Towards Robot-Assisted Retinal Vein Cannulation

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01/16/2012
Content

- Clinical Overview
- Prior Research
- Proposed Work
- Future Directions
Clinical Relevance

- Retinal vein occlusion (RVO) is the second leading retinal vascular disease\(^1\)

- Affects 16.4 million adults worldwide (disease prevalence between 0.3-1.6\%)\(^2\)

- In US, $5.8 billion in direct annual costs\(^2\)
Pathology and Treatment

- Laser photocoagulation\textsuperscript{3,4}
- Radial optic neurotomy\textsuperscript{3,4}
- Intravitreal injection\textsuperscript{3,4}
- Anastomosis (via laser or surgery)\textsuperscript{3,4}

Marcucci et al.
Retinal Vein Cannulation (RVC)

- Direct injection of tissue plasminogen activator (tPA) upstream of the vein occlusion

Advantages of RVC

- Easy visualization of clot and its resolution\(^5\)
- Higher concentration and flow rate of drug delivered\(^5\)

- RVC attempted in humans\(^5\), rabbits\(^6\), and dogs\(^7\)
RVC Approaches

- **Freehand Approach**
  - Flexible guide wire or catheter system
  - Use forceps for vein puncture
  - Requires multiple ports of entry

- **Robot-Assisted Approach**
  - Rigid micropipette insertion through trocar
  - Reduce tremor, provide better accuracy
  - Must protect tip of cannula during insertion

Tameesh et al.

CIIS website
Other Approaches

- **Wireless magnetic microrobots**\(^8\)
  - Magnetic force to steer and puncture vessel
  - Multi-layer drug coating

- **Robot-assisted microstenting**\(^9\)
  - Miniaturized stenting procedure
  - Wire guide placement of stent

Dogangil et al.

Simaan et al.
Objective

- Demonstrate the clinical feasibility of robot-assisted RVC with quantifiable advantages over the freehand method

- In a comparison study, show significant differences between the robot-assisted and freehand RVC methods

- In a bunny model, demonstrate successful RVC
Vein Cannulation on CAM model

- **Humagen MIC-SI-45 micropipette**: short neck bent tip pipette, bent at 45%, 0.5 mm from the tip, 5μm ID, beveled tip and a spike

*Figure:* (A) System Overview. (B) The tool holder and micro-injection tool during a cannulation. (C) Chicken embryo CAM with a bent tip micropipette.

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Cannulation Tool

Eye Robot 2

Eye

18 G tube

Quick release tool shaft

Air/liquid flexible tube

Tool handle

18 G tube

Eye

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Cannulation Tool

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Comparison Study

- HIRB #2008095 amendment approved
- Recruit additional 25-35 human subjects including Wilmer Eye Institute residents and surgeons

Experimental workflow
- Informed consent, safety (10)
- Tool and robot orientation (10)
- First cannulation block (30)
- Break (5)
- Second cannulation block (30)
- Questionnaire (5)
Performance Metrics

- Time to guide to site and align with vessel
- Time to enter vessel
  - Cannulation success rate
  - Number of attempts to enter vessel
- Longest time maintained in vessel
- Total time of procedure
- Pipettes broken, trauma rating, retinal touches
- Learning curve, non-surgeon vs. surgeon
User Feedback

- Experience with micromanipulation (e.g. soldering)
- Dominant hand, non-dominant hand use
- Robot vs. freehand evaluation
  - Speed, accuracy, overall, comfort level, ease of use
  - General comments
Expected Results

- Surgeons show improved performance metrics over non-surgeons
- Robot-assisted procedure reduces time required while increasing success rate and time maintained
- Positive qualitative user feedback towards robot
Surgeon Evaluation

Surgeons: Dr. Handa and Dr. Gehlbach
Robot-Assisted Cannulation
Bunny Experiments

- Last experiment, 1/13/12
Bunny Experiments

Problems Encountered

- Orientation of rabbit is important (vessels inside eye and scleral entry points)
- Creation of a deliberate wound is necessary for tool insertion into the eye (large gauge tool)
- Vitreous within eye has to be completely removed or could clog up tool tip
- Tool development changes - create cap to protect pipette within tool or flush tool tip with air/fluid
Future Work

- **Tool development**
  - Reduce shaft diameter -> allow for more realistic surgical insertion through trocar
  - Deployment method -> current twist method is not very ergonomic and requires two hands

- **Image guidance of cannulation**
  - Use robot along with visualization techniques to track tool tip and guide insertion into vessel
Acknowledgements

- Advisors: Dr. Taylor and Dr. Iordachita
- Clinicians: Dr. Handa and Dr. Gehlbach
- Graduate Students: Marcin Balicki, Xingchi He, Kevin Olds
- Undergraduate Students: Daniel Peng, Steve Park


Questions?