students developing a science fair project would be to be passionate about their field of study. If you are genuinely interested in the subject, it becomes easy to absorb and communicate the information, and it makes science fair fun!