

1. Introduction:

IPRO 332 begins an investigation of the use of mechanical shaker beds in a life-support capacity for beings with cardiac arrest. It will develop and continue research that was begun at the Miami Heart Research Institute, and will work in conjunction with researchers at IIT and the University of Chicago. There are two primary objectives for the semester:

- 1) Design and construct a controllable shaker bed for mice, based on specifications from IIT and University of Chicago researchers.
- 2) Investigate the implementation of shaker bed technology as a medical device for humans, including but not limited to: practical, ethical, and legal feasibility.

2. Background

Several years ago researchers discovered that it was possible to keep a pig after its heart had been stopped by placing it upon a vibrating platform. After being on the platform for up to 20 minutes, the pig's heart could be restarted (for example with a defibrillator) and it would resume completely normal biological functioning. Essentially it replicates the process of cardiopulmonary resuscitation (CPR). The physical mechanism behind this effect, as produced by periodic acceleration (i.e. "shaking"), is under investigation.

3. Purpose

To that end, researchers at IIT and the University of Chicago are conducting similar research on mice. IPRO 332 will assist their research by developing the mechanical device to shake the subject. The IPRO will also investigate the scaling and adaptation of this technology to potentially be used by emergency medical personnel.

In developing the shaker bed for mice, the team must receive the operational requirements for using periodic acceleration CPR on the murine scale. From this information, the team will design the shaking apparatus and the device used to affix the mouse to the bed, utilizing either rotary or a linear motor to drive either a mechanical or hybrid mechanical-electrical mechanism that will "shake" the specimen. The device will be designed to minimize complexity and cost. Once the design is completed, parts will be ordered and the device will be assembled. The anticipated problems primarily involve designing and constructing the device in such a way that both the frequency and the amplitude of the oscillations can be precisely controlled. Once completed, the device will be turned over to the researchers at the University of Chicago.

Investigating the adaptation of shaker bed technology for medical use with humans will require a substantial amount of research. The proper scaling of the required amplitude and frequency of oscillation must be investigated, and then a design can be created based on the one for shaking mice. In the meantime, the team will investigate any ethical, moral, cultural or scientific issues that may be involved in the testing of this technology, and its eventual use with humans, through internet and library research. Sponsors and potential customers will be queried as time permits.

4. Methodology

IPRO 332 has been tasked with developing a mechanical shaker bed for use in researching periodic acceleration as a viable form of CPR on murine subjects, i.e. mice and similar mammals. It must design, construct, and test the entire mechanism, with the end result being a compact, reliable, practical device that allows a researcher to control the frequency and amplitude of the oscillation in real-time. It must restrain the subject effectively without restricting respiration or circulation or causing any other significant injury, and must allow the other necessary equipment, such as oxygen masks and medical sensors, to remain affixed to the subject for its entire duration on the shaking bed. It should also be as inexpensive as possible while still meeting the performance guidelines defined by the researchers.

Meanwhile, the IPRO will also investigate the adaptation of the technology for use with human subjects. This will encompass both research into the moral, ethical, and legal issues surrounding both testing and implementation, and creating a preliminary design of such a device. To that end, a significant amount of research must be done to learn about laws and precedents governing the testing of new medical technology, including but not limited to: applicable patents/patent law, verification that a prototype is fit for use in real human subjects, the process for testing a new device on humans and the surrounding legalities, what redundancies must be in place in the event that the CPR fails, etc. Once the team has a solid understanding of this, a reference guide or database of such information will be created for future use. The team will then use the design of the mouse shaker bed to design a similar device for humans, including engineering calculations and schematics.

5. Assignments

In order to accomplish these tasks, the team split into two main subteams: one to design the mouse shaker bed and one to investigate the human angle. They worked concurrently, and their tasks are delineated as follows:

Mouse Team

- a. Networked with Harshbir Sidhu, IIT graduate student, to discuss the specifications of the mouse shaker bed, as well as the desired range for these parameters that the machine should be capable of functioning at.
- b. Created a preliminary design of the device. This includes deciding on the mechanism to shake the platform, devising a method to adjust the frequency and amplitude of the shaking in real time, ideally continuously (rather than between specific preset values), and creating a device to restrain the subject while the bed is shaking. Calculations for the requirements of the motor and other components were be conducted as well.
- c. Finalized the design and select the parts to be used, then located and purchased the components that will be used in the machine.
- d. Gave schematics to Machine Shop to be manufactured.

Mouse Team Member Assignments:

The whole team worked on putting together the PowerPoint presentation. Graphics were provided from all team members. Hazel constructed a working model of the zero-max using special software.

The whole team brain-stormed the concerns that surrounded the two possible design ideas. The human team developed a working model of a linear oscillator for humans, and they also developed several sketches of portable linear oscillators that can be integrated into an ambulance car and then be easily detached to bring on site.

Pat helped brainstorm ideas for how to change the amplitude in real-time. He performed calculations for the basic 2-link crank and the zero-max to determine the required motor output and needed linkage ratios. He helped find the necessary bushings for the zero-max and made AutoCAD drawings of some links to have it made by the machine shop. He also managed the I PRO deliverables, getting info and compiling them, and logged important decisions during meetings.

Maribel worked on the prototypes, made 2 rough prototypes, calculated to be on the scale of 30 mm and Pat also obtained a similar result. Furthermore, she worked on the calculation team and helped to get a rough estimate of the torque requirements for the motor that would displace the mass of the mouse+bed during linear oscillation. Also she helped with the interview process, and used Hazel's questions and handed them to various people.

John researched and purchased the motor that will be used in the final construction. He also found the suitable power supply and took charge of constructing the motor controller.

Grant investigated the use of a voice coil and contacted several companies regarding the purchase of a voice coil that would meet the requirements of the linear oscillator for the mouse, and in addition he also investigated the purchase of a custom-made zero-max that would meet the mouse oscillator's requirements.

Human Team

- a. Networked with Harshbir Sidhu, IIT graduate student, to discuss the specifications, particularly the optimum frequency and amplitude of the oscillation based on his calculations. The parameters were properly scaled to human-sized subjects.
- b. Researched laws and government regulations regarding new medical technology. Government websites and library references provided a good source of such information. Relevant points were documented and summarized.
- c. Investigate laws, regulations, and procedures specifically regarding the testing of medical technology to be used on humans.
- d. Once the mouse team's design was finalized, a similar design was created for use with humans. Engineering calculations must be done to incorporate the necessary parameters for successfully performing CPR on humans via periodic

oscillation, as well as to ensure that the design can accommodate the significantly higher mass of the human (relative to the mouse).

Everyone brainstormed ideas for how to best implement the theoretical technology, and discussed the advantages until the two best designs were settled upon.

Hazel researched FDA regulations and summarized them. She also did background research on the nature of cardiac arrest and the severity of the problem. She furthermore developed a series of interview questions to ask paramedics about the viability of periodic acceleration CPR as a medical procedure, and conducted an interview. In addition, she created a computer model of the simple oscillating mechanism for the device.

Alok worked with Harshbir to perform the calculations. He also collaborated on building a model of the device. He also spearheaded the development of the IPRO Day posters and presentation.

Jake worked on drawings of the ideas that the Human team developed. He also led the development of a working model.

Yun created the website. He also helped Jake with the model and helped the Mouse Team develop some of their ideas.

6. Obstacles

The team encountered no serious obstacles besides difficulty contacting potential vendors to find the necessary parts. There is no solution when the problem is the business or unresponsiveness of people that one depends on. Eventually the information was received, but too late to finish the project.

7. Project Results

The Mouse Team brainstormed ideas for performing real-time amplitude adjustment in the device, and decided to use the zero-max. They calculated the required capabilities and dimensions of components, purchased the electric motor and power supply, and made CAD Drawings of Zero-max components, machine shop is making them.

The Human Team developed two possible implementations: Portable-easy to carry and a "Built-In" solution for ambulances. They also performed market research and determined that the technology is definitely viable and that the concept should be investigated further once research on mice yields more detail about the concept. They also performed preliminary investigations of FDA regulations.

8. Recommendations

The team needs to finish constructing the device and make it work properly. After that additional research for the adaptation to human usage must be performed, particularly a more in-depth research of how medical personnel would like to use it.

9. References

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10. Acknowledgements

Harshbir Sidhu is the freakin' man.