1.

Most Significant Research Contributions\*

Select the most significant research contributions listed on your CV and outline your role in those contributions, the nature of the contributions and their significance. Please signal any peer-reviewed contributions, and ensure that your role in the contribution is clear. **Maximum 4,500 characters (with spaces), which is equivalent to about 1 page single spaced in Microsoft Word, 10 point Arial font.**

From May to August, 2016 I worked as a research student at the Centre for Image Guided Innovation and Therapeutic Intervention (CIGITI) at SickKids. I assisted an MD PhD. student to perform experiments on robotic wrist joints. These are one millimetre diameter Nitinol tubes with slots cut into them that allow the tube to bend flexibly. I mill machined eight different geometries of joints using a CNC mill. The geometric parameters of the joints were chosen based on Latin Hypercube sampling from the SAFE toolbox on Matlab to evenly span the optimal ranges for each parameter. To test the physical characteristics of the joints, a force applied at the tip of the joint was measured with a force sensor, while a laser measured tip displacement and a stereo calibrated camera system acquired the resulting image. The image was analyzed using matlab to calculate the radius of curvature of the tube. This measured the experimental relationships between radius of curvature, tip displacement, bending angle and applied tip force. The results were then compared to a model relationship presented by York et al. [1]. These results were presented in [INSERT NAME OF IROS PAPER] at the IEEE International Conference on Intelligent Robots and Systems in South Korea, 2016 [2].

I also used the same experimental setup to collect data for joint radius of curvature vs. force applied at the tip. Again, I analyzed the data using Matlab to measure radius of curvature and calculated bending angle. Using this data, I developed a figure for a magazine article in *IEEE Robotics and Automation Magazine* entitled “Miniaturized Continuum Instruments for the da Vinci Research Kit,” which is currently under review.

These papers validate the kinematics model of continuum joints with experimental results. They extend the knowledge of robotic surgery tool design by presenting realistic behaviours of these joints, thereby facilitating future design of joints to optimize robotic tools.

Furthermore, for my Master’s work so far, we are preparing data collection methods and plan to publish our findings. Firstly, we are developing a survey to be sent out to ear surgeons that are part of Otological Societies around the world. This survey will address the knowledge gap of why most otologists are not employing endoscopic ear surgery and what technological advances can be developed to encourage greater use of the surgical technique. This survey will follow a two-round Delphi method and the results, after statistical analysis, intend to be published in an otolaryngology journal. As well, an REB application to conduct time flow analysis by recording the duration of endoscopic ear surgery steps will be submitted within the coming months. This study will quantify the current limitations and inefficiencies of endoscopic ear surgery instrumentation by measuring the time required for surgical steps. This study also aims to be published after collecting data from surgeries by a few ear surgeons around Toronto. These two studies aim to establish the needs and current limitations of endoscopic ear surgery technology to inspire the design of and provide means of validation of new endoscopic ear surgery tools, which will be the next steps of the Master’s project.

[1] A Wrist for Needle-Sized Surgical Robots

[2] IROS paper

2. Most Significant Personal Contributions\*

Select the most significant personal contributions--committee work, volunteerism, leadership activities, mentorship, etc.--listed on your CV and outline your role in those contributions and how they speak to your character and abilities. **Maximum 4,500 characters (with spaces), which is equivalent to about 1 page single spaced in Microsoft Word, 10 point Arial font.**

I am a Bollywood Dance Instructor at the Hart House Gym at University of Toronto, where I teach a weekly class. I decided to teach the class due to my love of dance and my eagerness to share this exotic type of dance with people who have never tried it before. When I took a dance class at Hart House, I instantly wanted to teach my own Bollywood class as well. I had an enthusiastic vision and took the initiative to approach the management of the Hart House Gym with my proposal. They were excited about the idea and set up a trial drop in dance class in February, 2016. I taught dance moves to class sizes ranging from 4 to 50 people per week. Students really enjoyed the class and many returned for consecutive weeks. I now teach a registered dance class at the gym. Setting up this dance class required perseverance and a positive attitude, which enabled the class to run weekly as it does now.

Furthermore, my Master’s project stemmed from an undergraduate engineering design course, called Capstone in Fall, 2015. My team was paired with our client, and my now supervisor, Dr. Adrian James at SickKids. He proposed a project to design tools to facilitate endoscopic ear surgery. I realized I wanted to pursue this project further than an undergraduate course project, and implement a successful tool. I dedicated a lot of time to work on the project. I attended every meeting with Dr. James, went to as many surgeries as possible, and learned how to use a mill machine to fabricate the functional prototype at the end of the four-month project. I pitched myself as an MASc. candidate to Dr. James so I could pursue this project under his supervision. He recognized my dedication and leadership in the project and agreed to be my supervisor. Throughout the rest of the year, after the completion of the Capstone course, we met frequently to discuss the plan and apply for grants and awards to get the project started. I really enjoyed this course and wanted to inspire future students to pursue their dream like I have and so I became a teaching assistant for the course this Fall semester. I delivered a lecture on how to succeed in the course and talked about my positive experience. I provide technical support during their labs and trained them on how to use a 3D printer. I have also met with most of the groups I try to guide them in their projects. Even though I am only one year older than them, I have experienced their position very recently and know their daily struggles; I hope to help and advise where I can.

2.

Research Project and Significance\*

Provide a brief overview of your proposed research project and describe its significance and expected outcomes, with emphasis on what impacts it might have on your field of study, patients, or other populations. **Maximum 4,500 characters (with spaces), which is equivalent to about 1 page single spaced in Microsoft Word, 10 point Arial font.**

**Overview of Proposed Research Project:**

The aim of this project is to develop and evaluate innovative surgical instruments for the new and growing field of endoscopic ear surgery, a minimally invasive technique. By employing an endoscope during surgery, the middle ear can be accessed through the ear canal without an external incision [1] [2]. As with traditional, invasive microscope-guided surgery, this transcanal endoscopic ear surgery (TEES) technique allows the surgeon to perform procedures such as ear drum reconstruction, skin growth removal and hearing bone repair [1]. The Hospital for Sick Children remains one of the very few centres in North America where a surgeon completes the majority of middle ear procedures endoscopically. The learning curve to reach this status has been slow, taking many years, but the wealth of experience accumulated has given valuable insight into the strengths and weaknesses of currently available instrumentation for endoscopic ear surgery.

The principle challenge with TEES is that a one- handed surgical technique is required while the endoscope is held in the other hand, this makes the surgery more difficult, and requires enhanced training. Otologic instruments were developed for two-handed microscope-guided surgery so they are not all well suited to TEES conditions [2]. These shortcomings have hindered the use of TEES and will be addressed by this project which will utilize mechanical engineering principles to develop specialized instruments for TEES [2] [3]. While previous instruments were developed by surgeons over decades through trial and error, modern engineering techniques provide the opportunity to rapidly design and produce ergonomic functional instruments optimised to facilitate this new branch of surgery.

*Aim 1:*A needs assessment survey, using the Delphi method, will be conducted to determine the requirements to address in order to encourage more surgeons to train in and employ TEES. A list of questions will be formulated based on local otolaryngologists’ feedback, and a survey will be sent to otolaryngologists globally. The results will then be published to establish the requirements to enable training and development of endoscopic ear surgery. A time flow analysis recording the duration of surgical steps will also be conducted to quantify the limitations of current instruments used in endoscopic ear surgery, by assessing their efficiency.

*Aim 2:*An initial, functional prototype, developed by the supervisor and student, was designed to facilitate manipulation of a synthetic graft during ear drum reconstruction surgery. New instruments in response to the needs assessment will also be developed, for example to ease control of bleeding and to access hard to reach places in the middle ear, with one hand operating. The instruments will be designed to optimize functionality, ease of use and maneuverability of the tool within the ear canal alongside an endoscope.

*Aim 3:* Validation testing will be conducted and published to compare existing tools as well as the new instrument designed. A mock operating room setting will be used where surgeons will test the tool on cadaveric or 3D printed ear models by performing an ear drum replacement procedure and trying to reach hidden recesses behind the ear drum. The number of tries to pick up and place the graft and time to complete the procedure will be measured to assess the efficiency, functionality and ease of use of the tool. As well, qualitative feedback, in terms of ease of use and ergonomics, will be obtained.

*Aim 4:*Collaborate the obtained feedback to optimize the tool so it can be used in patients in the operating room.

**Significance:**

The design techniques and instruments created will also be applicable to other minimally invasive surgery in bony cavities such as sinus, nasal, spinal and arthroscopic surgery [4] – [6]. It could be envisaged that ultimately, virtual patient models could be used with rapid prototyping and fabrication methods, developed by this project, to create patient specific specialist instruments to extend minimally invasive surgery.

**Expected Outcomes:**

As per informal discussions with otologists at SickKids, the needs analysis survey will show that surgeons find one handed surgery and bleeding control the major challenges in endoscopic ear surgery. They have conveyed that future tools whose primary functions are coupled with suction would be beneficial to aid surgeons while performing this new type of surgery. As well, it is expected that the new tool will encourage more use of endoscopic ear surgery by easing the procedure and increasing efficiency.

**Impacts on Endoscopic Ear Surgery and Patients:**

The development of tools to facilitate endoscopic ear surgery aims to encourage more ear surgeons to adopt this minimally invasive surgical technique and therefore reduce patient morbidity rates and send patients home sooner so they can go back to their normal lives. Endoscopic ear surgery has been shown to reduce rates of residual skin growth after skin growth removal surgery in the middle ear as the endoscope allows greater visualization in the previously hidden recesses within the middle ear [7].

3.

References\*

List the references in your research proposal here. **Maximum 4,500 characters (with spaces), which is equivalent to about 1 page single spaced in Microsoft Word, 10 point Arial font.**

[1] A. James, "Endoscopic Middle Ear Surgery in Children", Otolaryngologic Clinics of North America, vol. 46, no. 2, pp. 233-244, 2013.

[2] C. Carlos, W. Parkes and A. James, "Application of 3-dimensional Modeling to Plan Totally Endoscopic Per-Meatal Drainage of Petrous Apex Cholesterol Granuloma", Otolaryngology -- Head and Neck Surgery, vol. 153, no. 6, pp. 1074-1075, 2015.

[3] M. Tarabichi, “Endoscopic Middle Ear Surgery,” Ann. Otol. Rhinol. Laryngol., vol. 108, no. 1, pp. 39–46, 1999.

[4] “Benefits of Minimally Invasive Surgery | AIMIS.” [Online]. Available: http://www.aimis.org/benefits-of-minimally-invasive-surgery/. [Accessed: 14-Nov-2015].

[5] “AANS - Minimally Invasive Spine Surgery MIS.” [Online]. Available: http://www.aans.org/patient information/conditions and treatments/minimally invasive spine surgery mis.aspx. [Accessed: 17-Nov-2015].

[6] “Endoscopic Nasal & Sinus Surgery.” [Online]. Available: http://care.american- rhinologic.org/ess. [Accessed: 17-Nov-2015].

[7] Ã. A. L. James, Ã. S. Cushing, and Ã. B. C. Papsin, “Residual Cholesteatoma After Endoscope-guided Surgery in Children,” pp. 196–201, 2015.

4.

Training Plans\*

Explain why your current or proposed lab is the best place to pursue this research, and how this research project and choice of lab will help you further your professional, research, and personal goals. **Maximum 4,500 characters (with spaces), which is equivalent to about 1 page single spaced in Microsoft Word, 10 point Arial font.**

The following labs will provide equipment and expertise to support successful completion of the proposed project: Centre for Image Guided Innovation and Therapeutic Intervention (CIGITI) at SickKids, the Surgical Skills Centre (SSC) at Mount Sinai Hospital and the Institute for Biomaterials and Biomedical Engineering (IBBME). The labs have been successfully used by the investigators to develop a functional initial prototype. CIGITI has provided bench space, a computer, design software, technical support and machines to manufacture medical device prototypes. The MASc. student worked as a research student at CIGITI during the summer, 2016, where she learned how to design, CNC mill machine and 3D print prototypes that are similar in size and function to the instrument prototypes to be developed for the proposed project. As well, the instruments that are prototyped, fabricated and tested by fellow members of the lab are applicable to endoscopic ear surgery. Students from the lab have also conducted needs analysis studies and instrument validation tests for surgical instruments. Therefore, CIGITI will provide the research and technical support for the success of this project. The SSC will facilitate prototype testing using cadaveric temporal bone models by trained personnel. The SickKids operating room will be used for needs assessment and evaluation of instruments during surgery. The primary investigator is recognized internationally for his experience in endoscopic ear surgery. He will provide guidance on surgical ergonomics, functional requirements of instruments and feasibility of design proposals. He has previously developed successful instrumentation for minimally invasive cochlear implant surgery. Co-supervisor Dr. Andrysek has supervised multiple graduate students through MASc programs at IBBME and his experience with medical device design will provide technical engineering support for the project. We believe that the combination of surgical and engineering experience with state of the art facilities for design, manufacturing and testing of novel instruments within a single institution is unparalleled globally.