Accurate and Reusable Chemotherapy Pump

Members: Joseph Hudspeth, Mina Matta, Gracie O’Neill, Jacob Scutt
Advisors: Dr. Mark Fehlberg, Dr. Ryan Stanfield

Introduction

Chemotherapy is administered in 2–6-week cycles consisting of multiple infusion sessions. The IV pumps used are typically either expensive reusable units with high accuracy or very inexpensive disposable elastomeric units with terrible accuracy. A less expensive, less disposable electro-mechanical pump can deliver high accuracy through feedback motor control and high value through being reusable for the entire treatment cycle.

Objectives

- Create a single-therapy pump for chemotherapy patients
- Ensure 5% flow rate accuracy to compete with leading single-therapy pumps
- Explore different pumping mechanisms to reduce cost
- Pump must be lightweight and small (ambulatory)

The desired specifications are defined in Table 1.

Design Requirements

Table 1. Performance standards and specifications

<table>
<thead>
<tr>
<th>Metric</th>
<th>Unit</th>
<th>Desired Value</th>
<th>Achieved Value</th>
<th>Relevant Need</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow rate accuracy</td>
<td>%</td>
<td>&lt; ±5</td>
<td>±1.5</td>
<td>Accuracy</td>
</tr>
<tr>
<td>Volumetric flow rate</td>
<td>mL/h</td>
<td>1 - 30</td>
<td>1-30</td>
<td>Accuracy</td>
</tr>
<tr>
<td>Cost</td>
<td>$</td>
<td>&lt; 150</td>
<td>$109</td>
<td>Affordability</td>
</tr>
<tr>
<td>Zero-Flow Pressure</td>
<td>psi</td>
<td>&gt; 10</td>
<td>12</td>
<td>Safety</td>
</tr>
<tr>
<td>Pump weight</td>
<td>lb.</td>
<td>&lt; 1.1</td>
<td>0.39</td>
<td>Ambulatory</td>
</tr>
<tr>
<td>Physical volume of pump</td>
<td>in³</td>
<td>&lt; 40</td>
<td>17.95</td>
<td>Ambulatory</td>
</tr>
<tr>
<td>Battery life</td>
<td>hours</td>
<td>48 hours</td>
<td>48 hours @ 5 mL/hour</td>
<td>Usability</td>
</tr>
</tbody>
</table>

Methods

A test bed consisting of an adjustable sliding rail (to control the stretch/tension of the tubing), and a custom rotor was designed to determine the following pump properties:

1. Tubing properties – Diameter, Flexibility, Tension, Length
2. Number of Rollers
3. Power Usage

An additional test was designed to determine:

1. Volumetric Flow Rate and Accuracy
2. Zero-Flow Pressure

Key Design Components

- A - Cover to prevent outside debris from entangling between rotor and tubing.
- B - Disposable cassette that is fixed in the housing to maintain tube tension.
- C - Rotor with 4-roller configuration to ensure the tube is in contact with a roller at all times during the pumping cycle.
- D - Pump housing to protect pump interior mechanism.
- E - User interface including an infusion start/stop button and led light to show the pump status.

Results

To validate the pump’s accuracy, fluid is pumped into a mass scale over a period of time. The data is converted into flow rates (see Figure 3). The accuracy is determined using statistical confidence intervals. Zero-flow pressure is tested to ensure backflow cannot occur. The test results of these parameters are shown below and are compared to their required specifications.

Table 2. Results of tested values against required metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Unit</th>
<th>Required Value</th>
<th>Achieved Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow rate accuracy</td>
<td>%</td>
<td>&lt; ±5</td>
<td>±1.5</td>
</tr>
<tr>
<td>Zero-Flow Pressure</td>
<td>psi</td>
<td>&gt; 10</td>
<td>12</td>
</tr>
</tbody>
</table>

The above metrics have been met, validating safe pump operation.

Conclusion

The chemotherapy pump met all specifications. These findings prove that an affordable, accurate, and lightweight single therapy pump is feasible in the realm of medical devices.