Liquid Medication Delivery System

Team Members: Padraic Casserly, Angwei Law, Allison McArton , Grant Smith
Department of Biomedical Engineering
Advisor: Professor John G. Webster, UW-Madison
Client: Engineering World Health

Abstract

In the developing world, AIDS has become a rampant problem, especially its transmission from mothers to newborn children. In order to combat the spread of AIDS, single doses of nevirapine, an anti-HIV drug, are given to infected pregnant mothers. This project seeks to design an inexpensive bottle-top dispenser for Viramune®, a brand of nevirapine. By consistently, easily, and efficiently measuring single doses of medication, the treatment will become more affordable; thus, more patients can be reached and the spread of disease will slow. The team designed a device that acts like a manually operated one-way valve, incorporating two clamps and a syringe. A prototype was assembled and tested. Preliminary results suggest the device meets expectations, especially cost restrictions.

Problem Statement

Motivation/Background

AIDS kills 3.1 million people every year, over 80% of whom live in developing nations.[1] In the developed world, the progression of AIDS can be slowed significantly and held stagnant in a relatively non-threatening state. However, the medications which effectively treat AIDS are quite expensive and thus not a practical solution for many parts of the world. Fortunately, a single 0.6 mL dose of nevirapine (sold commercially as Viramune®) administered at birth has been shown to effectively reduce HIV transmission from mother to child by nearly 50%.[2]

Well, if nevirapine is really so useful in these settings, why aren't all newborns of infected mothers treated at birth? Unfortunately, societies in many parts of the world are not set up with adequate access to healthcare. In many parts of Africa for example, a pregnant mother will only see a doctor once and give birth at a location relatively remote from any medical facility or pharmacy. Therefore, the mother must have an appropriate dose of medication that lasts from the visit to the doctor to the time she gives birth. A type of foil packet has been designed to help maintain the dose during this period, but a cheap way to measure the dose and dispense it into the packet is needed.[3]

Photo courtesy of Dr. Vivian Rexroad, Pharm D.

http://www.healthcare-packaging.com/images/PATH.jpg

Figure 1: Top: Liquid nevirapine medicine bottle with oral syringe and cap currently used to deliver doses. Bottom: Foil packets used to contain doses of liquid nevirapine.

Client Requirements

- Liquid medication bottle-top dispenser
- Sterilely deliver fixed doses of liquid nevirapine into foil packages
- Dispense 0.6 mL (± 0.03 mL) of medicine (5% error margin)
- Accurately deliver 400 doses; operable for 6 months
- Seal medicine bottle and prevent contamination
- Cost ≤ $2.00 (USD)

Final Design

The team considered several design alternatives including inverting the bottle, using one-way valves, and using a plug. However, those were either too costly or impractical; the following design was deemed the most suitable:

Construction

- Drill a hole in cap 1/4" diameter or slightly smaller
- Cut pieces of tube as follows:
  - 16 cm of 1/4" OD, 1/8" ID tubing
  - 5 cm of 1/4" OD, 1/8" ID tubing
  - 1.5 cm of 3/16" OD, 1/8" ID tubing
  - 8 cm of 1/8" OD, 1/16" ID tubing
- Force the 16 cm tube through the hole in the cap
- Place the clamp, opening upwards around the tubing extending from bottle
- Connect the central outlet of the T-connector to that tube
- Connect the 5 cm tube to one of the open ends of the T-connector
- Connect the 1.5 cm tube to one of the open ends of the T-connector
- Connect the syringe tightly to the 1.5 cm tube
- Place the clamp around the 5 cm tube opening away from the T-connector
- Force the 8 cm tube into the open end of the 5 cm tube
- Close both clamps

Figure 2: Prototype attached to a Viramune® medicine bottle.

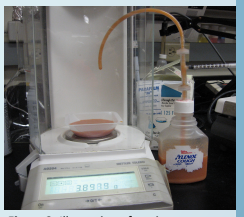

Figure 3: Illustration of testing apparatus. Note that prototype displayed is from the previous semester.

Usage

- Open the clamp nearest the bottle
- Withdraw the desired dosage into the syringe
- Close the clamp nearest the bottle
- Open the outlet clamp
- Depress the syringe
- Close the outlet clamp

DO NOT

- Open both clamps at the same time
- Pull forcefully on any element of the device
- Operate the syringe without opening one clamp

Pros

- Very inexpensive
- Accurate and precise
- Allows variable dosing

Cons

- Difficult to operate
- Can be operated incorrectly

Acknowledgements

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References

1. Yale Aids Watch. Yale University. <http://www.yale.edu/yaw/world.html>
2. Guay LA, Musoke P, Fleming, T, et.al (1999) Intrapartum and Neonatal single-dose Nevirapine compared with zidovudine for prevention of mother-to-child transmission of HIV-1 in Kampala, Uganda: HIVNET012 randomised [sic] trial Lancet 354:785-802.
3. Engineering World Health. Available Design Projects. Liquid Medication Delivery System. <http://www.ewh.org/youth/design_projects.php>

Testing

In order to develop a mixture that had a similar viscosity to Viramune® (400 cP), we did viscosity testing of different combinations of corn syrup and water. To determine the viscosity of the solutions, a steel ball was dropped into a graduated cylinder filled with the liquid. The amount of time the ball took to pass two different points at a given distance was recorded and velocity was calculated. The following equation (Stokes' Law) was used to determine viscosity for each mixture:

$$\mu = \frac{2(\rho_b - \rho_l)}{9 v_t} g R^2$$

μ = viscosity of liquid
ρ_l = density of liquid
g = gravitational acceleration
ρ_b = density of ball
v_t = terminal velocity
R = radius of ball

Several trials were performed until a 419 cP mixture was created. This particular mixture contained 15.5% water by volume.

Using this mixture, the team moved on to accuracy testing. We found the mass of 0.6 mL of the corn syrup/water mixture to be 0.800 (± 0.008) g (n = 10). We then wrote a procedure on how to operate the device, and each team member independently conducted ten trials. This demonstrates variation in operation by different users.

In Figure 4, the black line shows the actual mass of 0.6 mL of our Viramune® analog. The trial average was 0.804 g (n = 40), slightly higher than the mass of 0.6 mL. The overall standard deviation of the trials was 0.008 g. The average percent error was 0.56%, well within the required ± 5% error range.

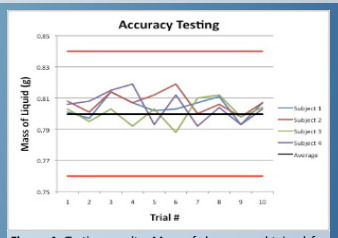

Figure 4: Testing results. Mass of dose was obtained for ten trials for each member and compared to the standard.

Future Work

- Test reliability of device after repeated usage
- Test device with Viramune® and the foil packages
- Assemble a construction kit with instructions and visuals for setting up the device

Cost Analysis

Quantity	Item	Price per Unit	Sub-total
2	Dura-Clamp Registered Tubing Control	14¢	$0.28
1	Polypropylene Cap with Foamed PE Liner	5¢	$0.05
1	Precision-Glide, Tuberculin Syringe- 1mL	22.11¢	$0.22
1	1/16" T Type Polypropylene Connector	26¢	$0.26
21 cm	1/4" OD x 1/8" ID Superthane® Tubing	0.59¢	$0.12
1.5 cm	3/16" OD x 1/8" ID Superthane® Tubing	0.42¢	$0.01
8 cm	1/8" OD x 1/16" ID Superthane® Tubing	0.31¢	$0.02
		Total:	**$0.97**