Minimally Invasive Surgery in the Middle Ear: an OCT-guided micro-robotic system to efficiently remove cholesteatoma

**Consortium**

FEMTO-ST Institute, Université de Franche-Comté, Besançon (FR)
Nicolas Andreff (Professor, UFC), Brahim Tamadazte (CR, CNRS)

ARTORG Center for Biomedical Engineering, University of Bern (CH)
Stefan Weber (Professor)

CHU Jean Minjoz, ORL Department, Besançon (FR)
Laurent Tavernier (Professor, UFC/CHU)

**Context (Medical needs)**

Cholesteatoma is a skin growth that occurs in an abnormal location. It is usually due to repeated infection. It was estimated that one new case per 10,000 citizens occur each year.

Over the time, cholesteatoma expands in the middle ear, filling in the empty cavity around the ossicles and then eroding the bones themselves (ossicles, mastoid).

Cholesteatoma is often infected and results in chronically draining ears. It also results in hearing losses and may even spread through the base of the skull into the brain.

Surgery is the only known treatment to remove the growth. It is performed under general anaesthesia in most cases and must preserve as much as possible the normal functions of the ear. Because of the delicate structure of the ossicle, such a surgery is performed under microscope.

Due to the anatomical constraints, the usual procedures split into two categories: closed-wall and open-wall techniques. In the closed-wall techniques, the bone wall of
the external auditory canal (mastoid) is kept untouched and surgery is done below the ear drum. However, such techniques, by lack of appropriate tools, cannot access the entire epitympanum cavity where cholesteatoma develops, which means residual disease and repeated operations.

Alternately, open-wall surgery (mastoidectomy) destroys the bone to allow for complete access to the cavity and full removal of the cholesteatoma. However, it may result in an increased risk of infection and recurrence of a deeper cholesteatoma by the exposure of the ossicle. It is thus reserved to severe or recurring cases.

Therefore, there is a real need for a system able to access the epitympanum cavity, with high accuracy and dexterity and without bone effraction.

**Objectives Description of the Swiss Partner**

The ARTORG Center for Biomedical Engineering at the University of Bern has been active in the field of computer assisted surgery and biomechanics research since 1993 with a focus on the transfer of novel technology into clinical routine. The ARTORG Center was established in 2008 to more effectively continue research improvements in engineering, medicine, and its main focus area of Image-guided Therapy (IGT) to strengthen its specific research in the IGS field. The center is closely linked to the Inselspital, University Hospital Bern. Specifically, the department of ENT Surgery is one of the early adopters of computer assisted and image-guided procedures around the head. Early work in the field dates back to 1995, when some of the first of such interventions were carried out. Today, the department’s research focuses on the advancement of IGS technologies towards novel indications and a combination with the latest developments in hearing aid technology and physiological measurements. The department is extensively involved in ongoing research projects both on a national as well as on an international level.

During the last six years, the ARTORG Center of the University of Bern together with the Department of ENT Surgery Inselspital Bern has investigated the feasibility and clinical implications of stereotactic and robotics assisted microsurgery to support minimally invasive cochlear implantation. It is believed, that outpatient and non-traumatic CI implantation will allow affordable treatments for a larger number of
patients worldwide in the future. Additionally, on a long term scale a surgical approach, drastically reduced in invasiveness will corroborate the development of smaller and simpler hearing implants. This work resulted in the development of a image-guided robot system, which has a documented drilling accuracy of 0.15±0.08 mm in 2013\textsuperscript{1}. Next to the development of an image-guided microsurgical approach, current research addresses additional measures to cope with the safety requirements of this minimally invasive approach. Such measures include the investigation of holistic computer-based surgery planning incorporating anatomical, functional and physiological information\textsuperscript{2}, the introduction of Neuromonitoring\textsuperscript{3} and tool pose estimation in inhomogeneous bone\textsuperscript{4} as well as in CI electrode implantation efficacy\textsuperscript{5}.

**Local Context**

It will be hosted by the MiNaRoB (Micro-/Nano-Robotique Biomédicale) group of the AS2M department at FEMTO-ST. This group was recently founded (Jan. 2012) and is composed of 1 Professor (UFC/UFR-ST/GAP), 1 Research Director (CNRS), 1 MCF-HDR (UFC/UFR-ST/GAP), 2 MCF (UFC/UFR-ST/GAP and ENSMM), 2 Research Fellows (CNRS).

One of the long term research tracks at MiNaRoB is intracorporeal microrobotics. In this track, MiNaRoB is involved in the **FP7 µRALP project** (Scientific Co-Coordinator: N. Andreff) dedicated to micro-robot-assisted surgery in the larynx, together with the ORL department at CHUB (L. Tavernier). MiNaRoB is also involved in the **LABEX ACTION** through the **Demonstrator 4** (Coordinator: N. Andreff) dedicated to the development of an active OCT endomicroscope for digestive surgery. MiNaRoB also participates to **Biom’@x**, the transversal action on biomedical engineering at FEMTO-ST as well as to the discussions on the creation of a **joint research platform on surgical microrobotics** in Besançon, involving (among others) the ORL department of CHUB.

In line with the PhD proposal, MiNaRoB has a long track record in image-guided robotics\textsuperscript{6} (especially using sequential acquisition cameras\textsuperscript{7}) and control of robots

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\textsuperscript{7} Dahmouche, R. Andreff, N., Mezouar, Y Ait-Aider, O., Martinet, P., Visual servoing from sequential regions of interest acquisition, International Journal of Robotics Research, 31, 520-537,
with complex kinematics\textsuperscript{8}. It also has an excellent track-record in image-guided microrobotics\textsuperscript{9}, intracorporeal microrobot design\textsuperscript{10} as well as in position/force control at standard\textsuperscript{11} and micro-scale\textsuperscript{12}.

The proposed PhD comes as a follow-up work of the µRALP project with a new challenge in terms of scale and dexterity: from the throat to the ear. It comes also as a complement to the LABEX ACTION – Demo4 by the shared exploitation of OCT signal in the control of microrobots (1 PhD on the basics of OCT-based control and a Région Franche-Comté project, under review, for the acquisition of a fiber-based OCT system). It could also be complemented by a BQR Bourgogne-Franche-Comté on imaging (fluorescence and OCT) of the cholesteatoma, recently submitted by LE2I and FEMTO-ST/Optique.

**Objectives**

The objectives of this PhD thesis is to propose a novel robotic system that will accurately and efficiently remove the cholesteatoma from the middle ear, especially in the area located behind the mastoid bone (epitympanum cavity) which is unreachable without effraction. The proposed system will travel through the ear canal, enter the middle ear by a small incision below the ear drum and have enough mobility to access the upper cavity of the middle ear. It will be equipped with a recent imaging modality (fiber-based optical coherence tomography) which allows performing preoperative optical biopsies. It will be guided by the images and incorporate recent micro-robotic technologies.

**Application**

The candidate must demonstrate certain personal and interpersonal skills: scientific curiosity, methodology, autonomy, discipline and communication skills and initiative.

Interested candidates should send a CV, a cover letter, transcript M2 and the

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\textsuperscript{10} M. T. Chikhaoui, K. Rabenorosoa, and N. Andreff, Geometric model of an EAP actuated continuum robot for active micro-endoscopy, accepted in Advances in Robots Kinematics, Ljubljana, Slovenia, 2014


The thesis starts in October 1st, 2014.