"Laryngeal Bioreactor" – Design Excellence Award Summary
Kyle Anderson, Peter Guerin, Rebecca Stoebe, Daniel Thompson

Design Excellence Award Summary

Background and Current Devices

Disorders of the larynx, such as laryngeal cancer, affect over 136,000 individuals worldwide each year. Many of these individuals require a partial or total laryngectomy, which often requires respiration through a stoma and causes them to be mute. At this time, laryngeal transplant is not an option for these patients due to tissue mismatch and transplant rejection. Therefore, it is vital that research into engineering this organ continue. Researchers are attempting to create a procedure that successfully decellularizes and recellularizes a laryngeal tissue with patient cells. Our bioreactor provides a user-friendly yet flexible platform for this endeavor. Additionally, our device includes an accompanying model that computationally describes flows within the device, including shear stresses at the cellular level. At present, there are no bioreactors that are designed for the specific needs of laryngeal tissues. Notably, currently available bioreactors lack either the ability to perfuse media through multiple apertures within the tissue, in this case tissue vasculature and inner lumen, or the ability to provide structural support for a large organ over the course of long-term experimentation. Many available bioreactors also lack the ability to exert precision control over position and rotation of the tissue and automated control of all features of the device. O**ur team created a bioreactor capable of decellularizing and recellularizing a laryngeal tissue that allows researchers greater control and precision over this procedure than currently available bioreactors.**

Device Design

Our current device has improved upon commercially available bioreactors with the use of a more stable and accessible prototype coupled with improved technology and accompanying modeling. We have created a clear, polycarbonate based prototype that is watertight and features a moveable support cage for the laryngeal tissue that accommodates varying organ dimensions. This prototype is accompanied by an Arduino-programmed control system that allows precise user control over the rotation speed, frequency, and directionality of the cage as well as control over the speed, flow rate, and directionality of media flow through the tissue vasculature and inner lumen. Finally, we have also created an accompanying ANSYS-Fluent based model of the device that displays shear stresses and resulting Reynolds numbers at varying flow rates and locations within the device and larynx.

Testing and Future Work

We have conducted longevity and specificity testing of the device, which demonstrates that the device is capable of achieving flow profiles and rotation profiles specified by the user for at least 5 continuous days, thus assuring the longevity and precision of this device. Decellularization of a canine larynx using our device showed a 97% reduction of protein (weight percentage) in biopsied samples of tissue and histological staining showed no visible nuclei. Thus, we have confirmed that our device is capable of adequately decellularizing a laryngeal tissue. In the future, recellularization testing will determine the efficacy of the device in successfully seeding and fostering proliferation and differentiation of stem cells in decellularized tissue.

At a prototype cost of less than $200, this device provides a low-cost and extensible device that is tailored very specifically to the needs of the client for the use of the device with laryngeal tissue. This device allows easy setup, operation, and cleanup in an incubator, a refrigerator, and a normal benchtop environment. Additionally, the accompanying CFD stress model serves to inform and guide the researchers in their experimentation by allowing them to make associations between the more qualitative cellular based results seen with the device and the quantitative predictions made with the model. Taken together, our laryngeal bioreactor and the subsequent laryngeal organ regeneration research allows an expandable, easy to use, and specifically tailored solution for improving the research of our clients.