High Throughput Quantitative Ex Vivo Murine Brain MRI Capsule

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Introduction

Client: Dr. JP Yu's Lab at WIMR

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Team photo (Anna, Erwin, Leo, Ray, Allicia, Joel)

Overview

- Problem Statement
- Background Material
- Design Alternatives
- Design Criteria
- Designs
  - Cylinder
  - Honeycomb
  - Integrated Insert
- Design Matrix
- Future Work

Rat brain

Mouse brain

Problem Statement

- Packing efficiency [1]
- Scientific, reproducible process
- Main Change to Initial Problem Statement:
  - Consistent orientation

Current modified syringe system from Dr. Yu's lab in WIMR

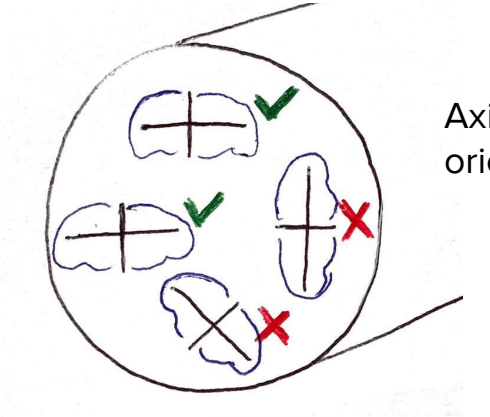
Background Material

- Laboratory Research [3][4]
  - Impacts on brain microstructure
  - MR and PET neuroimaging
  - Imaging diagnostics and outcome tracking
- Project Goals
  - Data pipeline from consistent orientation
  - Translation of biomarkers

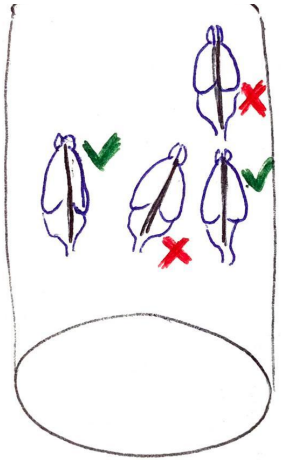
WIMR Small Animal MR Machine [2]

Product Design Specifications

- Packing efficiency
  - > 3 rat brains and > 6 mice brains per scan
- Very specific orientation
  - Keep brain aligned within 2 degrees
- No magnetic metal or polar materials [5]
- No leaking and no air bubbles
- Must fit in MRI coil
  - d = 37.29mm



Axial rotation orientation



Longitudinal rotation orientation

Design Alternatives

- Bundled Syringes
  - Non-uniform scans
  - Time consuming
  - Risk damage to brains
  - Wasteful

Three Rat Brains

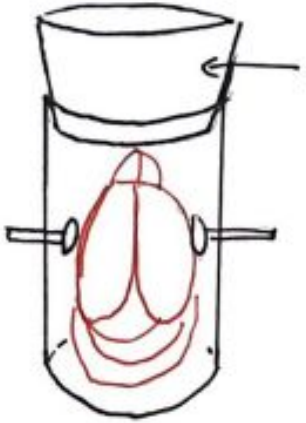
Six Mouse Brains

MRI Coil

Universal Design Ideas

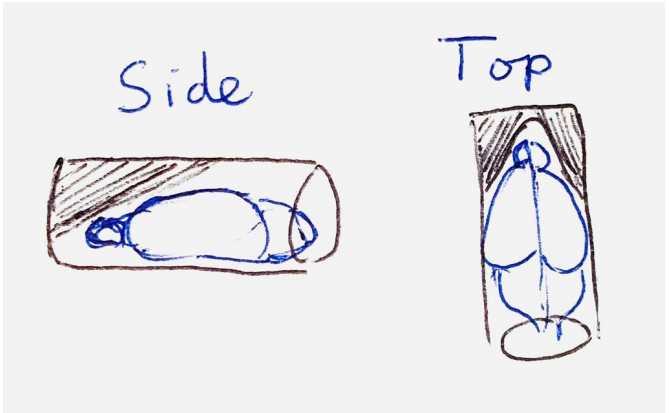
From research and from individual designs,

Airtight seal of overflowing units with rubber stopper



Sealing capsules with stopper

Securing orientation with ramp



Ramp to aid orientation

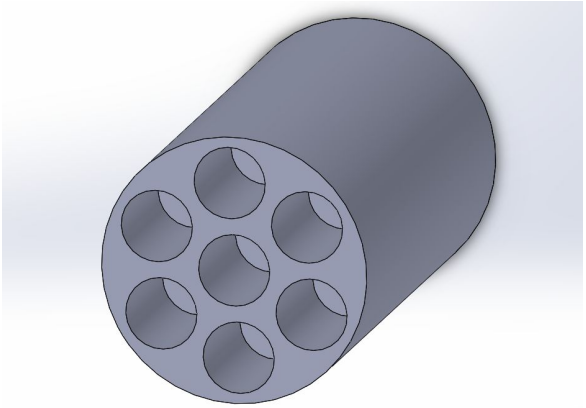
Cylinder

Description: Insert for MRI coil, cylinder, and capsules containing brains: 4 rat / 7 mice

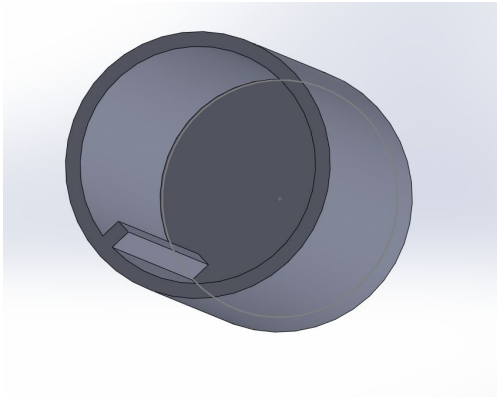
Advantages: Fin and/or ramp to stabilize brain

Interlocking with cylinder holder

Challenges: Lots of pieces, which means more space used by plastic



Cylinder concept



Capsule concept

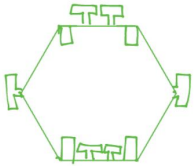
Fin concept

Honeycomb

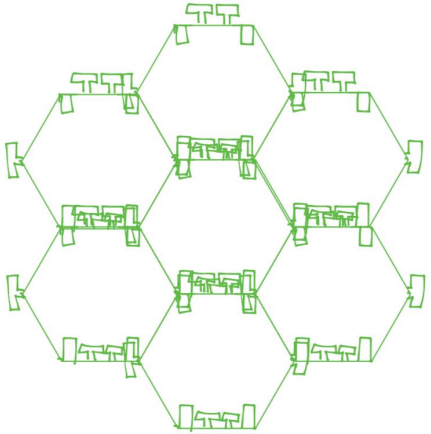
Description: Honeycomb like lattice of capsules with locking mechanism to hold orientation

Advantages: Locking and shape prevents tilting

Challenges: Sealing the entrance of a hexagonal shape



Honeycomb capsule



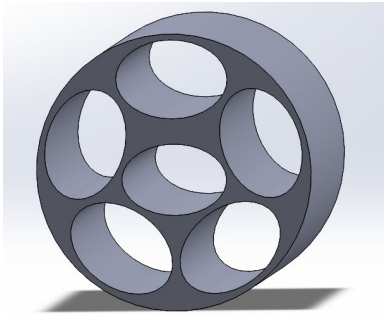
Honeycomb lattice

Integrated Insert

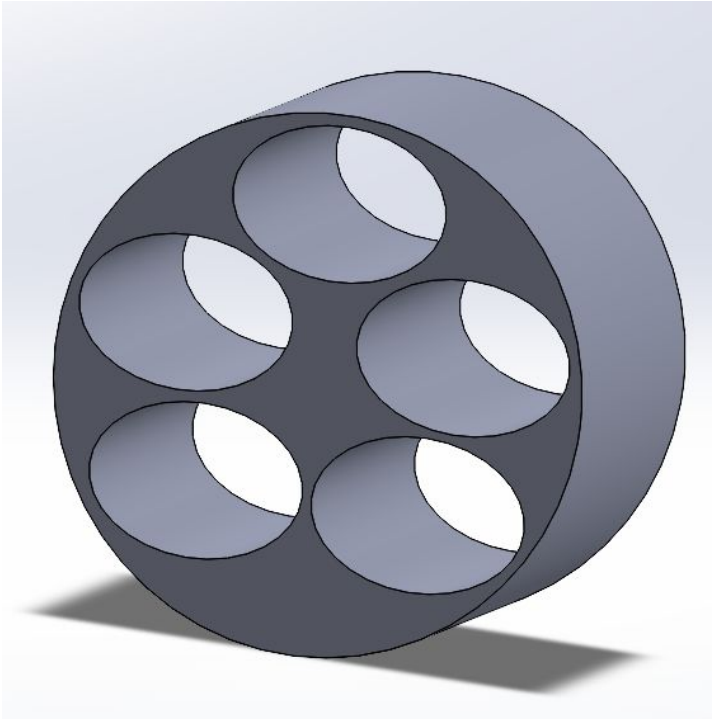
Description: Cylinder insert perfectly fits the bore of MRI with integrated oval holes

Advantages: Maximizes spacial efficiency

Challenges: Safely removing brains



Quantitatively fits 6 rat brains radially



Quantitatively fits 5 Rat brains

Design Criteria

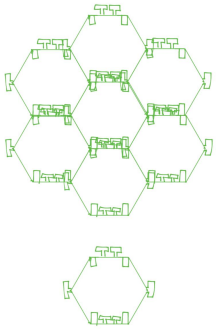
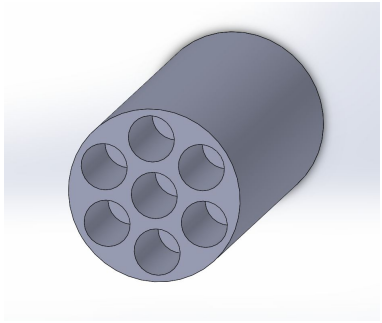
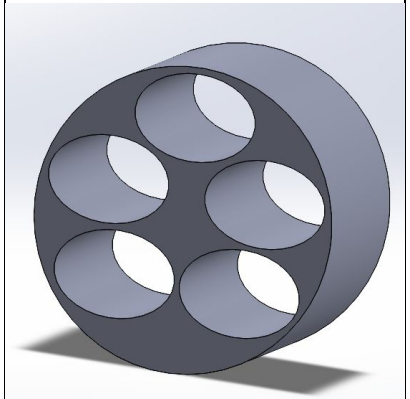
Packing Efficiency - Max number of brains that can fit during scanning

Orientation - establish and maintain a standard orientation

Airtight - minimize air bubbles

Ease - Ease of loading and unloading brains

Other Criteria: Durability, Time and Cost of Manufacturing, Safety

Design Matrix		Honeycomb Design		Cylinder Insert Design		Integrated Insert	
							
Criteria	**Weight**						
Packing and Unpacking Efficiency	30	5	30	4	24	5	30
Standardization and Consistency of Orientation	20	5	20	4	16	4	16
Airtight	15	3	9	5	15	3	9
Ease of Use	15	4	12	3	9	3	9
Durability	10	3	6	4	8	5	10
Time and Cost of Manufacturing	5	3	3	2	2	5	5
Safety	5	5	5	5	5	4	4
Total	**100**	80		79		83	

Future Work

- Keeping the brains oriented properly during scan
- Durable design
- Resize designs for Mice Brains

Conclusion

- Saves lab time
- Saves lab money
- Freedom to use saved resources elsewhere

References

[1] “High throughput quantitative ex vivo MRI of the mouse brain.” https://bmedesign.engr.wisc.edu/selection/projects/943013f3-278d-4fa5-abba-3bbd74da54c1 (accessed Oct. 07, 2022).

[2] K. Kania, “Small Animal MR Facility - Services & Equipment,” Mallinckrodt Institute of Radiology - Washington University School of Medicine in St. Louis. https://www.mir.wustl.edu/research/core-resources/small-animal-magnetic-resonance-facility/services-equipment/ (accessed Oct. 07, 2022).

[3] J.P. Yu, “Profile,” Department of Radiology. https://radiology.wisc.edu/profile/ (accessed Oct. 07, 2022).

[4]S. Yi, B. Barnett, M. Poetzel, N. Stowe and J. Yu, "Clinical translational neuroimaging of the antioxidant effect of N‐acetylcysteine on neural microstructure", Magnetic Resonance in Medicine, vol. 87, no. 2, pp. 820-836, 2021.

[5] T. Woods, “MRI Safety and Compatibility of Implants and Medical Devices,” *ASTM International*, pp. 82–90, doi: 10.1520/STP11156S.