Literature Review:

Robotics in Neurosurgery: Evolution, Current Challenges, and Compromises

Project Group 1
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Motorized Fixation to Tubular Retractor in Brain Surgery

Problem: Tubular retractors are unconstrained and can be shaky during surgery

Project Goal: Enhance tubular retraction in brain surgery through automation

Individual Goals:

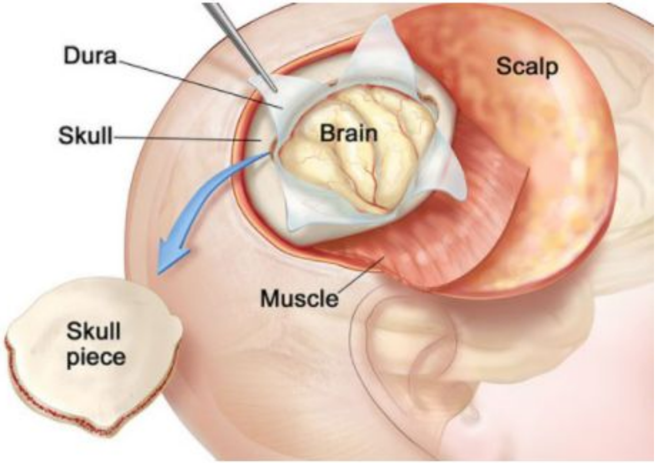
1. Create stabilizing component for tubular retractor
2. Develop hardware to allow for 2 DOF movement of the tubular retractor
3. Implement simple control method with a focus on good surgical usability
4. Retrofit surgical tools with sensors and use for automatic retractor alignment

Paper Selection: Robotics in Neurosurgery: Evolution, Current Challenges, and Compromises

- Talks about current robotics in surgery and its limitations.
- Our project is a sort of bridge between manual and robotic neurosurgery.
- Can help determine what is missing in manual surgery but is difficult to accomplish with robots. Will help us adjust specific methods based on this.

Summary

- Less robots in neurosurgery than other fields
- Mechanical factors largely act as constraints
  - Tools, working area, applied force
- Human-robot interaction
  - Natural haptic feedback limited
  - Proprioceptive learning curve



Significance

- Highlights problems current robotic systems have that restrict their adoption
- Calls for solutions involving automated neurosurgery
- Suggests that a hybrid manual/mechatronic solution such as our project could have usefulness, at least in the short term

Background

- Pathfinder - stereotactic 6 DoF system (Doulgeris, 3)
- NeuroArm - needle, cutting, cauterization, irrigation, telesurgery (Doulgeris, 3)
- Neuromate - DBS, endoscopy, stereo encephalography (Doulgeris, 2)
- DaVinci - skull base tumors and aneurysms possible, but has issues such as
  - Bulky
  - Limited tools
  - Limited ports for tools

  (Doulgeris, 3-4)

Pathfinder
(not much info)

NeuroArm
(not very active)

Neuromate
(neuromonitoring)

DaVinci
(limited brain)

Content - Mechanical Factors

Tools (Doulgeris, 4-5)

- Rigid tools - surgeon has more DoF than robot: can move tool-holding hand in space
- Curved - good for reach around obstacles, but difficult to locate and control

Compromises (Doulgeris, 5)

- Strength/size tradeoff - tool has to fit, but cannot deflect
- Limited room is a big theme - crowded instruments and limited motion
- Can increase force through motor power, but tools may now deflect more as they are thinner than regular surgery tools

Content - Human-Robot Interaction

Haptic Feedback (Doulgeris, 5)

- Completely removed in telesurgery
- Strain gauges require wires and are hard to sterilize; optical methods are promising

Proprioception - associated learning curve, and still not fully natural (Doulgeris, 6)

Kinematics - tremor removal can improve safety and make surgeon feel more at ease (Doulgeris, 6)

Visualization - Only reliable feedback mechanism in telesurgery; 2D limitation extends surgery time (Doulgeris, 6-7)

- Microscopy in telesurgery limited by minimally invasive surgery - obscured field of view
- Augmented Reality can help regain insight by showing important hidden structures

Training - possibilities are deceased donor and VR. Obstacle for technology adoption. (Doulgeris, 7)

Relevance

Clear need to somehow monitor/limit force. Relevant because:

- We can limit the force surgeons can apply from moving the retractor.
- Possible since solution is no longer manual and much more regulated.

Limitations of straight tools are important to avoid. Relevant because:

- Encourages application of real tools to anticipate + account for limitations.
- If such limitations are avoided, it is clear there is a value proposition.

These insights directly affect our group's maximum deliverables and priorities.

Assessment

- Paper gives a good overview of current robotic neurosurgery to form initial opinion
- Pros
  - Put in very concise, understandable terms
  - Touched on many important characteristics such as types of robotic tools, mechanical compromises, and drawbacks of human-robot interaction
- Cons
  - Could have gone more in depth/elaborated more about current robot applications with more examples of relevant procedures or conditions
  - Could have directly explained what past studies have focused on rather than just saying their results

Next Steps

- Determine a possible method for force regulation
    - Allow surgeon to gently push against retractor wall
    - If surgeon pushes too quickly, limit velocity, thereby resisting stronger forces
- Select a comprehensive variety of tools to retrofit
    - Focus on rigid tools
    - Select most commonly used tools in brain surgery, specifically in tubular retraction

Conclusions

This project has a clear purpose and is relevant to brain surgery

The project's maximum deliverables should be focused on:

1. force control and limiting
2. surgical instrument sensor integration

References

1. **Doulgeris** JJ, Gonzalez-Blohm SA, Filis AK, Shea TM, Aghayev K, Vrionis FD. "Robotics in Neurosurgery: Evolution, Current Challenges, and Compromises. Cancer Control." 2015 Jul;22(3):352-9. doi: 10.1177/107327481502200314. PMID: 26351892.
2. Deacon, G, et al. "The Pathfinder Image-Guided Surgical Robot." *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine*, vol. 224, no. 5, 2009, pp. 691–713., doi:10.1243/09544119jeim617.
3. "Craniotomy Surgery Cost in India: Craniotomy Surgery in India." *Medsurge India*, 20 Oct. 2020, medsurgeindia.com/cost/craniotomy-surgery-cost-in-india/.

Thanks for listening!