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 span the optimal ranges for each geometric parameter. I mill machined eight different geometries of joints using a CNC mill.

An experiment was setup to test the physical characteristics of the joints, which included techniques and protocols used in the field and presented in papers we used for reference [1]. 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 range of motion parameters of the joint. The data was analylzed using statistical analysis to calculate the mean and standard error. Before these experiments, the accuracy of the image acquisition system was determined. I measured the geometric paramters of curves where these values were known. This data was analyzed to determine the accuracy and minimum detectable change of any measurement acquired by the system. This quantified the error in the image acquisition system, and would be presented with our results in a publication or presentation.

The 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 [2]. 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. 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, I compiled a summary of all my research during the summer in a document which lists the details, process of statistical data analysis and photographs of the experimental setup. This was made so that when writing future publications, there will be a record of the methods and data we collected. 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 myself and my team developed a functional prototype tool to be used 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 understand the current limitations within the novel field of endoscopic ear surgery. The survey will be sent to otolaryngologists, specifically those specializing in ear surgery, who are current members of any international Otological Society. The aim of this study is 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. This survey will follow a two-round Delphi method and the results, after statistical analysis, will be disseminated in an otolaryngology journal. Additionally, I am in the process of submitting an REB application to conduct a series of experiments that analyze the time to complete various surgical manoeuvres in endoscopic ear surgery. This application will be submitted within the coming months. The study will quantify the current limitations and inefficiencies of endoscopic ear surgery instrumentation by measuring the duration of surgical steps. This study’s publication will present data where the time to complete the steps of ear drum reconstruction surgery was measured. The procedure will by completed 50 times 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, which will be the next steps of the Master’s project.

[1] A Wrist for Needle-Sized Surgical Robots

[2] IROS paper

~~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 attitude and a 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. 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 working as a teaching assistant for the Engineering Science Capstone course. I chose to apply for this position because I want to inspire future students to pursue their interests like I have done. So far in this fall semester, I have delivered a lecture on how to succeed in the course and spoke about my positive experience. My role as a teaching assistant is to provide technical support during the student labs and to train the students 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.

Upon completion of my undergraduate degree in Engineering Science, Biomedical Systems Option, I saw potential for improvement in the curriculum regarding the mandatory biomedical engineering course we took in second year. The course focused on only one branch of the vast field of biomedical engineering and did not give a wholistic view to the students about the field. I approached the curriculum coordinator at IBBME and gave her an informal curriculum overview on what I think the course should cover, based on what I learned during my third and fourth year. I want the course to encompass the four streams of biomedical engineering that are emphasized at IBBME and focus more on reading research papers rather than a textbook, which is what I do now as a biomedical engineering graduate student.

During my time as a research student at CIGITI, I developed many technical skills including CNC mill machining, computer aided design (CAD) and 3D printing and integrating all these skills to create prototypes. There were many summer students in the lab as well 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 lost or unable to ask a question. I offered to help these students, as a mentor, when they required technical help with CAD or prototyping using the 3D printer. I also taught a few students how to use the CNC mill machine and helped them fabricate simple prototypes. I had an approachable demeanor and it I use it now during my role now as a Capstone Teaching Assistant.

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:*To conduct a needs assessment survey, using the two-round Delphi method, that examines the current limitations of TEES. The study aims to identify the technical problems that need to be addressed in order to encourage more surgeons to train in and employ TEES. A list of questions will be formulated from a literature review and using focused interviews with local otolaryngologists’. The generated survey will then be sent to otolaryngologists globally. The results will be published to establish the requirements to enable the 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 the 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, 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 instrument design. 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:*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. With increased adoption there will be a reduction in patient morbidity rates and a reduction in recovery time and hospital stay. 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 this space [7].

Further, the design techniques and the instruments created from this project 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, it could be envisaged that the techniques developed in this project could be used to create patient specific instruments. Specifically, using the virtual patient models and rapid prototyping 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 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 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.