Design of dextrous, soft endoscope for performing endoscopic third ventriculostomy

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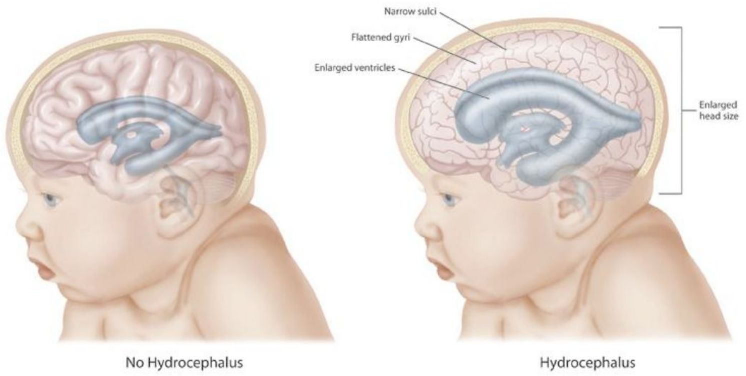
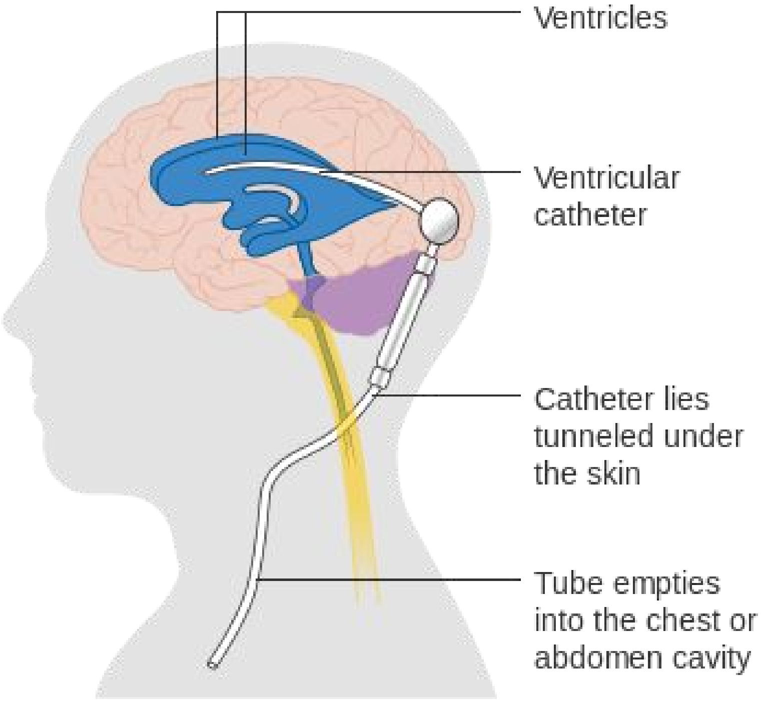
Hydrocephalus

- A condition of excessive cerebrospinal fluid in the brain
- Symptoms
  - Headaches
  - Seizures
  - Mental impairment
- 700,000 adults in the United States and suffer from a form of hydrocephalus
- 1 in every 2000 babies are born with hydrocephalus



Treatment of Hydrocephalus: Cerebrospinal Fluid Shunt

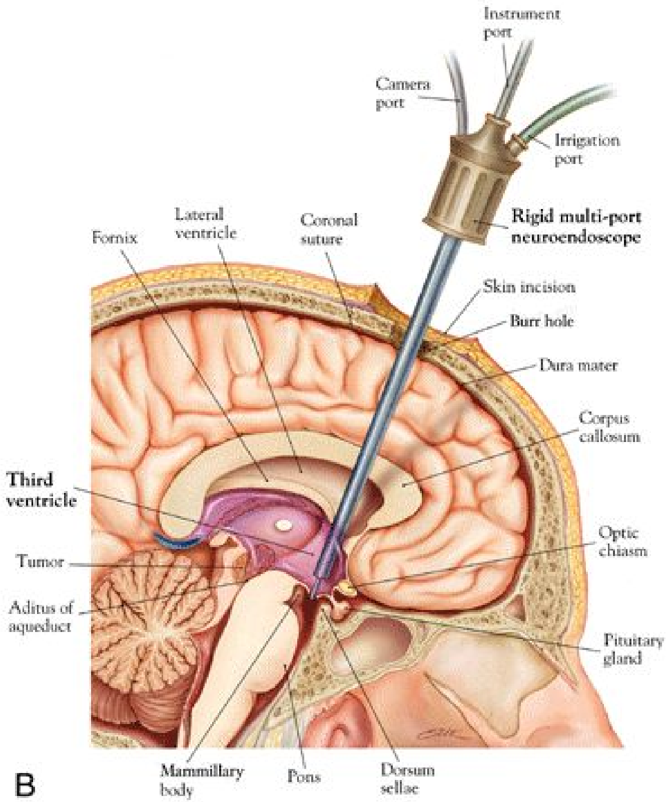
- A catheter is placed inside the body to drain excess cerebrospinal fluid when the ventricular pressure increases to unsafe levels



Treatment of Hydrocephalus: Endoscopic Third Ventriculostomy

- A rigid neuroendoscope is inserted into the ventricular system

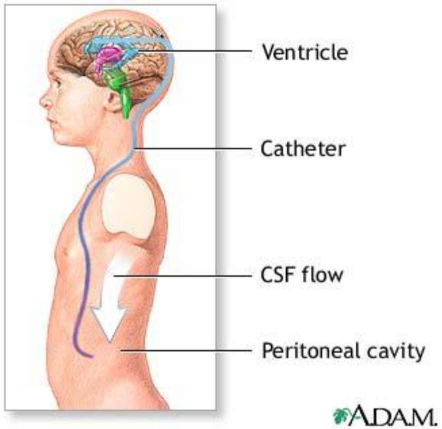
- An opening is created in the floor of the third ventricle to allow circulation of the cerebrospinal fluid



Comparison of CSF shunts and ETV surgery

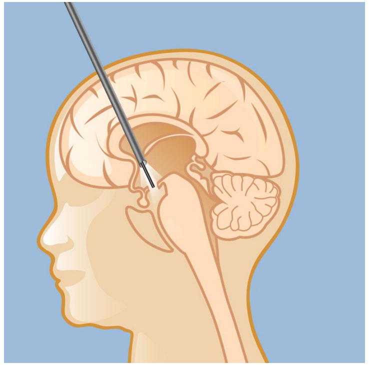
CSF shunts:

- Foreign object in body
- Long term complications:
  - Infection
  - Shunt Malfunction
- Long term costs



ETV Surgery:

- Prefered treatment in most cases
- No foreign body
- No long term complications



- **Complications can still occur during surgery**
- **Still deemed unsafe for infants under 6 months old, and patients at higher chance of hemorrhage**

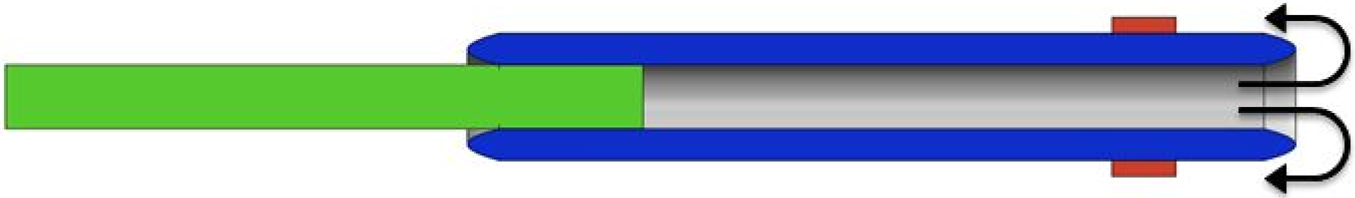
Complications in ETV Surgery:

- Complications due to physician error are mostly apparent in a surgeon's early career:
  - Solution: An endoscope that is simpler to manipulate

- Conventional rigid endoscopes can damage tissue as they slide into position
  - Much larger threat in infants and patients at higher risk of hemorrhage
  - Solution: Reduce friction contact between endoscope and brain tissue and normal force on the brain tissue

Addressing the issues:

- Growing, soft endoscope
  - Drastically reduces friction contact
- Can be manufactured to follow a desired path as it grows
  - Patient Specific
  - Reduces physician error
  - Reduces normal forces on brain tissue



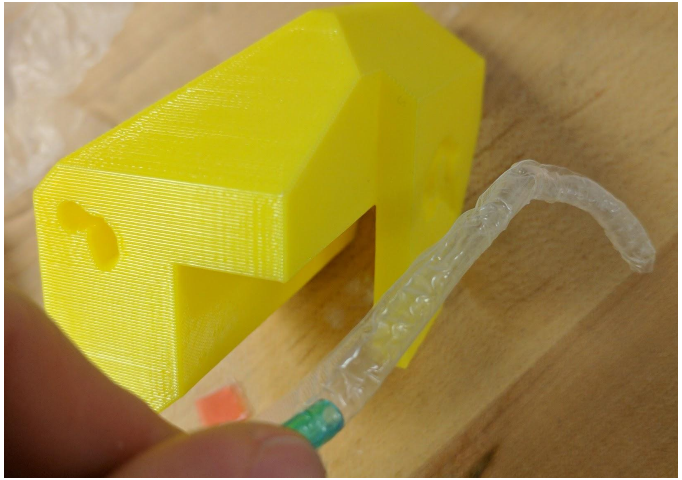
Outcomes:

- Decreased complication and morbidity rate in ETV surgeries

- Making ETV available for infants under 6 months old and patients at high risk of hemorrhage:
    - Spares the long term complications and costs of CSF shunts

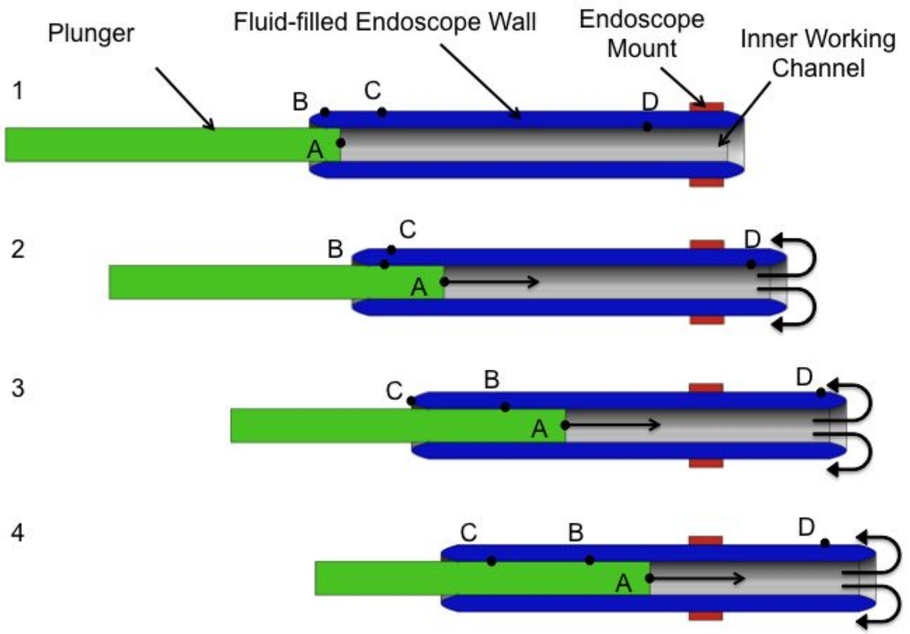
Innovation

- Conventional endoscope categories: flexible, steerable, and rigid fiberscopes as well as rigid rod lense endoscopes
  - Trade-off in visualization, dexterity, and working channel
- Damage caused by endoscope body not following path of tip
- First soft endoscope for ETV
  - Minimize forces and retain working channel



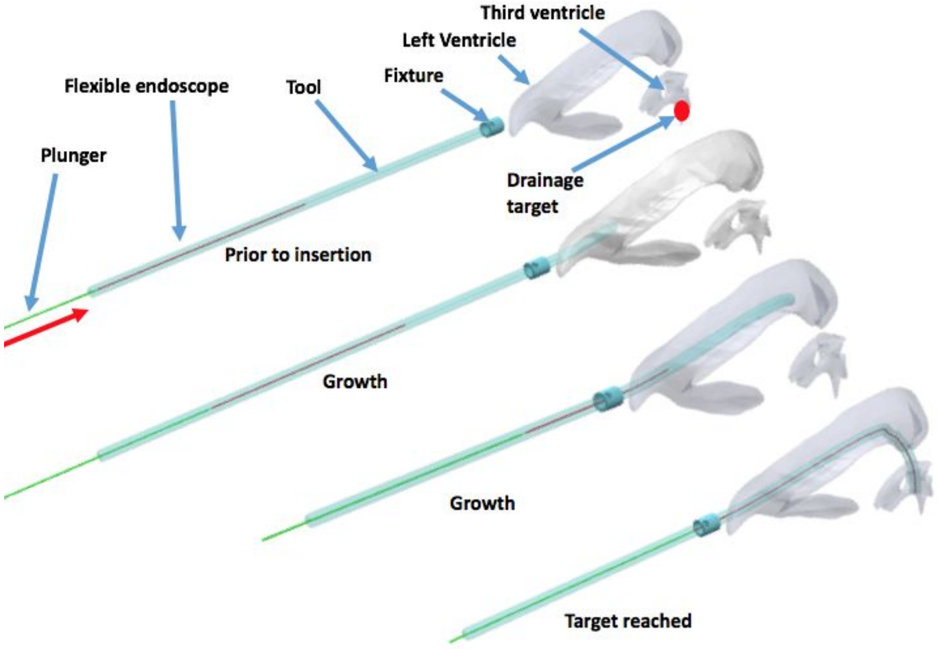
Innovation

- Frictionless traversal of ventricle
- Thin membrane toroid with single continuous motion
- Locomotion method previously shown but only in straight line
- Coupling with predefined path forming results in no sliding along brain tissue



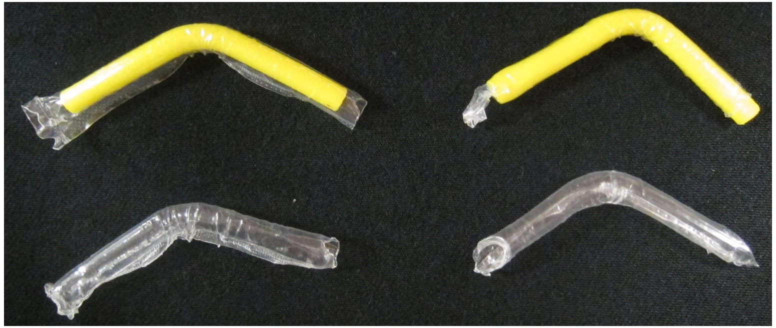
Innovation

- Pre-formed to patient-specific shape
- Combine heat shrink process with MRI images to get custom 3D spline
- Limits need for visual feedback
- Skill required to perform manual insertion significantly lowered
- Thin wall design allows for significant size reduction
    - Increases number of entry methods



Specific Aim 1

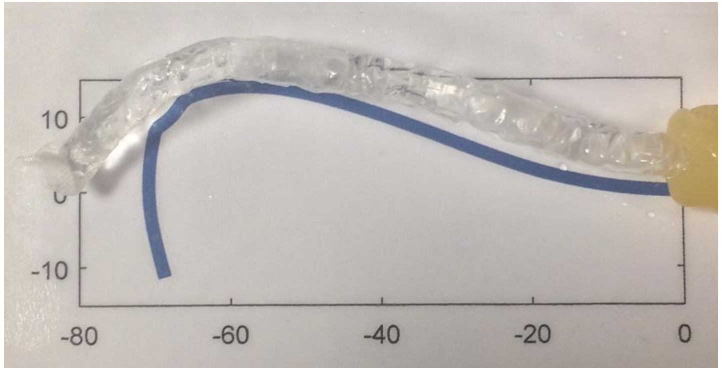
- Fabricate soft endoscopes capable of being formed to follow a predetermined trajectory.
  - Task 1.1: Extend this investigation to include the testing of various combinations of angles and radii to model the shape resulting from any trajectory
  - Task 1.2: Investigate different types of thermosets and thicknesses to find the optimal one for least shrinkage and change in the angle after forming
  - Task 1.3: Develop mathematical models to predict systematic errors in the heat treatment



Nominal Angle	Average Angle	Average Difference	Standard Deviation
30°	30.1°	2.1°	2.9°
60°	59.8°	2.4°	2.8°
90°	88.4°	2.3°	2.4°

Specific Aim 2

- Grow and retract the soft endoscopes along predetermined trajectory through brain.
  - Task 2.1: Develop a manual plunger system that allows the endoscope to be extended and retracted.
  - Task 2.2: Compare ease-of-use through a user study with experienced and novice surgeons.
  - Task 2.3: Analyze how the endoscope changes shape during retraction.

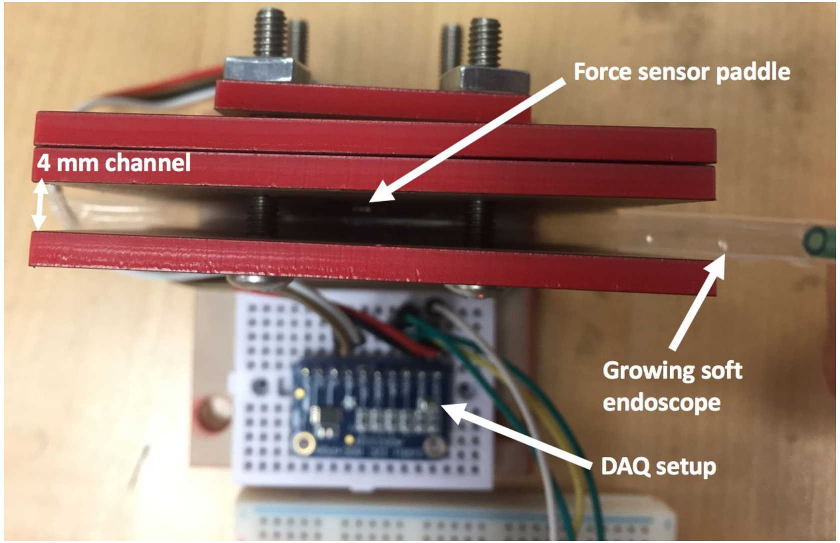


Specific Aim 3

- Test the functionality of the soft endoscope used in conjunction with tools necessary for ETV.
    - Task 3.1: Analyze how incorporation of tools affects endoscope stiffness and trajectory error.
    - Task 3.2: Conduct a user study of a mock surgery in ex vivo tissue to quantify surgical success rates, range of motion, and forces applied between soft and conventional endoscopes.

Specific Aim 4

- Study stress and health of brain tissue in response to soft endoscope growth
  - Task 4.1: Measure radial forces exerted on tissue during growth and retraction
  - Task 4.2: Study forces exerted on a ventricle wall path when impact with tissue occurs (trajectory error, swelling, unexpected obstacles)
  - Task 4.3: Mock surgery in ex vivo brain model followed by histological analysis of tissue damage to determine parameters such as growth speed and tool manipulation



Angle	Force measured (N)	Pressure (kPa)
Inflated in 4 mm gap	0.05	2.5
Impact at 10°	0.03	1.4
Impact at 45°	0.04	2.0
Impact 90°	0.06	3.0

Questions?