My name is Arushri Swarup and I am a Master’s in Applied Science (MASc.) student at the Institute for Biomaterials and Biomedical Engineering (IBBME) at the University of Toronto. I started my MASc. in September, 2016. I am supervised by Dr. Adrian James, Otolaryngologist at SickKids and

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 at SickKids. I assisted an MD PhD. student to perform experiments on robotic wrist joints. I mill machined 8 different geometries of the joints using a CNC mill machine out of Nitinol Tubes. 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. These tubes were tested using a force sensor to apply a load to the tip of the joint and laser to measure its displacement. The image of each experimental data point was captured via a stereo calibrated camera system and analyzed using matlab to determine the radius of curvature and displacement. This experiment measured the experimental relationship between radius of curvature, tip displacement and 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 [2].

I also used the same experimental setup to collect data for tube radius of curvature vs. force and analyzed the data to measure radius of curvature and calculate bending angle for a magazine article in IEEE Robotics and Automation Magazine called Continuum Joints for the Da Vinci Research Kit, which is currently under review. I made the figures and calculated bending angle of the joint using the data collected.

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.

[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 University of Toronto where I teach a class once per week. I decided to teach the class due to my love of dance and my eagerness to share this type of dance with people who have never experienced it before. When I took a dance class at Hart House, a gym at U of T, I instantly wanted to teach my own class Bollywood as well. I had a vision, and took initiative, and approached the management of the gym with my idea. They were enthusiastic and set up a trial drop in dance class for me. I taught combos to class sizes ranging from 4-50 people weekly. I now teach a registered dance class at the gym. Setting up this dance class required me to take initiate and perservere until the dance class was ready to go.

I am also a teaching assistant for a Capstone Engineering Design class at the University of Toronto. I took this course in the fall of 2015 and that is what inspired my Master’s project. This class pairs student teams with a client from the biomedical field. My team was paired with Dr. Adrian James at SickKids and he proposed this project, about designing tools to facilitate endoscopic ear surgery. After meeting with Dr. James at SickKids, my team and I watched him operate to gain a sense of the technical challenges he faces in the operating room. The biomedical engineering portion of this project is to translate these challenges into an engineering problem, for which a solution is designed which needs to be translated to be used in a clinical OR setting. As soon as I saw the first endoscopic ear surgery, I realized this and knew that I wanted to be a part of this project to succeed and go beyond a one-semester student project. This project would requires more time and effort than two months of student work, I put a lot of time into this project, and attended every meeting with Dr. James and saw as many surgeries as possible. I then collaborated with my team and we designed a prototype using Solidworks. I got it 3D printed and we tested the tool for functionality at the clinic with Dr. James. He told us the limitations of the prototype and we went back to the drawing board to fix it. He also connected us with CIGITI, where we could fabricate the tool using Nitinol. I then went to CIGITI and helped mill machine a part of the tool, which was then assembled with the rest of the parts to develop a phase I functional prototype.

I really enjoyed this course, as it teaches students how to design a solution from the client’s perspective and yields a functional prototype at the end. This allows students to experience the design cycle first-hand and face the challenges that engineers face daily. It also teaches the student how to interact with the client and how to translate clinical needs to the field of engiereing. It encourages multi-disciplinary collaboration which results in better solutions for the problem at hand. I then approached Dr. James, with my vision for continuing to work on the project and and he agreed to be my supervisor. Since November, 2015 we have been applying for grants to fund the project, alongside being a full time student because we both believe in the goal of the project.

I never thought that this would happen and I was amazed when I finally got a position in this lab. This course offered me a project and that formulated my career goals in academia, and instrument design for clinical and surgical use. I want to inspire more studnets to follow their dreams and find projects that really interest them and make them a reality. Thus, I decided to apply for a teaching assistant position for this course, to share my experience with them and to help them with their career path. Even though I am only one year older than them, I have experienced their position very recently and know their daily struggles and I hope to help and advise where I can on how to achieve things.

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 middle ear surgery, the middle ear can be accessed through the ear canal without an external incision [2, 3]. 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 [2]. 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 [3]. 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 [3, 4]. 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 graft replacement 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 resident and staff surgeons will test the tool on cadaveric or 3D printed ear models by performing an ear drum replacement procedure. 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 [5-7]. 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 expected outcomes from the needs analysis survey will be that surgeons find that with endoscopic ear surgery, one handed surgery and maintenance of a clean operating field are the major challenges. 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.

**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 showns to reduce rates of residual skin growth after skin growth removal surgery in the middle ear as the endoscope allows greater visualization into the previously hidden recesses within the middle ear [8].

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

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

[3] 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.

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

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

[6] “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].

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

[8] 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 of Biomaterial and Biomedical Engineering (IBBME). The labs have been successfully used

by the investigators to develop a functional initial prototype. CIGITI will provide bench space, technical support and

machines to manufacture medical device prototypes. The IBBME will provide office space and computer software to design

instruments. 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

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.