

Small Animal Barostat Instrument Design

ECE 480 Design Team 7
Sponsor: Michigan State University
Department of Pharmacology & Toxicology

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Executive Summary

The Department of Pharmacology and Toxicology at Michigan State University is currently conducting research to better understand the symptoms and treatment of Irritable Bowel Syndrome (IBS). The use of a barostat could prove to be an effective tool in this field of research. The only model currently available on the market is a high-cost instrument more appropriate for use in a user-facility or institution rather than in a university research group. ECE 480 Design Team 7 will design and develop an alternative small animal barostat with comparable to the market equivalent. The alternative barostat design will enable new research in the Department of Pharmacology and Toxicology, with the potential for mass production for the university research group and small commercial laboratory market.

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1. Introduction

1.1 Irritable Bowel Syndrome

Irritable bowel syndrome (IBS) is the most common gastrointestinal (GI) disorder in the United States. It is estimated that between 2.4 and 3.5 million annual physician visits are related to IBS [1]. It is also estimated that roughly 20 percent of American adults are suffering from this disorder [2]. IBS is a major health concern for women in that 60 to 65 percent of the reported cases of IBS are women [4]. Furthermore upwards of 70 percent of people with IBS go undiagnosed as a result of them not seeking medical assistance [2]. It is for these reasons that the Department of Pharmacology and Toxicology at Michigan State University invests in research related to this topic.

1.2 Department of Pharmacology and Toxicology Research

Dr. James J. Galligan is an associate chair with the Department of Pharmacology and Toxicology at Michigan State University and is responsible for research into IBS and related diseases. Dr. Galligan and his team conduct research to quantify the symptoms of IBS as a means to better help identify the possible causes of IBS. It has been found that there could be a direct correlation between IBS and low production of serotonin. Low levels of serotonin could be directly related to levels of estrogen in a patient, which could help explain why women are more affected by this disorder than men. To research this possibility, Dr. Galligan and his team are testing groups of mutated female rats which have no serotonin delivery system. These rats are tested to determine the relation of their gastrointestinal hypersensitivity to a constant pressure on their GI tract. The results are then compared with the tolerances of non-mutated rats.

1.3 Current Laboratory Setup

The rat is led into a holder in which the test takes place. The rat is equipped with electrodes to measure the rat's electro-muscular response to the increased pressure. The end of the inserted device consists of a distention balloon made of a medical glove fingertip. The balloon is attached to a rubber hose from which air enters the balloon via a syringe. An analog to digital converter takes in both the EMG response as well as the air pressure as inputs. Inside the converter is a transducer that consists of a Wheatstone bridge that uses a voltage drop to convert to millimeters of Mercury (mmHg) to determine the current pressure level. These two measurements are then plotted and recorded on a software program called Axoscope. The syringe has to be pushed and a constant pressure maintained by a laboratory assistant. This operation requirement leads to human error.

2. Research Project

2.1 Project Overview

ECE 480 Design Team 7 will develop and design a small animal barostat capable of maintaining a desired constant pressure. This device will be designed in compliance with the specificity and needs of the Michigan State University Department of Pharmacology and Toxicology. The design will be user friendly, economically reasonable, and serve to eliminate human error.

2.2 What is a Barostat

A barostat is a medical device or structure that is used to deliver a constant pressure to a region of interest [3]. In order to maintain a constant pressure, most barostats will use a distention. The balloon will be inflated and deflated rapidly by use of a mechanical device.

2.3 Current Barostat on the Market

There is currently one model on the market made by G and J Electronics Inc. that will meet all of the specifications needed for the purpose of gastrointestinal pressure on small mammals (rats and mice). Due to the fact that each of these barostats is assembled by hand the cost of this device is extraordinarily high at \$25,000. It is almost not feasible to buy one of these units for use in a laboratory where funding may be limited. If a new product can be created and sold for a much cheaper cost, it will be more appealing to several groups that need to make use of such a device. Also the recent models have not been updated much from the previous models due to the lack of competition in the market. The high cost limits access by university research groups and small commercial laboratories.

3. Customer Design Specifications and Objectives

In order to have a great product, the customer must be satisfied with the appearance, performance, and convenience of the design. This design must meet certain expectations or the use of the device may be situational at best. The device must be able to perform all desired tasks and exceed the expectations of the customer. Our sponsor, the Pharmacology and Toxicology Department of Michigan State University, has specified what tasks the device must be able to perform in order to replace the current system used in the laboratory environment:

- The device must be able to go from 0 mmHg to the desired target pressure as instantaneously as possible and do this with an accuracy of $\pm 10\%$.
- The device must supply a range of pressure from 10 mmHg to 80 mmHg (maximum).
- The device must be capable of holding this pressure constant for a time duration of 10 seconds.
- The device must have outputs that can be interfaced with the existing computer software.

4. FAST Diagram

A FAST Diagram is under development for inclusion in the final proposal.

5. Conceptual Design Descriptions

5.1 Introduction

The basic requirement for the design is that it must be able to quickly inflate a distension balloon to a target pressure, and maintain that pressure for the duration of the test. This requires that the design be capable of producing airflow through a piece of surgical tubing, and continuously measuring the pressure in the tubing.

All possible designs will include a user interface that consists of an LCD screen and keypad entry. All designs will be microprocessor controlled, and all sensors and actuators will interface to and be monitored by the microprocessor.

The system should include safeguards that prevent system parameters (such as the air pressure in the system) from reaching hazardous/damaging levels. The system should be able to detect any problems that may occur with the pressure control system and associated electronics and hardware.

5.2 Proposed Design 1 - Motor controlled syringe

The first possibility for airflow control is to create an electromechanical emulation of the current test setup. This would require a motor to control the position of a syringe, interfaced with a microprocessor. The microprocessor would be required to accurately measure both the position of the syringe, and the air pressure in the system.

This design would entail the use of a commercial pre-built motorized syringe, or an electromechanical syringe system that is constructed by our team.

5.3 Proposed Design 2 - Single low-pressure pump

Proposed design 2 would use a low-pressure air pump to provide the air supply to the distension balloon. Since a pump is used, there is no limit to the total amount of air that could flow into the balloon. This would require additional safeguards to prevent excessive air from being pumped into the system in the event that the balloon ruptures. A software algorithm with a feedback control loop would meet this requirement. This design would also require the use of two electromechanical solenoids to control the air flow - one solenoid to fill the balloon, and another solenoid to vent air from the balloon.

5.4 Proposed Design 3 - Pressure/Vacuum pump combination

Proposed design 3 is a variation of proposed design 2. This design uses a vacuum pump in conjunction with the pressure pump. Each pump has a control solenoid which connects/isolates the pump from the system. Only one solenoid is active at any one time. This system uses the vacuum pump to remove air from the system more quickly, allowing the system to quickly compensate for changes in pressure on the distension balloon.

This will eliminate the possibility that simply venting the air from the distension balloon may not occur quickly enough to compensate for changes in the external forces on the distension balloon.

6. Implementation Aspects of Proposed Design Solutions

6.1 Consideration of Conceptual Designs

The use of a pressure and/or vacuum pump introduces a great deal of complexity to the system. Most of the pumps in our price range are diaphragm-type pumps which introduce pressure pulsations to the system when running. These pulsations would cause difficulty in getting precise readings with our pressure

sensors; additional hardware and circuitry would be required to filter these pulsations from the signal. Furthermore, each pump introduces the need for two additional solenoids, one to connect the pump to the barostat air system, and one to vent the pump pressure. The cost of the air control solenoids can be nearly as much as the pumps themselves, depending on how much leakage is acceptable. Due to the cost and complexity considerations, the current goal is to proceed with proposed design 1 and construct a usable electromechanical syringe to control the airflow. This design could possibly use syringes that are currently available from the Department of Pharmacology & Toxicology.

The user interface will consist of an ASCII character-based LCD screen, coupled with a numeric keypad that also incorporates 5-7 special-function buttons.

The microprocessor must have at least one Analog-to-Digital converter, and should have sufficient processing power to simultaneously interface with the user, monitor all system parameters, and control of all system functions.

The end product must use parts that can be easily sourced, and that are robust enough to stand up to the conditions that they are subjected to during live animal laboratory testing. The product must also be able to withstand any physical conditions that it may be subjected to, such as external exposure to moisture during normal operation.

6.2 Testing and Implementation

Each subsystem must be tested for proper function before being assembled into the complete prototype. These subsystems include the air pressure delivery system, the user interface, and the main control board which contains the microprocessor and all associated circuitry. The main control board must be tested first, as all other subsystems are dependent on it for proper operation. Once the main control board has been tested, the use interface should be tested

for proper operation. This test should include verification that the outputs to the final subsystem (air pressure control) are functioning as expected. The final test involves installing the air delivery system and verifying that it functions properly. Proper functionality should include the ability to pressurize and depressurize the system without exceeding target pressure, and maintain this pressure within acceptable limits for the duration of the testing. The system should be able to detect a forced overpressure condition and safely recover from this condition.

The second stage of testing involves rigorous tests of the full design prototype with a simulated distension balloon. The design must be tested under any and all possible conditions that could occur, and it must be verified that the system can compensate for any of these conditions while maintaining system parameters within the defined limits.

The third stage of testing must occur after rigorous second stage testing. This stage of testing is done in the sponsor's lab, and is performed by the sponsor's laboratory assistant. The assistant must be trained in proper operation of the design prototype before the test begins. The laboratory assistant will perform a series of distension tests in collaboration with the design team. All system parameters will be monitored at all times, and the test will be interrupted if any system parameters exceed the set limits.

Once the third stage of testing is satisfactorily completed with all system parameters meeting design specifications, the design will undergo final packaging to prepare it for presentation at Design Day.

7. Risk Analysis

As with any other medical device, there is always an element of risk involved during use. An overpressure release valve will be crucial for the designed barostat. If the device supplies too much pressure, the rat will feel pain, and the experiment will not yield valuable data. There must exist a safety valve that can release some of the air so the pressure does not become dangerous.

Another issue is current and voltage leakages. These values must be low so the animal does not receive a potentially serious shock. All of the external instruments will have to be electrically isolated from the major power supplies to avoid these issues.

The current lab setup involves the finger tip of a medical glove. By replacing the glove fingertip with a distention balloon, there exists less of a possibility that the balloon will burst causing a pressure problem inside of the rat. The measured results will be more accurate and thereby decrease the risk.

8. Project Management Plan

8.1 Team Member Roles

Every member of the ECE 480 Design Team 7 will have both a formal technical role assigned by the team, as well as an administrative role determined by Dr. Shanblatt. Although individual technical and administrative roles are important, it is up to the team as a whole to work together toward a common goal to guarantee success. The formal technical and administrative roles of each team member are described below. ECE 480 Design Team 7 will work collectively to ensure each member's individual tasks are met.

8.1.1 Jacob Scott

User Interface / Processor Technology, General Management

Mr. Scott is responsible for defining the systems requirements for a user interface, the microcontroller, and the associated circuitry. He is responsible for taking the initial design requirements and selecting a range of components that are to be evaluated for possible use in this project. He will also assist with selecting the components for the final design. Mr. Scott's administrative role is that of team manager. It is his responsibility as team manager to coordinate meetings, facilitate communications with the facilitator, sponsor and team, and maintain the GANTT chart.

8.1.2 Casey Davidson

Air Distribution / Pressure Sensor Technology, Document Preparation

Mr. Davidson will assist in the design and building of the air distribution apparatus to be used in the barostat. It is also his responsibility to test this device for accuracy and correct possible errors. In addition, Mr. Davidson will utilize his background in control systems to select and test the pressure sensor to be utilized by the barostat system. Mr. Davidson's administrative role is that of documentation preparation. His responsibilities include the preparation and coordination of all written documents as well as all final editing of all document submitted. It is also his responsibility to organize and maintain the team documentation portfolio.

8.1.3 Thomas Gordon

User Interface / Processor Technology, Website Management

Mr. Gordon will utilize his prior knowledge of control systems to streamline the user interaction. He will be working with Mr. Scott to implement the barostat pressure system with the desired sensors. Also, with Mr. Scott, he will be responsible for coding the devices to communicate with one another. Mr. Gordon's administrative role is that of website management. He is responsible for the upkeep of the website so all interested parties may look at documents related to the design project. He will be responsible for any necessary troubleshooting of the user interface.

8.1.4 Cody Knowles

Air Distribution / Pressure Sensor Technology, Presentation Preparation

Mr. Knowles is responsible for designing and building the air distribution apparatus of the barostat with Mr. Davidson. This task includes selecting appropriate sensors, valves, and/or pumps that meet customer specifications and test their functionality as a system. In addition to this, his electromagnetics background may be utilized should the need for wireless components become necessary or electromagnetic compatibility issues arise. Mr. Knowles' administrative role is that of presentation preparation. This includes managing the preparation and execution of any material to be presented. The presented material will be coordinated via power point slides and prepared for using effective and engaging presentation techniques.

8.2 GANTT Chart

A GANNT Chart is still under development for inclusion in the final proposal.

9. Budget

The budget is under development for inclusion in the final proposal. Initial estimates suggest that the design specifications and objectives can be met within the proposed research budget of \$500.00.

10. References

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