Design of a CSF shunt for hydrocephalus

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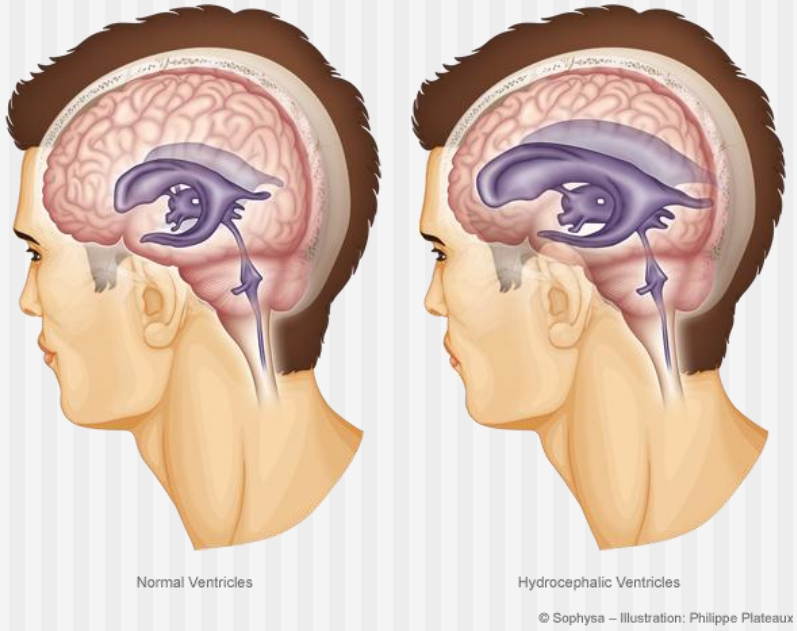
Outline

- Background
  - Hydrocephalus
  - Shunts
- Shunt Complications
- Problem Statement
- Potential Designs
- Design Matrices
- Final Design
- Future Work

Background: Hydrocephalus

- "Water on the brain"
- Common in children
- Build up of CSF
  - Obstruction
  - Over production
  - Inadequate drainage
- Many causes
- Brain damage, death



Background: Shunts

- Shunts are placed to drain CSF
  - Greatly reduced instances of brain damage
  - Greatly reduced death rate
- Shunt placed in the head
  - Pressure sensitive valve restricts drainage
  - Catheter drains into the peritoneal cavity

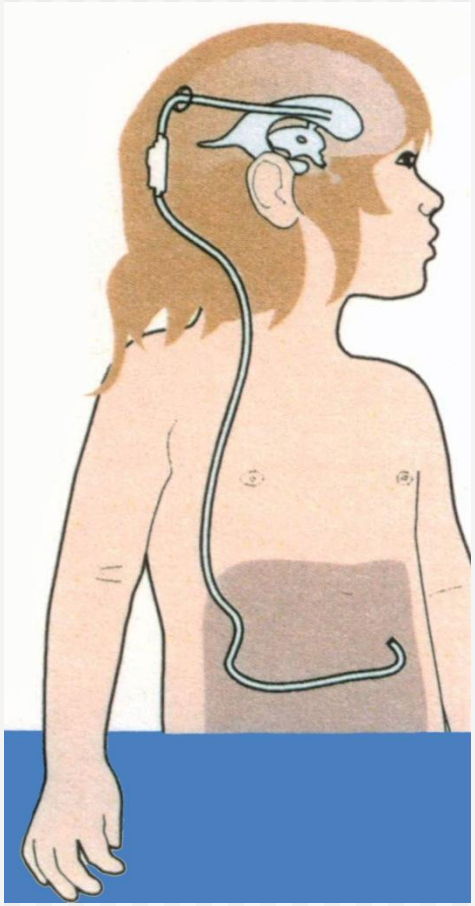


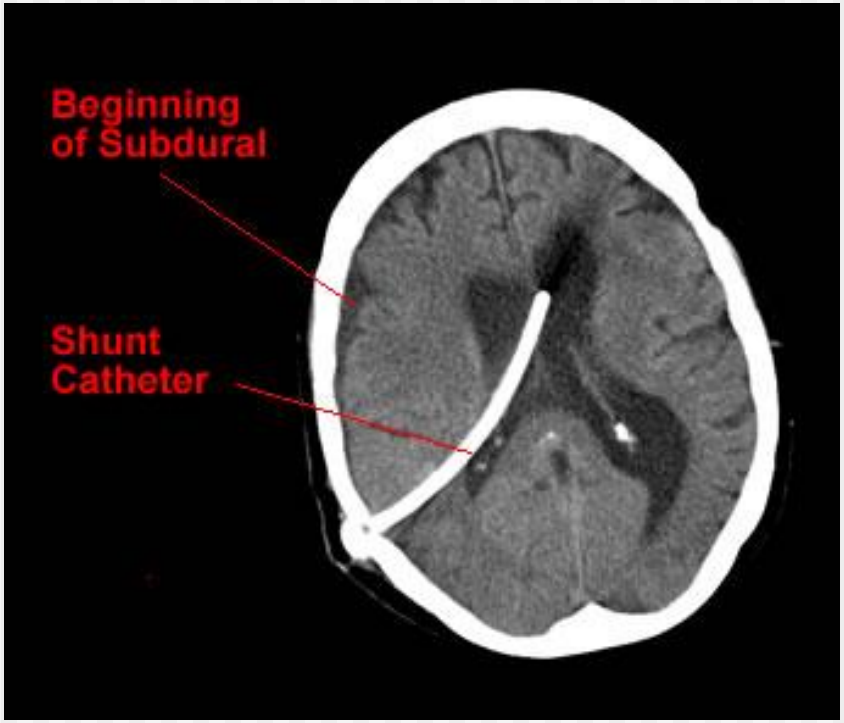
Image from a presentation of Dr. Bermans Iskandar

Shunt Complications

- Over siphoning leads to ventricular collapse
  - Cardiac pulsations
  - Gravity
- Ventricular brain tissue obstructs the shunt
- Pressure can increase
  - Brain damage
  - Death
- Main reason for shunt replacement or revision

Problem Statement

- Slit Ventricle Syndrome
- Work with current design
  - Design componenets
  - Fabricate
  - Test



Design 1: Single Valve

- Standard of care
- Single pressure threshold
- Disadvantages:
  - Over drainage
  - Siphon effect
  - No gravity adjustment
  - No cardiac pulsation adjustment

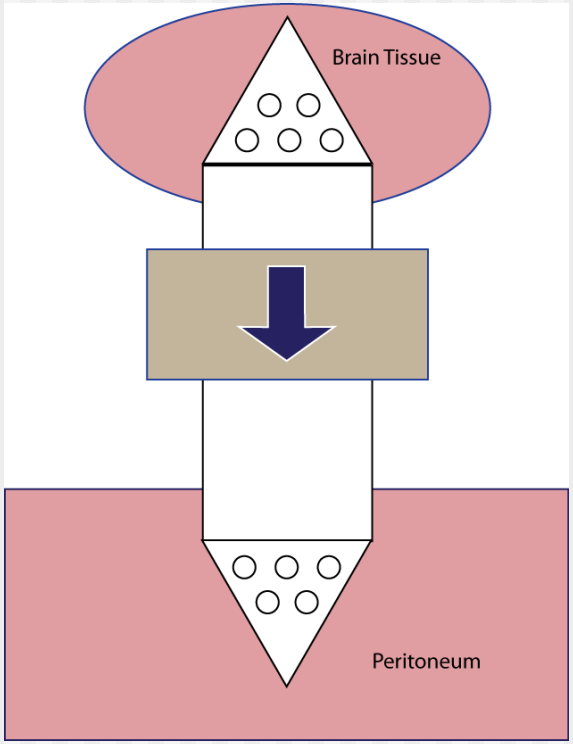


Figure from Dr. David Hsu

Design 2: Valves in Series

- Recent advancement
- Cascade allows for some control of the effect of cardiac pulsations
- Still affected by over siphoning

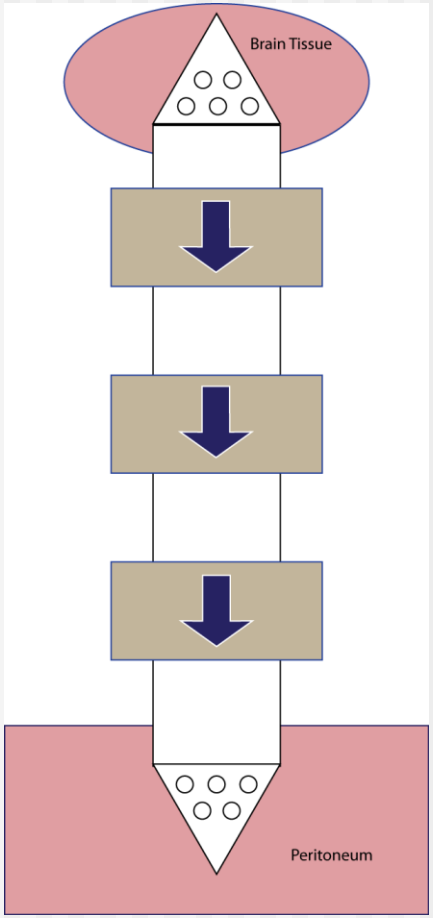


Figure from Dr. David Hsu

Design 3: Feedback loop with novel valve

- Pressure differential valves in the loop correct for cardiac pulsations
- Novel valve addresses gravitational and positional over siphoning
- Called the "Wisconsin Loop"

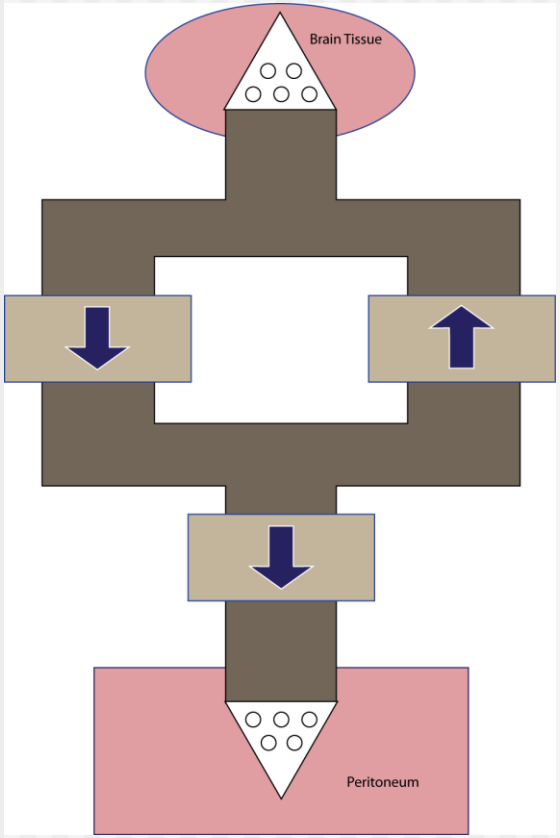


Figure from Dr. David Hsu

Design 3: Novel Valve

- Three important design elements:
  - Casing
  - Ball
  - Spring

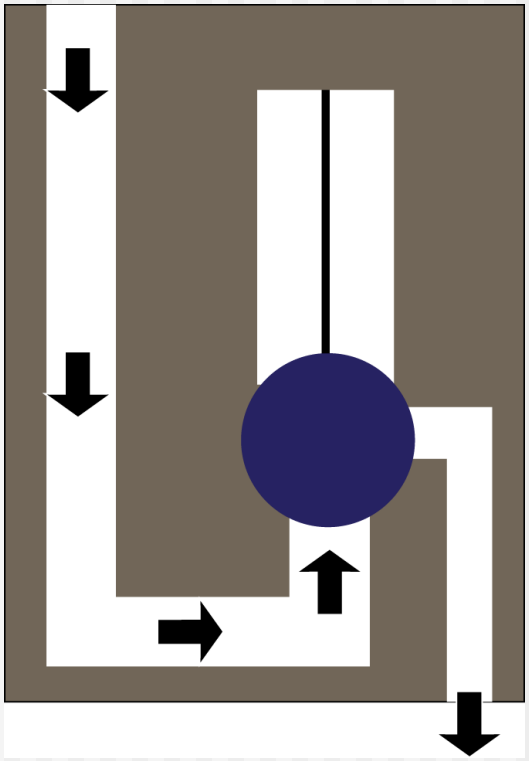


Figure from Dr. David Hsu

Design Matrix: Feedback Loop Valves

Model	MF Resistance (30)	Artifact generation (20)	Qualitative MR artifact (20)	Client Preference (5)	MR Torque (10)	Total (85)
Miethke Pro-GAV	30	15	7	5	7	72
Medtronic Strata	15	5	3	4	3	32
Codman Hakim Regulator	8	19	10	3	10	58

Design Matrix: Valve Casing

Material	Biocompatibility (40)	Durability (30)	Ease of Manufacture (20)	Cost of manufacture (10)	Total (100)
High Density Polyethylene (HDPE)	35	25	15	8	83
Acrylonitrile-butadiene-styrene (ABS)	30	20	10	7	67
Polytetrafluoro-ethylene (PTFE)	35	15	5	5	60
Stainless Steel (361L, grade 2)	35	25	5	3	68

Design Matrix: Spring

Material	Biocompatibility (30)	Cost (10)	Life (25)	MRI Compatibility (35)	Total (100)
Stainless Steel 316L	20	10	20	5	55
Carbon Valve ASTM 229	25	9	25	10	69
Plastic Composite	25	8	18	30	81

Design Matrix: Ball

Material	Biocompatibility (30)	Ease of Fabrication (10)	Cost (20)	Life (10)	MRI Compatibility (30)	Total (100)
Si-Rubber	25	8	18	9	15	75
Stainless Steel 316L	20	10	20	10	0	60
Si-Rubber with Ba	25	6	16	9	30	86

Final Design

- "Wisconsin Loop"
- Miethke Pro-GAV valves used in parallel for feedback loop

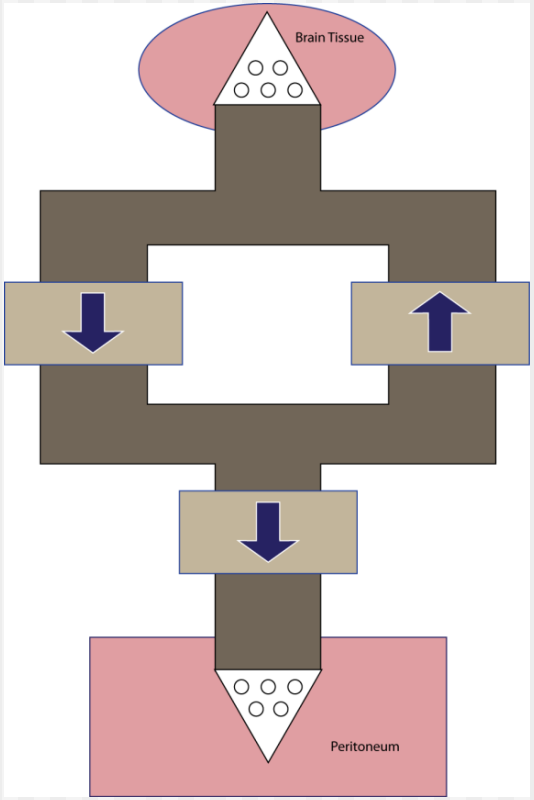


Figure from Dr. David Hsu

Final Design

- Novel Valve:
  - Casing: HDPE
  - Spring: Plastic Composite
  - Ball: Si Rubber with Ba

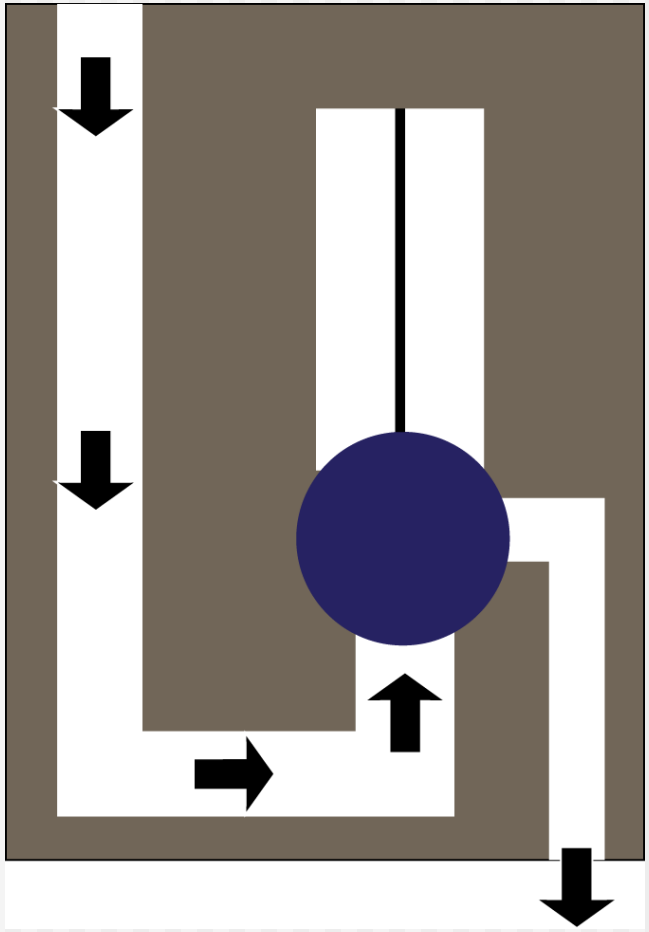
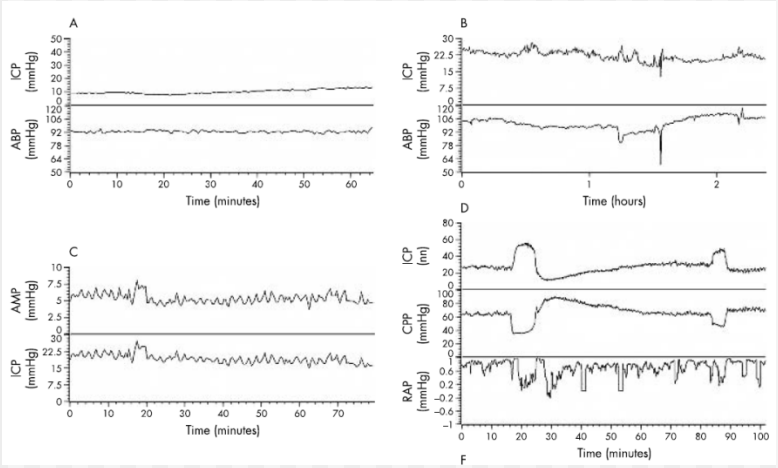


Figure from Dr. David Hsu

Future Work

- Fabrication
- Testing
  - Controlled pressure supply
  - ICP waveform and Plateau Waves
- WARF



Acknowledgements

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References

- Czoshyka M, Pickard JD. Monitoring and interpretation of intracranial pressure. *J Neurol Neurosur Psychiatry*. 2004;75:813-821.
- http://neuroanimations.com/Hydrocephalus/graphics/ShuntXtraxial.jpg
- Barrett SP, and Howard K. Barium sulfate radio-opacity and bacterial adhesion to silicone catheter material. 1989. J Clin Path 42: 1226
- Issel ALC. Biocompatibility of Stent Material. 2004. MURJ 11:33-37.
- Lee Spring Limited. Engineers Guide: Designing & Specifying Compression, Extension and Torsion Springs.
- Larinio A, Harding S, Van Der Boogaard F, Czosnyka M, Smielewski P, Richards HK, Pickard JD, Czosnyka ZH. Magnetic field interactions in adjustable hydrocephalus shunts. J Neurosurg Pediatrics. 2008;2:222-228.
- Ratner BD, et all, ed. *Biomaterials Science: An Introduction to Materials in Medicine.* Academic Press. Burlington, MA. 1996.
- Osswald TA, Baur E, Brinkmann S, Oberbach K, Schmachtenberg E. (2006). *International Plastics Handbook: The Resource for Plastics Engineers.* Hanser Gardner Publications, Inc. Cincinnati, OH.
- Newaz G, Mian A, Sultana T, Mahmood T, Georgiev DG, Auner G, Witte R, Herfurth H. A comparison between glass/polyimide and titanium/polyimide microjoint performances in cerebrospinal fluid.
- http://www.sophysa.com/hydrocephalus-treatment_154.html

Questions?