

Executive Summary

In collaboration with Children’s Medical Center of Dallas, we developed an ergonomic electrocautery pen with integrated smoke evacuation to address the health risks of surgical smoke while improving surgeon control. Existing systems are often underutilized due to poor ergonomics, tubing drag, and workflow disruption.

Our design maintains the familiar form of the Stryker electrocautery pencil while introducing key modifications, including an enlarged internal lumen to improve airflow and reduce noise, and a custom swivel mechanism to minimize tubing-induced torque and enhance maneuverability.

Experimental testing demonstrated that the device achieved AORN-recommended capture velocities (100–150 ft/min) and maintained sound levels below the 45 dB design threshold, while improving overall usability.

Background

Electrocautery procedures generate surgical smoke containing hazardous components, including volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), ultrafine particles, and biological material. These byproducts pose significant health risks to both operating room staff and patients, with cumulative exposure linked to respiratory and carcinogenic effects.

Despite these risks, current smoke evacuation systems are inconsistently used due to limitations in ergonomics and interference with surgical workflow. Surgeons frequently report reduced control, increased noise, and resistance from attached tubing, particularly in pediatric settings where precision is critical.

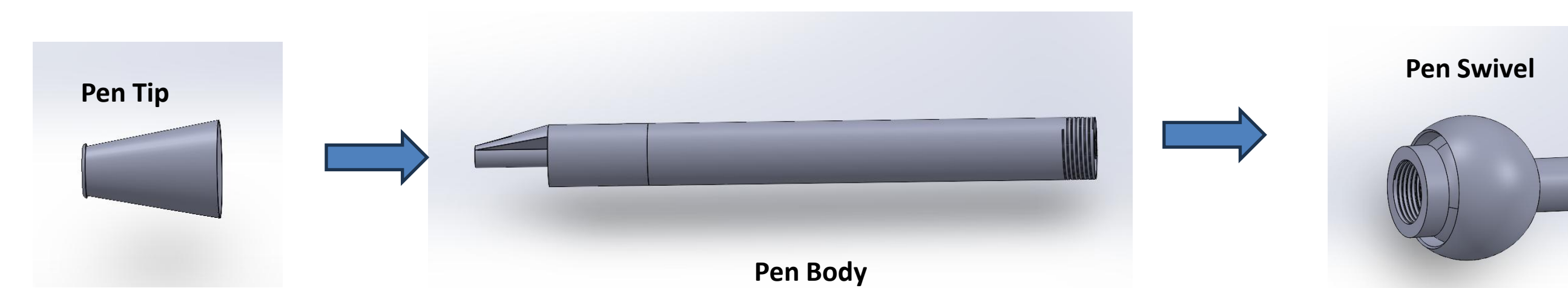
This project aims to address these limitations by integrating smoke evacuation directly into the electrocautery pen while preserving familiarity, improving maneuverability, and maintaining effective plume capture at the source.



Experimental Setup

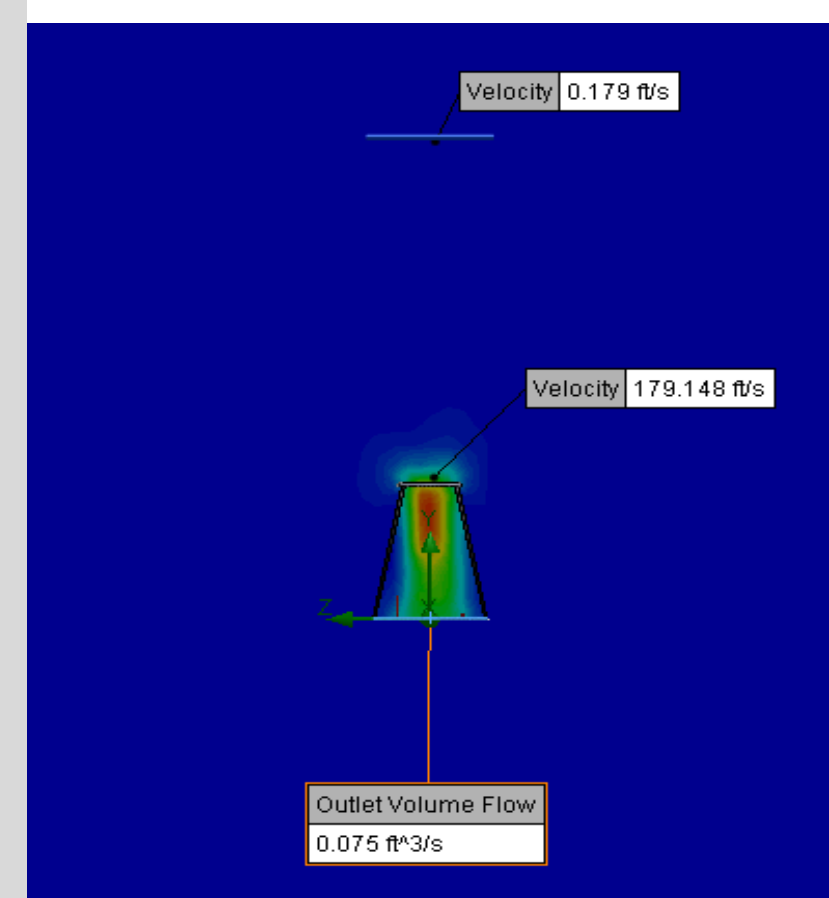
Design Rationale : Improve smoke capture directly at the source while addressing surgeon concerns about tubing drag and loss of control.

Category	Details
Design Basis	Modeled after the Neptune Stryker pencil to preserve familiar size, grip, and workflow for surgeons.
Pen Modification 1	Enlarged internal lumen to improve airflow, reduce resistance, and lower noise while maintaining similar external geometry.
Pen Modification 2	Custom ball-joint swivel with barbed tubing connection to reduce tubing-induced torque and improve maneuverability.
Pen Material	Polypropylene, supporting a lightweight disposable design with PEEK near tip



Experimental Test Plan

Test	Rationale	Procedure
Capture Velocity Test	Measure airflow at the pen tip to evaluate smoke capture performance near the source	Place a hot-wire anemometer 2 inches from the pen tip and record capture velocity during operation
Nozzle Tip Test	Evaluate airflow through three nozzle tip types of the electrocautery pen	Change nozzle tip dimensions in SolidWorks, analyze airflow using SolidWorks Flow Simulation, then 3D print the selected electrocautery pen tip design
Noise Level Test	Measure sound produced during operation at average arm-length distance	Use a smartphone decibel meter app, place phone 2.5 ft from the pen, perform multiple trials, and average readings
Ergonomics Test	Evaluate comfort, grip, maneuverability, and overall ease of handling during simulated use	Have users complete the same brief task with tubing attached, then collect 5-point Likert scale ratings and calculate the average score



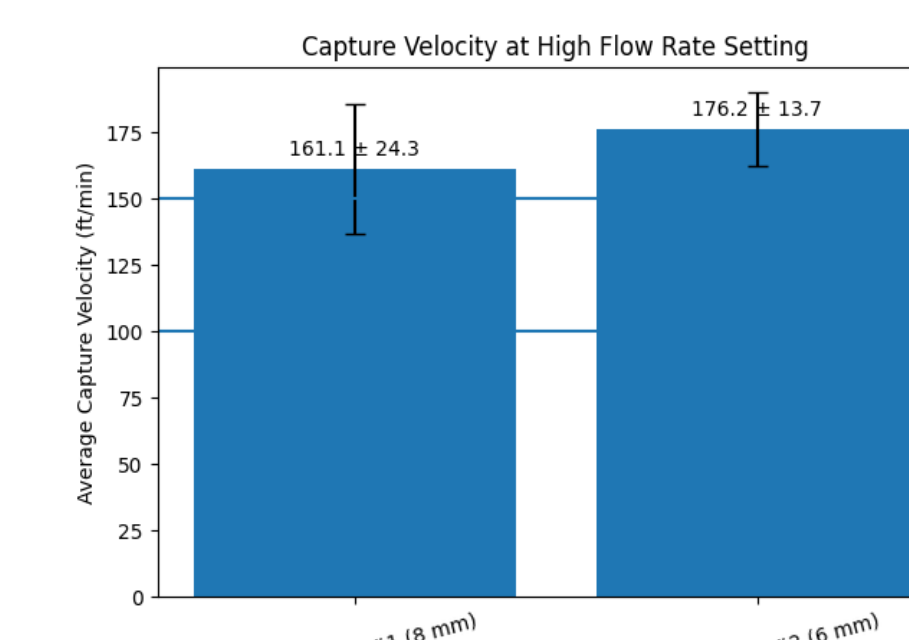
Nozzle tip geometry evaluated through SolidWorks Flow Simulation and physical prototyping to optimize airflow and smoke capture efficiency.



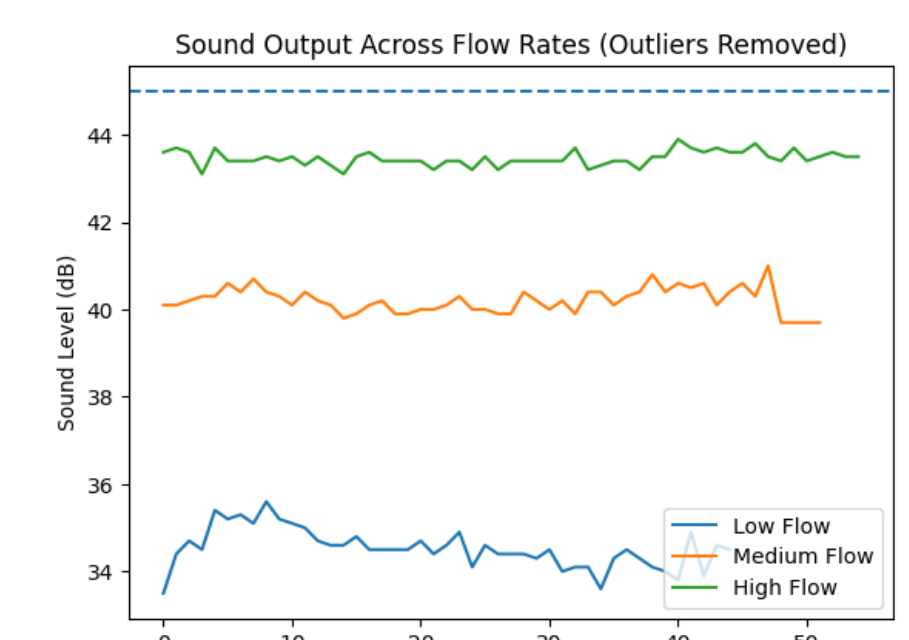
Capture velocity testing setup with hot-wire anemometer positioned 2 inches from the pen tip to measure airflow performance relative to AORN standards.

Experimental Results

Test	Target
Capture Velocity Test	AORN target of 100–150 ft/min minimum
Nozzle Tip Test	Optimize nozzle geometry to improve airflow through the pen tip
Noise Level Test	Target: <45 dB
Ergonomics Test	Target: ≥4/5



Capture velocity measured at high flow rate (maximum suction). Values shown as mean ± standard deviation (n = 20). The 6 mm tip demonstrated higher velocity with reduced variability.



Sound output was evaluated across low, medium, and high flow rate conditions. Outliers were removed using the IQR method to eliminate transient noise spikes. Results demonstrate a consistent increase in sound level with increasing flow rate, while maintaining values below the 45 dB design requirement.

Conclusions

The proposed electrocautery pen successfully met key design requirements for smoke capture, noise reduction, and ergonomic performance. Capture velocity testing confirmed compliance with AORN standards (100–150 ft/min), while noise levels remained below the 45 dB threshold across operating conditions. Ergonomic enhancements, including the swivel mechanism and optimized pen geometry, improved maneuverability and reduced tubing-induced torque. These results demonstrate that effective smoke evacuation can be achieved without compromising surgical control or workflow. By maintaining a familiar form factor while addressing key usability challenges, this design provides a practical solution to improve adoption of smoke evacuation systems. Future work should focus on integrating the electrocautery tip with the smoke evacuation system while ensuring functionality, thermal safety, and compatibility with existing electrocautery units. We would like to thank our mentors, Stephen Van Noy and Dr. Jun Liao, as well as Children’s Medical Center of Dallas for their guidance, support, and collaboration throughout this project.

References

- Benaïm, E. H. (2024). Surgical smoke and its components, effects, and mitigation. Toxicological Sciences. Advance online publication. <https://doi.org/10.1093/toxsci/kfae005> PMC+1
- Feng, X., Ding, B., & Shen, Y. (2023). The feasibility and efficacy of a novel nano filter in reducing the hazards of surgical smoke exposure during gynecological laparoscopic surgery. Surgical Innovation, 30(5), 654–656. <https://doi.org/10.1177/15533506231157169>
- Wu, J., Shen, H., Zhan, X., & Zhu, Y. (2020). Study on influencing factors and control strategies of surgical smoke concentration distribution. Aerosol and Air Quality Research, 20, 2941–2952. <https://doi.org/10.4209/aaqr.2020.05.0190>
- Avantor. (n.d.). Silicone (platinum-cured) tubing. Avantor Sciences. <https://www.avantorsciences.com/us/en/cms/tech-article-silicone-platinum-cured-tubing>
- LePure Biotech. (n.d.). LFRS Platinum Cured Silicone Tubing – Datasheet. LePure Biotech. https://www.lepurebiotech.com/wp-content/uploads/dlm_uploads/2024/03/Datasheet-LFRS_Platinum-Cured-Silicone_Tubing.pdf
- Dohrman, P. (2017, April 24). How to convert mm to fractional inches. Sciencing. Retrieved from <https://www.sciencing.com/convert-mm-fractional-inches-6108935/>
- 1. Horner, Shawn K, Graham Overstreet, Jeffrey W. Clymer and Crystal D. Ricketts. “A Comparison of Flow Rates and Noise Levels for Two Commercial Smoke Evacuators.” J Surg 19 (2023): 94. <https://doi.org/10.37421/1584-9341.2023.19.94>