A. James Clark School of Engineering
THE FISCHELL DEPARTMENT *of* BIOENGINEERING
University of Maryland
University of Maryland School of Medicine

ElutoCAT Drug-Eluting Thoracic Catheter

Emily Blick, Christopher Hiner, Katherine Jones, Drishti Maniar, and Thea Ornstein
Clinical Advisor: Dr. Joseph S. Friedberg, Division of Thoracic Surgery Head, University of Maryland School of Medicine
Research Advisor : Associate Professor Christopher Jewell, Department of Bioengineering, University of Maryland

Introduction

Thoracic catheters, also known as a chest tube, is inserted into the pleural cavity and helps with the drainage of fluid, blood and air from the plural space.

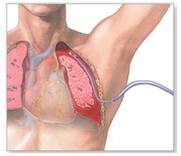


Figure 1. Medical procedure for chest tube insertion [1].

Problem: the insertion and continuous presence of the tube for 1-2 weeks causes patient pain that *cannot be solved with current treatments* such as local analgesic injections, epidural and intravenous analgesic. Patient's Chronic pain influences the physician's ability to repeatedly remove and reinsert the tube and respiratory splinting. Physicians and our *main motivator* is enhancing ***patient comfort***.

*"Thoracic catheters have **NOT CHANGED** in the past 25 years…patients complain of chest tube discomfort **MORE THAN** any other aspect of the surgical procedure." –*
Dr. Joseph Friedberg

Our Solution: *ElutoCAT*

- **Proposed Solution**: a analgesic-eluting, silicon thoracic catheter that releases lidocaine from a polymer coating to mitigate patient pain

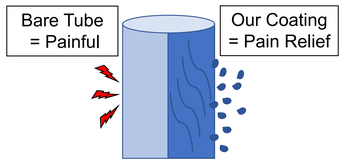


Figure 2. Comparison between desired effects of old and new product.

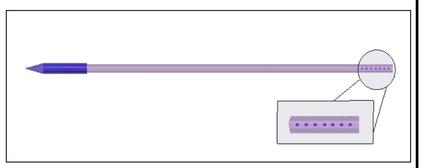


Figure 3. CAD drawing of ElutoCAT.

- **Long-Term Value**: mitigation of patient pain in a cost-effective manner

Business Plan

- Current thoracic catheters generate ~$20 of revenue per unit. ElutoCAT is planned to sell for $50 per unit.
  - Increased price is feasible due to time and cost saved by hospital.
- Marketing will target hospitals and, more specifically, their surgeons as customers for the product.
- Total Global Market Revenue in 2016: **$280 M** [2]
- Compound Annual Growth Rate of **6.5%**
- Predicted Global Market Revenue in 2024: **$410 M** [3]
- **The ultimate goal of the ElutoCAT is to phase out conventional thoracic catheters around the world**

Step #1	Step #2	Step #3	Step #4	Step #5
2019-2020: R&D	**2020-2021: FDA approval**	**2022: Entry to Market**	**2022-2024: Expansion**	**2025 or Later: Acquisition**
Finish design improvements to extend release profile, scale up manufacturing capabilities and undergo animal testing.	Submit 510(k) Premarket Notification and receive clearance	Begin selling locally to University of Maryland Medical Center and market product at medical conferences	Expand sales to hospitals around the U.S	Be acquired by a larger medical device company such as Cardinal Health, Inc.

Methods: Solvent Selection

- **Purpose:** To select the appropriate polymer-solvent combination.
- **Methods:** Each polymer was placed in each solvent and observed for complete dissolution after 15 minutes and after 3 days of shaking. The polymers tested were polycaprolactone (PCL), 50:50 poly(lactic-co-glycolic acid) (PLGA) and polyethylene glycol (PEG). Triplicates were completed. Protocol is described in Figure 4.
- **Results:** DCM was shown to dissolve all polymers after 15 minutes. PLGA was shown to dissolve in acetone. All other solvents failed to dissolve the polymers. The same results were seen after both time periods.
- **Takeaway**: PLGA was chosen as our polymer and DCM as our solvent.

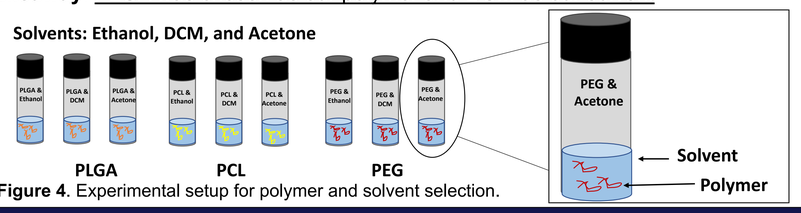


Figure 4. Experimental setup for polymer and solvent selection.

Prototyping: Dip Coating

- **Purpose:** To coat the silicon tube with 600mg/ml of lidocaine and 100mg/ml of PLGA.
- **Methods:** 10 mm x 2 mm slabs of silicon were either 1) uncoated, 2) coated with 600mg/ml of lidocaine, 3) coated with 100mg/ml of PLGA or 4) coated with a mixture of 600 mg/ml lidocaine and 100mg/ml of PLGA. UV spectroscopy and scanning electron microscopy (SEM) was performed. Triplicates were completed. Protocol is described in Figure 5.
- **Results:** Spectroscopy showed that on average 1.5 mg of lidocaine was loaded per 100 mm^2 of tube (Figure 6). SEM images showed PLGA-lidocaine on the cross section of a silicon tube (Figure 7). The resulting scan of PLGA and lidocaine had a peak at 263 nm, confirming the presence of lidocaine in the coating (Figure 8).
- **Takeaway:** PLGA-lidocaine mixture was coated on the silicon tube.

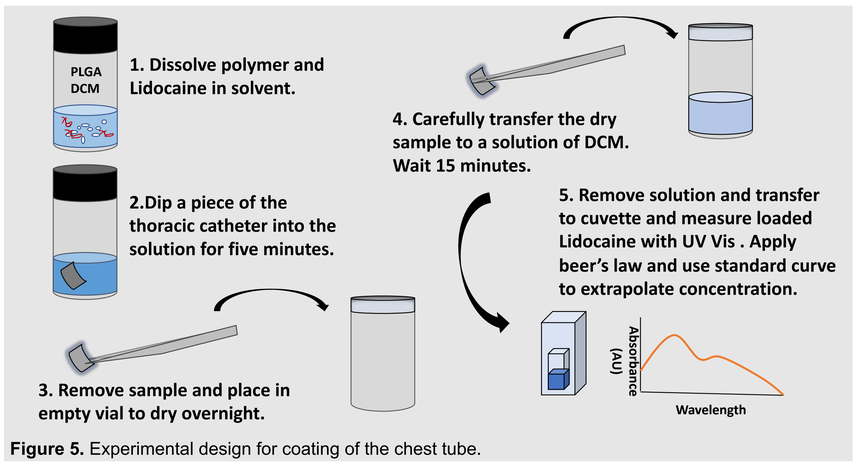


Figure 5. Experimental design for coating of the chest tube.

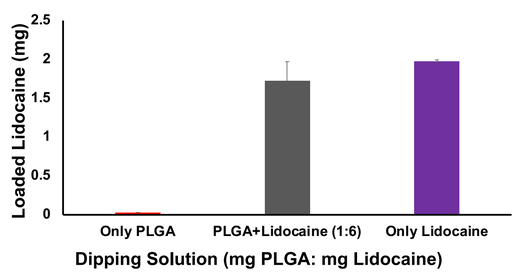


Figure 6. Mass of lidocaine coated onto silicon tube fragments, coated with PLGA and lidocaine (100 mg/ml: 600 mg/ml), only PLGA and only lidocaine. From the PLGA+ lidocaine coating, 1.5 mg of lidocaine on average was loaded per 100 mm^2 of tube.

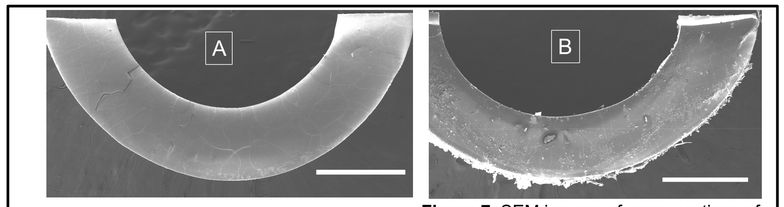


Figure 7. SEM images of cross sections of bare silicon tube [A] and of PLGA-lidocaine coated tube [B]. Scale bars are 1mm.

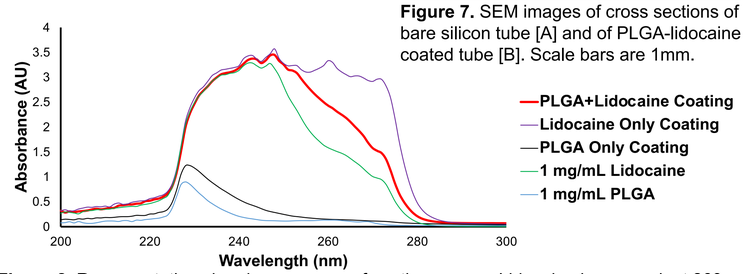
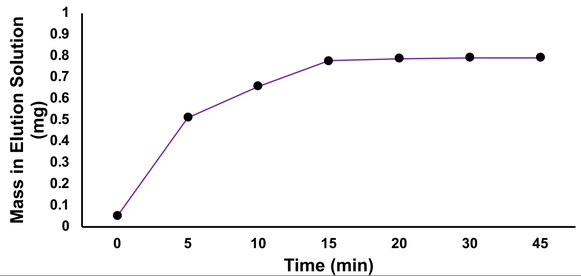


Figure 8. Representative absorbance scans of coating groups. Lidocaine has a peak at 263 nm and lidocaine and PLGA have a shared peak at 228 nm.

Testing: Elution Study

- **Purpose**: To elute lidocaine from coated silicon tube.
- **Methods:** PLGA-lidocaine coated silicon tubes were made as described in Figure 5. Tubes were immersed in a phosphate buffer for 1 hour and UV spectroscopy was performed on the solution every 5-10 minutes. Triplicates were completed.
- **Results:** All loaded lidocaine (0.75 mg/ 100 mm^2 of tube) was eluted over 20 minutes (Figure 9).
- **Takeaway:** Lidocaine can elute out of the PLGA coating in a time dependent manner.

Figure 9. Elution profile of PLGA-lidocaine coated silicon tube slab in a phosphate buffer.



Conclusions and Future Work

1. Demonstrated that thoracic catheters can be coated with a polymer and analgesic together.
2. Exhibited that lidocaine can be released from a chest tube over a short period of time.
3. Established that lidocaine elution from thoracic catheters has promise for being a viable pain management technique.
4. Future goals include increasing duration of sustained release, further characterizing coating with mechanical testing and devising protocols to scale-up production for entire chest tubes. In terms of **ethical implications**, animal and clinical trials will be completed to demonstrate safety and efficacy. No data can be fabricated to make the device appear any more safe or effective than it actually is.

References

[1] Heller, Jacob. (2018). Chest tube insertion. Retrieved from https://medlineplus.gov/ency/presentations /100008_4.htm **[2]** Global Chest Drainage Catheters Market Report 2017. (2017). Retrieved from https://www.slideshare.net/fionaqu11/global-chest-drainage-catheters-market-research-report-2017 **[3]** MarketWatch. (2019). At 6.5% CAGR... Retrieved from https://www.marketwatch.com/press-release/at-65-cagr-thoracic-catheters-market-size-set-to-register