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.**

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From May to August 2016, I worked as a research student at the Centre for Image Guided Innovation and Therapeutic Intervention (CIGITI) at the hospital for Sick Children. Here, I assisted an MD-PhD student in performing experiments that aim to optimize the design of robotic instruments for neurosurgery. The tool consists of a long tube which can be inserted into the brain to perform surgery. The tip of the tool consists of a continuum joint, allowing it to bend flexibly due to slots that are cut into it. This joint’s physical characteristics were experimentally measured to determine the relationship between the geometry and resulting range of motion of the tip. To do this, I learned basic design of experiments and used Latin Hypercube sampling on Matlab to evenly and randomly span the optimal ranges for each geometric parameter. I mill machined eight different geometries of joints using a CNC mill.

I setup an experiment to test the physical characteristics of the joints, including techniques and protocols used in this field and presented in papers we use for reference. A force applied at the tip of the joint was measured with a force sensor, while a laser measured tip displacement and a calibrated camera system acquired the resulting image. Image analysis via Matlab calculated the joint’s range of motion parameters. Statistical data analysis techniques were used to calculate the mean and standard error. Before these experiments, the accuracy of the image acquisition system was determined by statistically comparing measured data with known data to quantify the error.

The resulting data to characterize the stiffness properties of the joints were compared to a model developed by the MD-PhD student and presented in “Kinetostatic Design of Asymmetric Notch Joints for Surgical Tools” at the IEEE International Conference on Intelligent Robots and Systems in South Korea, 2016. The relationship between the force applied and range of motion parameters are part of an ongoing study and will be presented in a future paper where I will be co-author. As well, 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, I compiled a summary document that explains the details, process of statistical data analysis and figures of the experimental setup. This will be an aid while writing the methods for future publications. Finally, I delivered a presentation to my lab outlining my work during the summer and a discussion of my results.

Furthermore, my Master’s project is a continuation of a project I started in undergrad, where my team developed a functional prototype tool to facilitate endoscopic ear surgery. I enjoyed working on the project and am determined to see it through to its successful completion. For my Master’s work to date, I am designing a survey study that will be used to address the knowledge gap of why most otologists are not currently employing endoscopic ear surgery techniques and what technological advances can be developed to encourage greater use of this new surgical approach. The survey will be sent to ear surgeons who are current members of any international Otological Society. This survey will follow a two-round Delphi method and the statistically analyzed results will be disseminated in an otolaryngology journal. Additionally, I will submit an REB application to measure the time to complete various surgical manoeuvres in endoscopic ear surgery. The study will quantify the current limitations and inefficiencies of endoscopic ear surgery instrumentation by measuring the duration of surgical steps. This publication will present data where the time to complete the steps of ear drum reconstruction surgery was measured. The procedure will by completed 10 times each by five ear surgeons independently. 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, for new endoscopic ear surgery tools. This is the next step of the Master’s project.

~~These tools are constructed from one millimeter diameter nickel-titanium metal tubes with slots cut into them that allow the tubes to bend with increased flexibility. 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. 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 [Kinetostatic Design of Asymmetric Notch Joints for Surgical Tools] at the IEEE International Conference on Intelligent Robots and Systems in South Korea, 2016 [2].~~

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.**

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I am currently a dance instructor at the University of Toronto’s Hart House Gym. In the Winter of 2016, I started a new weekly Bollywood dance program. I decided to start this class, in part, because of my love of dance, and also because I recognized an opportunity to share this exotic dance style with people who have never tried it before. During my undergrad, when I participated in dance classes at Hart House as a student, I enthusiastically developed a vision for leading my own dance program. Once I developed a curriculum plan**,** I took the initiative and approached the management team of 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, a positive leadership mentality, which enabled the class to run weekly, as it does now.

Furthermore, my Master’s project stemmed from an undergraduate engineering design course, called a Capstone project, during the Fall of 2015. In this project, I led a team of five engineering students as we were paired with our client, and my now supervisor, Dr. Adrian James at SickKids. Dr. James proposed a project to design tools to better facilitate endoscopic ear surgery. From this opportunity, I realized that I wanted to pursue this project further, and help to fully develop the device into a pre-clinical testing stage. During the 4-month Capstone project, whilst completing four other courses, I dedicated over 80 hours to developing a prototype instrument. I attended several planning meetings with Dr. James, I observed three endoscopic ear surgeries, and I developed new technical skills in order to fabricate the functional prototype myself. Following the completion of the Capstone course work, I decided to pitch myself as an MASc. candidate to Dr. James so that I could continue to pursue this project under his supervision. He recognized my dedication and the leadership role that I took on within my group, and he agreed to be my supervisor. Throughout the rest of the year, we met frequently to discuss the plan and to apply for grants and awards to get the project started. Since I gained a lot from my Capstone project, and because I thoroughly enjoyed it, I am now a teaching assistant (TA) for the course. I chose to be a TA because I want to not only mentor but also inspire future students to pursue their interests like I have done. So far in this fall semester, I delivered a lecture on how to succeed in the course, relating my advice to personal experience in the course and other research projects. I also provide technical support during labs and delivered training on how to safely use a 3D printer. These are skills that I developed during the time I completed my Capstone project. I have also met with most of the groups and provided guidance to them in selecting their projects. Since I have very recently been in their position, I believe that I can relate well to their daily struggles; I hope to help and advise where I can.

As well, upon completion of my undergraduate degree in biomedical engineering (BME), I saw potential for improvement in the introductory BME course, which focused on one subject in the field, generating low interest among students. I took initiative, and approached the curriculum coordinator with a proposal on what I thought the course should cover, based on my own experience. I want the course to emphasize research at U of T and focus on understanding journal articles rather than a textbook to better reflect biomedical engineering. I have followed up with the curriculum committee and I hope that I can help make the course more engaging for young engineers.

Finally, during my time as a research student at CIGITI, I applied and further developed many technical skills to create prototypes. There were many summer students in the lab who were just learning the basics of prototyping. I remembered what it was like to face these challenges as an intern, and I did not want these students to feel overwhelmed or confused. I offered to mentor these students, when they required technical help and I trained students to use the CNC mill machine to fabricate simple prototypes. I had an approachable demeanor and I use it now during my role as a Capstone TA.

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:**

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. An endoscope allows visualization of the middle ear 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 few centres in North America where a surgeon completes the majority of middle ear procedures endoscopically, due to the steep learning curve. The team at SickKids has accumulated valuable insight into the strengths and weaknesses of currently available instrumentation for TEES. The principle challenge with TEES is that a one-handed surgical technique is required while the endoscope is held in the other hand. Otologic instruments were developed for two-handed microscope-guided surgery so they are not optimized for TEES conditions [2]. These shortcomings have hindered the use of TEES; this project will address them by engineering specialized instruments to facilitate TEES [2] [3].

**Aims:**

*Aim 1:*To conduct a needs assessment survey, using the two-round Delphi method, that examines the current limitations of TEES and how to encourage its adoption. A questionnaire will be formulated from a literature review and interviews with local otolaryngologists and sent to otolaryngologists globally. The results will be published to establish the requirements for training and instrument development to facilitate TEES. A time flow analysis, recording the duration of surgical steps, will also be conducted to quantify the limitations of the current instruments used in TEES, 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, a one-hand instrument designed to better control bleeding and to access hard to reach places within the middle ear. The instruments will be designed to optimize functionality, ease of use and maneuverability within the ear canal alongside an endoscope.

*Aim 3:* Validation testing will be conducted and published to compare existing tools to the new tool. Local ear surgeons will test the tool on cadaveric or 3D printed ear models by performing an ear drum reconstruction procedure whilst trying to reach hidden recesses behind the ear drum. The duration of the procedure will be measured to assess the efficiency, functionality and ease-of-use of the tool compared to the same procedure with existing tools. As well, qualitative feedback, in terms of ease of use and ergonomics will be obtained.

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

**Significance:**

The development of tools to facilitate endoscopic ear surgery aims to encourage more ear surgeons to adopt this minimally invasive surgical technique, which would reduce patient morbidity rates, recovery time and hospital stay. Endoscopic ear surgery has been shown to reduce rates of residual skin growth after surgery in the middle ear as the endoscope allows greater visualization in the previously hidden recesses within the ear [7].

Further, new instruments will also be applicable to other minimally invasive surgeries within bony cavities such as in sinus, nasal, spinal and arthroscopic surgery [4] – [6]. Presently, we have an existing collaboration with minimally invasive neurosurgery. Additionally, the techniques developed to create new, specialized instruments could be used to create patient specific instruments by using virtual patient models and rapid fabrication methods developed in this work.

**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 to be the major challenges in TEES. 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 greater acceptance of endoscopic ear surgery by improving the ergonomics of the procedure and increasing its efficiency compared to open techniques.

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 the 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). To date, these 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 the medical device prototypes. The MASc. student worked as a research student at CIGITI during the summer of 2016, where she learned how to design, CNC machine and 3D print prototypes that are similar in size and function to the proposed instrument prototypes to be developed in the 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 simialar needs analysis studies and instrument validation tests for surgical tools. 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 regarding surgical ergonomics, the functional requirements for the instruments and insight on the feasibility of proposed designs. Dr. James has previously developed successful instrumentation for minimally invasive cochlear implant surgery. My 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.