Head Holder for MR-Guided Drug Delivery Testing

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1. Abstract

The use of Convection-Enhanced Drug Delivery (CED) to overcome the blood brain barrier by direct infusion via catheter to the brain combined with real-time MRI monitoring is being researched as a treatment for Parkinson's disease (PD). Since the antenna array rests against the testing subject's ears and temples (Beagles and Rhesus monkeys), other head holders cannot be used due to the ear bars. It is important that the head holder restricts the translational movement of the head to 1 mm or less, allow reproducible positioning, and be entirely MRI-compatible.

A head holder device has been fabricated out of high-density polyethylene (HDPE) with modified ear bars. The device has been tested for reproducibility using still photography and ImageJ (NIH) as well as for tolerances to translational movement from the front, side, and top views by using pressure sensors to measure the force causing displacement. There was no significant difference between the means of the displacements of the control group and the final prototype (p=0.314).

2. Background/Motivation

Client: Dr. Walter Block, Professor in the Department of Biomedical Engineering

Background:

- Parkinson's disease (PD) - incurable degenerative brain disorder largely affecting the elderly population[1]
- Convection-Enhanced Drug Delivery (CED) + Real-time Magnetic Resonance Imaging (MRI): experimental PD treatment that aims to overcome the blood brain barrier by direct infusion via catheter to the brain

Motivation:

- Current head holders have ear bars that prevent proper positioning of the carotid coils

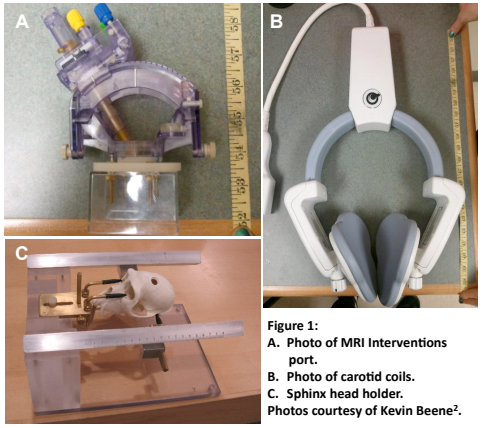


Figure 1:
A. Photo of MRI Interventions port.
B. Photo of carotid coils.
C. Sphinx head holder.
Photos courtesy of Kevin Beene[2].

3. Design Specifications

The device should:

- be compatible with MRI
- be compatible with the experimental setup
- restrict translational motion to less than 1 mm
- allow reproducible positioning
- work with Beagles and Rhesus monkeys

4. Testing

Force-Displacement Test

- *Purpose*: to assess the new head holder's ability to restrict translational movement to 1 mm or less
- *Procedure:*
  - Take baseline photographs of model skull held in both the new prototype and old head holder from three views (front, side, and top)
  - Apply force to skull in x-, y-, and z-directions
  - Use force sensor to measure amount of force applied
  - Take photograph of the device as the force is applied
  - Use ImageJ to measure the displacement of the head by using fixed reference points on the skull and device.

Reproducibility Test

- *Purpose*: to ensure that when the head can be removed and replaced in the device in the same position
- *Procedure*
  - Take baseline photographs of model skull held in both devices from the three views
  - Remove the skull from the device
  - Reposition the skull in the device and take photograph from three views
  - Use ImageJ to assess position of the head relative to fixed points

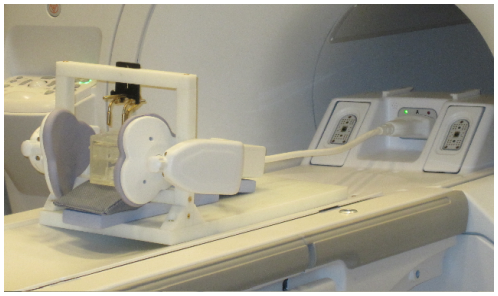


Figure 2: MRI Testing setup with carotid coils and cube phantom.

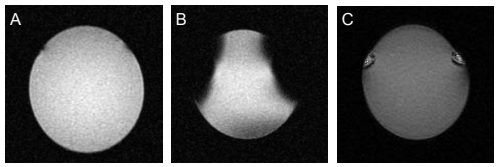
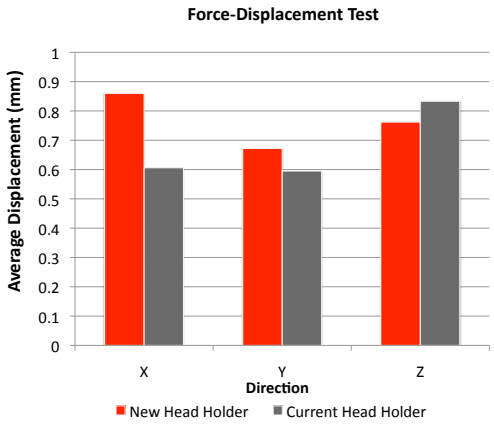
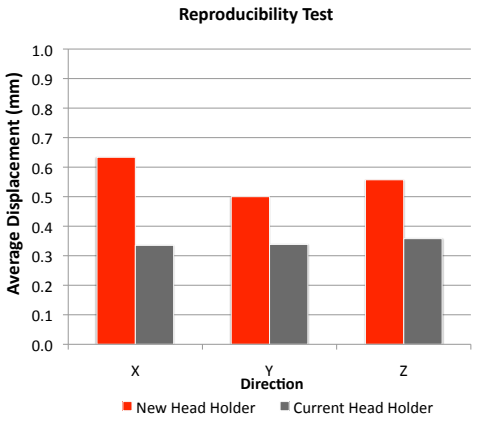


Figure 3: MRI Scans. A. Scan of sphinx design with 25 ms echo time. B. Scan of new design with 25 msec echo time. C. Scan on new design with 5.1 msec echo time. Photos courtesy of Wally Block.

5. Results



- Average applied force of 28.25 +/- 1.91 N
- Average of 7.30 +/- 4.44 pixels/mm
- Average displacement in the x-, y- and z-directions was 0.86 mm, 0.672 mm and 0.762 mm respectively
- Differed by no more than +/- 0.25 mm from the control
- No significant difference between the means of the displacements of the control group and the final prototype (p = 0.314)



- Average of 7.43 +/- 0.29 pixels/mm
- Average displacement in the x-, y- and z-directions was 0.633 mm, 0.50 mm and 0.557 mm respectively
- Differed by no more than +/- 0.3 mm from the control
- Significant difference between the means of the displacements of the control group and the final prototype (p = 0.002)

6. Final Design

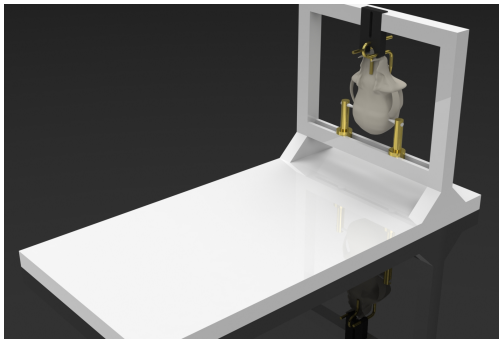


Figure 4: Redesigned head holder with stabilized Rhesus Monkey skull. Photo courtesy of Gabriel Bautista.

- Monkey in head-first position used in CED research
- Durable High Density Polyethylene (HDPE)
- Brass adjustable eye & ear bars
- Reproducible position
- Stabilizes head effectively (tolerance of 1 mm)

7. Cost Analysis

- Maximum Budget: $1,000

Table 1: Expense Report

ITEM	AMOUNT
12" x 24" x 1" High Density Polyethylene Sheets	$70.70
½" x 1 5/8" Brass Brackets	$5.94
12" of 1" OD Brass Rod	$43.00
Screws	$15.88
TOTAL	$135.52

8. Future Work

Design Modifications:

- Widen board for a better fit on MRI table
- Design clips to attach board to MRI table
- Use HDPE for the ear bar holders
- Modify vertical bars for better carotid coil fit

Testing:

- Test design in real time MRI with animal subject

9. Acknowledgements

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10.References

1. Jasmin, L. "Parkinson's Disease." *NIH A.D.A.M. Medical Encyclopedia*. 2011.
2. Lam MF, Thomas MG, and Lind CRP. "Neurosurgical convection-enhanced delivery of treatments for Parkinson's disease." *Journal of Clinical Neuroscience*. 2011 18: 1163-1167