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ARTORG CENTER
BIOMEDICAL ENGINEERING RESEARCH
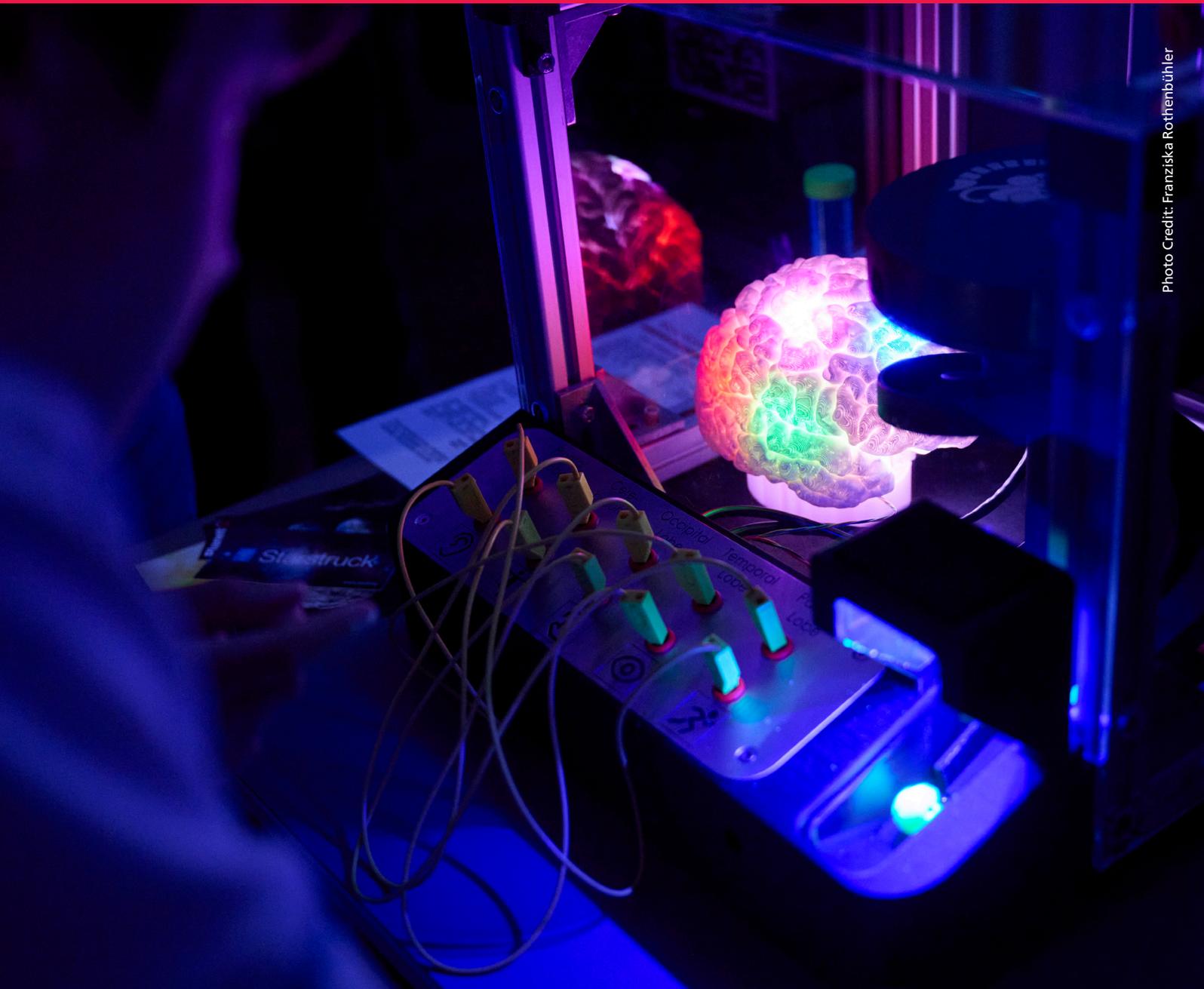
ARTORG CENTER
ANNUAL REPORT 2025

Photo Credit: Franziska Rothenbühler

Top 10 Highlights of 2025

1. UniBE INNO Grant for DextEgg project. Nic Krummenacher, PhD student with the Gerontechnology and Rehabilitation Group (GER), received the INNO Grant for the DextEgg project—a new, interactive, sensor-based rehabilitation system to train fine motor skills in clinic and at home. Due to lack of resources in clinics, patients are often tasked with at home training, which is frequently found to be monotonous and dull, and then abandoned or poorly implemented. DextEgg aims to make rehabilitation of fine motor skills more efficient, practical and exciting—the software tied to DextEgg is not merely for therapists to analyze the data and manage their patients' training plans, it also serves as an innovative, fun way for patients to engage in their rehabilitation training without dull, repetitive tasks. With the UniBE INNO Grant, Nic plans to develop the existing proof-of-concept prototype hardware further and get DextEgg production-ready for certification and manufacturing.
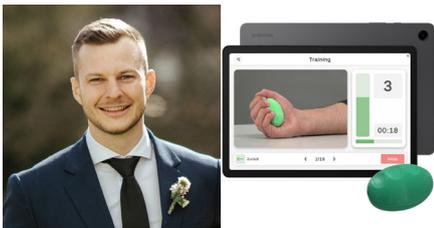
Nic Krummenacher and his DextEgg project

2. Two Venture Fellowships for ARTORG. The fourth cohort of the Venture Fellowship program at the University of Bern and the Inselspital were chosen— among them, two of ARTORG's own. Dr. Samuel Knobel, researcher with the Gerontechnology and Rehabilitation Group (GER), and Dr. Amith J. Kamath, researcher with the Medical Image Analysis Group (MIA), are two of five recipients of the fellowship. Samuel Knobel is concerned with the deterioration of fine motor skills. The fellowship allows him to further develop the software of DextEgg—a collaborative project with UniBE INNO Grant recipient Nic Krummenacher. Amith J. Kamath's project ContourAid aims to revolutionize radiotherapy by

streamlining the treatment planning process with AI. With the fellowship he can focus on ContourAid full-time and continue in his development process to eventually bring this tool to market.

Venture Fellows Amith J. Kamath (left) and Samuel Knobel (right)

3. As part of ARTORG's effort to foster diversity and create equal opportunities, a German Language beginners course was established, as well as a Care Grant. The German language course started its second year in Spring 2025 and added an A2 to the existing A1 course, due to the continued interest of international ARTORG members and even the greater community surrounding the Center. Following the great success of the language courses, a Care Grant was established to tackle another hurdle researchers frequently encounter in their work life: balancing care duties and an academic career. With the ARTORG Care Grant, our members can request financial support and make sure their care duties are covered even when they have to work outside of their regular schedule.

4. On Saturday, September 06, the ARTORG Center participated in the fifth "Nacht der Forschung" research night. Roughly 800 researchers presented their work on more than 80 projects throughout the night. An estimated 10,000 visitors found their way to the Grosse Schanze, where they could learn about the various research conducted at the University of Bern through presentations, games, and entertainment. Our research groups presented ARTORG's various research fields through interactive activities, where visitors could play games, collect

stickers, and win a prize. Throughout the night, visitors could also witness live surgery, test their strength and assemble a key chain. Venture Fellow Cornel Dillinger, member of the Urogenital Engineering Group (UGE), also participated in the Innovation Office's "Die Höhle der Bären," where he presented his research project to the audience.

5. Prof. Dr. Tobias Nef, head of the Gerontechnology and Rehabilitation Group (GER), co-leads the Innosuisse Flagship Initiative "SwissBrAInHealth" with Prof. Dr. Bogdan Draganski from the Department of Neurology, Brain Health Clinic at Inselspital. This project is one of four Innosuisse Flagship Initiatives Bernese researchers are involved in. It aims to develop and evaluate a so-called "Augmented Intelligence System" to individually reduce the risk of dementia in people with subjective cognitive complaints. Designed to run for 5 years, the project has 5 academic partners, 12 industrial partners, and was awarded a total of 9.6 million Swiss francs.

SwissBrAInHealth Project co-leads Bogdan Draganski (left) and Tobias Nef (right)

6. TightValve wins VentureKick's Stage 2 financial support. A spin-off venture of our Cardiovascular Engineering Group (CVE), TightValve was one of three start-ups selected in October for VentureKick's second financial and entrepreneurial support stage, receiving CHF 40,000 in funding to bring their device to hospitals and patients. They had already received the Stage 1 support of CHF 10,000 earlier in the year. As winners of Stage 2, they entered the draw for the third stage support of CHF 100,000 and are also eligible for the InnoBooster grant of CHF 150,000, ➜

→ funded by the Gebert Rüf Stiftung. We cross our fingers for TightValve in the 3rd stage, which is expected to be announced in Spring 2026.

TightValve – Silje Ekroll Jahren, Lukas Glaus, Emmanuel Zimmer and Dominik Obrist

7. Exciting business news for ARTORG. In January, Neosoma Inc. incorporated a wholly-owned Swiss subsidiary in Bern. Neosoma, developer of a software medical device platform to help advance brain cancer care and clinical trials, established a close research and development collaboration with the University of Bern in 2019, centered around a long-term licensing agreement leveraging deep learning technology developed at the ARTORG Center. Incorporating a Neosoma subsidiary in Bern allows this research collaboration to deepen even further. Alongside Neosoma's CEO Ken Kolodziej, Prof. Dr. Mauricio Reyes, head of ARTORG's Medical Image Analysis Laboratory (MIA), serves as Director of Neosoma GmbH. In October, RetinAI AG was acquired by EssilorLuxottica S.A., a global leader in vision care and optical innovation. RetinAI is a spin-off founded at the ARTORG Center. This transaction marks the first major commercial exit of an ARTORG origin start-up and the first ever acquisition and exit of a University of Bern MedTech spin-off to a global industry leader. This exit validates the ARTORG translational pipeline model, which combines engineering excellence, clinical collaboration and entrepreneurial partnership.

Neosoma GmbH Team (left to right): Daniel Aebersold, Ken Kolodziej and Mauricio Reyes

8. The ARTORG Center expands! This year, two new research groups joined the ARTORG community. In March, we welcomed Prof. Dr. Brice-Olivier Demory, Director of the Center for Space and Habitability (CSH) at the University of Bern, whose research group Medical Sensing Laboratory (MSL) develops novel imaging modalities focusing on real-time, non-invasive diagnostics used for tissue medicine, pathology and surgery. In November, we also welcomed Prof. Daniel Ahmed and his research group Acoustic Robotics Systems Lab (ARSL), previously housed at ETH Zurich. The group is engaged in developing innovative, cutting-edge research in micro- and nanorobotics and systems for life science applications, diagnostics, and translational medicine.

New group heads Brice-Olivier Demory (left) and Daniel Ahmed (right)

9. This year, the ARTORG Center was recipient of various competitive grants. In June, Prof. Dr. Mauricio Reyes, head of our Medical Image Analysis Laboratory (MIA), and his colleagues from Poland, Romania and Bulgaria received the highly competitive SNSF MAPS fund for their AI-based Brain Metastases Tracking and Segmentation project "A-BEACON." The Multilateral Academic Projects (MAPS) fund supports collaborative research projects between researchers in Switzerland and Eastern European countries. A-BEACON is an ambitious project tackling the unmet clinical need for more efficient, accurate, and reliable methods to assist clinicians in diagnosing and monitoring brain tumors. The project was awarded 1,019,505 Swiss francs for the duration of four years. In October, ARTORG also received three SNSF Spark Grants, a fund for the rapid testing or development of novel and unconventional scientific endeavors. Philipp Aebischer, head of the Hearing Research Laboratory (HRL), received CHF 99,999 for his project "Sonifying Tinnitus from EEG Signals"; Matteo Frigelli, research fellow with the Computational Bioengineering Group (CBE), received CHF 100,000 for his project "Through a New Lens: Injectable Stroma for Vision Correction"; and Tatiana Kochetkova, Postdoc with the Musculoskeletal Biomechanics Group (MSB), received CHF 99,500 for her project "Reinforcing Articular Cartilage: A Novel Approach Using Riboflavin-Induced Crosslinking."

SNSF funding recipients Reyes (t.l.), Aebischer (t.r.), Frigelli (b.l.) and Kochetkova (b.r.)

10. SNSF BRIDGE Grants for four ARTORG members. In Autumn, BRIDGE awarded our Center with three grants: Philippe Büchler, head of the Computational Bioengineering Group (CBE), received a BRIDGE Discovery grant of CHF 2,069,632 for his project "Patient-specific hydrogel-based corneal augmentation for vision restoration"; Raphael Sznitman, ARTORG's director and head of the AI in Medical Imaging Laboratory (AIMI), received a BRIDGE Discovery grant of CHF 1,201,642 for his project "PolAInsight: Cancer detection in biopsy tissue with AI-based automated Mueller Matrix polarimetry"; and Negin Ghamsarian, member of the AIMI Laboratory, was awarded a BRIDGE Proof-of-Concept grant of CHF 129,750 for her project "SurgExplore: AI-Powered Surgical Training, Reporting, and Discovery." Following this funding hat-trick in Autumn, the SNSF awarded another BRIDGE Proof-of-Concept grant in December to Matteo Frigelli, research fellow with the Computational Bioengineering Group (CBE) for his project "ReShape: New Frontiers in Corneal Cross-Linking." He received CHF 129,625 in funding. With this year's additions, BRIDGE has awarded ARTORG a total of 5 Discovery and 4 Proof-of-Concept grants.

SNSF BRIDGE grant recipients Sznitman (t.l.), Büchler, (t.r.), Ghamsarian (b.l.) and Frigelli (b.r.)

Foreword

Dear friends, colleagues, collaborators, and partners,

2025 has been a year that redefined ambition and reaffirmed ARTORG's role as a cornerstone of biomedical engineering excellence. Building upon a foundation of translational research, innovation, and interdisciplinary collaboration, the ARTORG Center continues to shape the future of healthcare technology—one project, one partnership, and one discovery at a time.

Our collective achievements this year underscore the Center's long-term commitment to advancing medical innovation that is both rigorous and relevant. ARTORG researchers secured multiple competitive grants, including UniBE INNO, SNSF MAPS, three highly competitive SNSF Spark grants promoting junior researchers, and four SNSF BRIDGE awards, underscoring our strength in attracting national and international recognition for pioneering ideas. These successes not only sustain our research ecosystem but also drive the next generation of medical technology toward clinical translation.

Entrepreneurial excellence also flourished in 2025: from the incorporation of Neosoma GmbH to TightValve's progression through multiple VentureKick stages, ARTORG-supported startups continue to transform visionary research into viable healthcare solutions. The acquisition of RetinAI AG by EssilorLuxottica stands as a powerful testament to ARTORG's long-term impact on industry and patient care alike.

This year also marked the deepening of our academic and public engagement. Events such as Spirit of Bern, BME Day, and the Zuppinger Symposium showcased our community's scientific vitality and openness to dialogue. The continued success of initiatives like the Diversity in AI for Medicine and Care Grant reflect our enduring commitment to inclusion, mentorship, and responsible innovation. We also welcomed the arrival of Prof. Brice-Olivier Demory as one of ARTORG's professors, leader of the new Medical Sensing Laboratory, and aiming to build the next generation of sensing technology to improve patient care.

Each milestone in 2025—be it a fellowship, a grant, or a collaboration—embodies ARTORG's central ethos: to translate research into tangible benefit for patients and society. Our researchers' work, spanning AI-supported diagnostics, advanced imaging, and precision interventions, exemplifies how engineering science and medicine can converge to deliver meaningful change.

As we look ahead, we do so with gratitude for the dedication of our teams, the trust of our partners, and the support of our broader community. Together, we continue to advance the ARTORG mission: empowering discovery, enabling translation, and engineering better health for all.

Sincerely,

Raphael Sznitman
ARTORG Director

Groups

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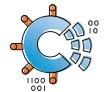**AIHN**
Artificial Intelligence in Health and Nutrition

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AIMI
Artificial Intelligence in Medical Imaging

↓
CVE
Cardiovascular Engineering

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CBE
Computational Bioengineering

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GER
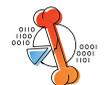Gerontechnology and Rehabilitation

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HRL
Hearing Research Laboratory

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MIA
Medical Image Analysis

↓
MSL
Medical Sensing Laboratory

↓
MSB
Musculoskeletal Biomechanics

↓
NRG
Neuro Robotics Group

↓
OOC
Organs-on-Chip Technologies

↓
UGE
Urogenital Engineering

↓
MDP
Mechanical Design and Production

Master of Science
Artificial Intelligence in Medicine

Master of Science
Biomedical Engineering

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www.bme.master.unibe.ch

Artificial Intelligence in Health and Nutrition

Stavroula Mougiakakou, Head of Research Laboratory
E-mail: stavroula.mougiakakou@unibe.ch
Phone: +41 31 684 14 89

Research Partners
Prof. Claudio Bassetti, Dept. of Neurology, Inselspital Bern
Prof. Aristomenis Exadaktylos, Dept. of Emergency Medicine, Inselspital Bern
Prof. Thomas Geiser, Dept. of Pneumology, Inselspital Bern
Prof. Johannes Heverhagen, Dept. of Diagnostic, Interventional and Paediatric
    Radiology, Inselspital Bern

Stavroula Mougiakakou

Lubnaa Abdur Rahman

Lorenzo Brigato

Ethan Dack

Vasileios Dedousis

Rafael Morand

Maria Panagiotou

Ioannis Papathanail

Rooholla Poursoleymani

Knut Joar Strømmen

Rachel Michelle Robles

Research Profile

The Artificial Intelligence in Health and Nutrition (AIHN) laboratory focuses primarily on the interface between machine learning, artificial intelligence (AI), and their application for improving health. The laboratory develops innovation to translate "data into knowledge" and "research into practice." Our ongoing research activities are:

- dietary monitoring, assessment and management
- causal modeling of lifestyle, genetic, and environmental risk factors for obesity
- diabetes self-management and treatment optimization
- diagnosis, prognosis and management of acute and chronic lung diseases
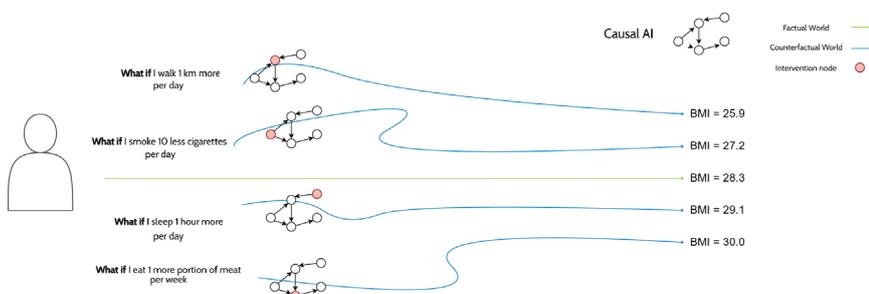- diagnosis for emergency medicine

Fig. 1: Conceptual overview of a counterfactual analysis framework illustrating "what-if" intervention scenarios within a causal model of obesity.
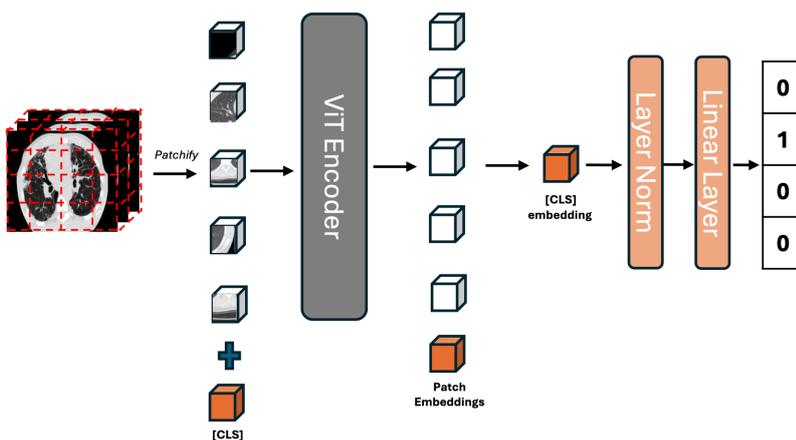

Fig. 2: Finetuning strategy for ILD diagnosis. The class token ([CLS]) is added to the patchified input and passed through the encoder.

Dietary Monitoring, Assessment and Management

Maintaining a healthy diet is vital for preventing and managing conditions like malnutrition, cardiovascular diseases, diabetes, and obesity. Traditional dietary assessment methods, while common, are often time-consuming, costly, and prone to error due to reliance on self-reported memory. To overcome these challenges and streamline the process, image-based automatic dietary assessment systems have been developed, leveraging advancements in AI and computer vision. However, current automatic dietary assessment systems are restricted by visual information only – they do not cater, for example, to contextual information, nor do they provide an interactive space for providing personalized nutrition recommendations adapted for user preferences.

To address these limitations, we introduce the Swiss Food Knowledge Graph, a comprehensive resource uniting recipes, ingredients, substitutions, allergens, and national nutrition guidelines. We propose a semi-automatic data enrichment pipeline to populate the graph using Large Language Models, with benchmarks showing that LLMs can effectively augment nutritional knowledge. Finally, we implement a Graph-Retrieval Augmented Generation system that leverages the enriched graph to provide context-aware, interactive nutrition recommendations, achieving up to 80% accuracy over 50 user queries, demonstrating its potential for personalized dietary guidance.

Causal AI for Personalized Obesity Intervention

Obesity is a complex, chronic condition driven by interactions between genetic, →
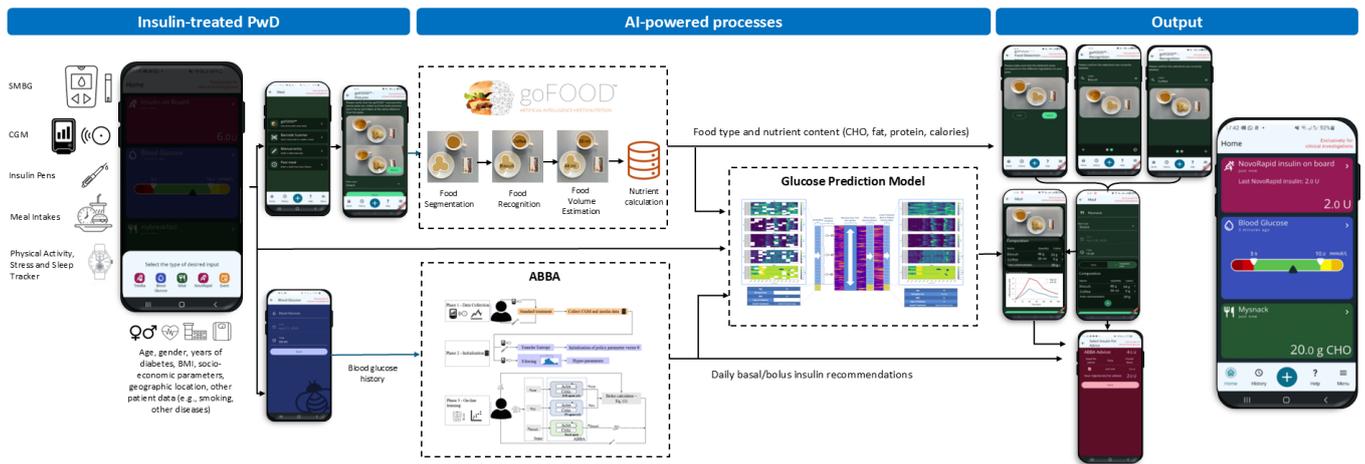
Fig. 3: Overview of the MELISSA trial technological pipeline via the mobile app, integrating AI-based methods for the insulin recommendations.

behavioral, and environmental factors, and it continues to pose major health risks worldwide. The AIHN Lab is leading the BETTER4U project in developing a privacy-preserving causal AI framework designed to move beyond simple correlations and uncover the true cause-and-effect relationships. Unlike traditional AI models, which often identify patterns without explaining why they occur, our causal approach can answer interventional questions such as "What would happen to a person's weight if they increased physical activity, improved diet, or changed sleep habits?" (Fig. 1).

This enables the creation of personalized, evidence-based strategies for preventing weight gain and supporting long-term health. To ensure privacy across partner sites, the project uses Federated Learning (FL), where local model updates are shared with a central server. This approach allows robust and generalizable learning across heterogeneous datasets without exposing sensitive individual data. The pipeline combines federated data imputation, causal discovery guided by expert knowledge, and the construction of a Structural Causal Model (SCM), which estimates the effect of risk factors and supports tailored intervention recommendations for each individual.

Diabetes Management and Personalized Insulin Treatment

Treating type 1 diabetes and some cases of type 2 diabetes requires the infusion of exogenous insulin. An innovative algorithm has been developed by the AIHN laboratory and allows daily adjustment of the insulin treatment based on fluctuations in the person's glucose and lifestyle-related information. Specifically, data from glucose monitoring devices (self-monitoring of blood glucose or continuous glucose monitors) and lifestyle (food intake) trackers provide input to the algorithm, which outputs basal daily insulin and boluses for the case of pump or insulin pens users. The algorithm is based on reinforcement learning (RL), and continuously learns from real-time data, avoiding biases associated with pre-training datasets. The approach is data-driven, real-time, and of low computational cost.

The algorithm was first evaluated in silico and, based on these results, a monocentric, crossover feasibility study involving 15 participants was conducted as a two-phase trial over four weeks. ABBA demonstrated promise as a safe and user-friendly RL-based advisor capable of personalizing insulin therapy and supporting glycemic management in MDI-treated diabetes. Although short-term improvements were modest, they are consistent with the adaptive nature of RL systems, which improve progressively over time. Together with encouraging in silico results, these findings strongly support further evaluation of ABBA in larger and longer-term trials. Consequently, a multicenter clinical trial, MELISSA, involving 492 insulin-treated people with diabetes has been initiated (Fig. 3).

Multimodal Data Analysis for Diagnosis & Disease Prediction of ILDs

Interstitial Lung Diseases (ILD) are a heterogeneous group of more than 200 chronic, overlapping lung disorders, characterized by fibrosis and/or inflammation of lung tissue. We investigate AI- and CV-based algorithms on high-resolution computed tomography images (HRCT) for the diagnosis and management of ILDs (Fig. 2). More specifically, we further strengthened these methods by incorporating self-supervised and foundation-model approaches, including masked autoencoder-based feature learning, and by examining sources of dataset bias to improve model robustness across clinical settings. The image analysis results, along with the additional disease-related information, are further analyzed not only to support faster diagnosis but also for more efficient disease management in terms of treatment selection and disease progression.

In parallel, we expanded our efforts toward multimodal disease characterization, integrating imaging, clinical information, and biomarker data to better differentiate inflammatory and fibrotic manifestations of ILD and to support treatment-relevant phenotyping. Additional work focused on acute lung disease, where we are investigating whether combining lung ultrasound, chest X-ray, and CT can improve diagnostic accuracy in complex cases. Using this multimodal dataset, we are developing deep learning methods for harmonizing heterogeneous imaging, learning cross-modal representations, and addressing missing-modality challenges, particularly relevant for ultrasound, where operator variability remains a limiting factor.

Selected Publications
1. Panagiotou, Maria, et al. "Personalised insulin adjustment with reinforcement learning: an in-silico validation for people with diabetes on intensive insulin treatment." IEEE Access (2025).
2. Dack, Ethan, et al. "Unmasking Interstitial Lung Diseases: Leveraging Masked Autoencoders for Diagnosis." MICCAI Workshop on Data Engineering in Medical Imaging.
3. Abdur Rahman, Lubnaa, et al. "Introducing the Swiss Food Knowledge Graph: AI for Context-Aware Nutrition Recommendation." ACM MM2025.

Artificial Intelligence in Medical Imaging

Raphael Sznitman, Head of Research Group
E-mail: raphael.sznitman@unibe.ch
Phone: +41 31 684 14 20

Research Partners
Prof. Martin Zinkernagel, Department of Ophthalmology, Inselspital Bern
Prof. Brice-Olivier Demory, Center for Space and Habitability, University of Bern
Prof. Aurel Perren, Institute of Tissue Medicine and Pathology, University of Bern
Prof. Daniel Candinas, Department Visceral Surgery and Medicine, Inselspital Bern
Prof. Adrian Hüber, Department of Diagnostic, Interventional and Pediatric
   Radiology, Inselspital Bern

Raphael Sznitman	Daniël Nobbe
Serge Bart	Newton Ollengo
Nika Celan	Dishan Otieno
Marta Colmenar Herrera	Tea Pula
Pablo Márquez-Neila	Paulo Sampaio
Veronica Mieites	Davide Scandella
Julia Milla Ortuño	Moritz Schmidt
Seyedeh Mirzargar	Aoto Soeda
Jeremy Ngao	Sofia Villar
Tina Nguyen	

Research Profile

The Artificial Intelligence in Medical Imaging (AIMI) lab is focused on designing novel machine learning and computer vision methods to solve unmet clinical needs. With a strong focus on methodology that spans basic-to-translational research, the emphasis is on engineering solutions in a holistic fashion, whereby taking into account how new approaches can be integrated in routine clinical care. As an interdisciplinary research team, the AIMI lab is involved with several research projects that involve research challenges in both diagnostic and interventional contexts.

Fig. 1: Qualitative results for six samples from the same patient. Each sample is shown as a pair: (left) annotated digital slide with ground truth label, and (right) model output with predicted segmentation mask and classification score. Cancer samples are accurately identified with high scores and localized masks, while healthy samples exhibit low predicted scores and uniform background segmentation, indicating strong intra-patient generalization.

Fig. 2: Quantitative evaluation of the multitask model across all cross-validation folds, with (MS-MMP) and without polarimetry (MS). Left: ROC and Precision-Recall (PR) curves for classification. Right: ROC and PR curves for segmentation. Shaded areas represent standard deviation across folds.

Mueller matrix polarimetry for fresh ex-vivo cancerous tissue segmentation

Pancreatic cancer, the third leading cause of cancer-related deaths, often requires complex surgery that relies on intraoperative diagnosis to assess resection margins. A common technique for this is frozen section (FS), in which a biopsy sample is snap-frozen, sectioned, stained, and evaluated by an expert pathologist. However, FS takes 20-30 minutes, and its accuracy is hindered by artifacts generated in the process.

In this context, widefield Mueller Matrix Polarimetry (MMP) imaging represents an advantageous and robust alternative. This study evaluates the usability of MMP to aid in assessing resection margins by segmenting the surface of freshly resected pancreatic tissue in cancer and non-cancer regions. We imaged 56 fresh pancreatic samples from 19 patients with a custom-built 16-wavelength Mueller matrix imaging polarimeter. Hematoxylin and eosin (H$\&$E) stained slides of these samples were used as ground truth to train a deep-learning binary segmentation model to detect the presence of cancer tissue surface from the MMP imager. Our pixel-wise segmentation model reached an AUC of 94 ± 5, clearly delineating cancer regions across different patients. Moreover, the end-to-end time for imaging a sample and generating a prediction is approximately 55 seconds, significantly shorter than the 20-30 minutes commonly required for RFS. These findings indicate that MMP-based segmentation has a strong potential as an intraoperative diagnosis alternative.
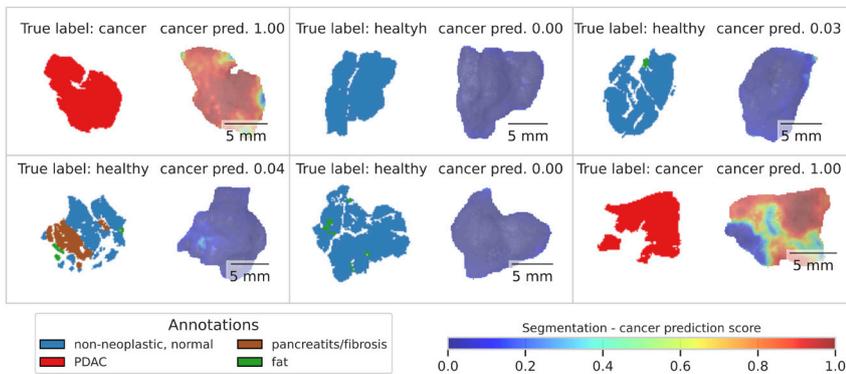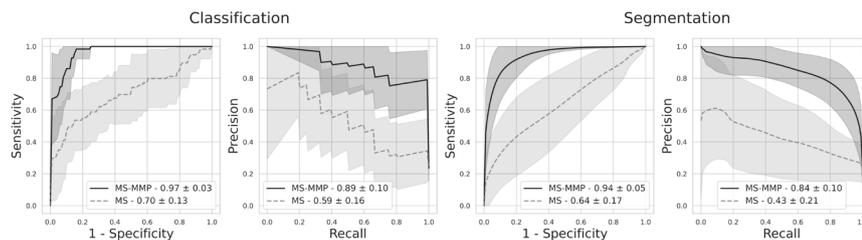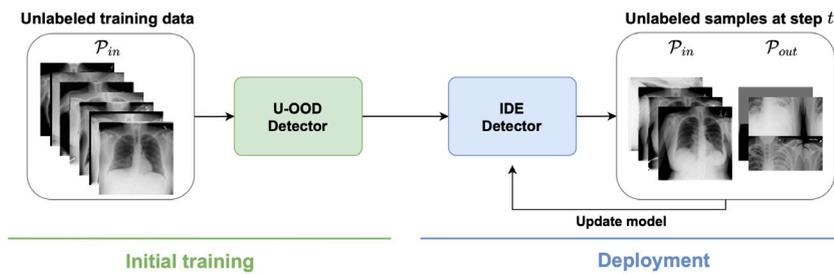
Fig. 3: Iterative deployment exposure. The initial detector, trained on unlabeled ID data, is iteratively refined with unlabeled deployment samples.

→ Iterative Deployment Exposure for Unsupervised Out-of-Distribution Detection

Deep learning models are vulnerable to performance degradation when encountering out-of-distribution (OOD) images, potentially leading to misdiagnoses and compromised patient care. These shortcomings have led to great interest in the field of OOD detection. Existing unsupervised OOD (U-OOD) detection methods typically assume that OOD samples originate from an unconcentrated distribution complementary to the training distribution, neglecting the reality that deployed models passively accumulate task-specific OOD samples over time. To better reflect this real-world scenario, we introduce Iterative Deployment Exposure (IDE), a novel and more realistic setting for U-OOD detection. We propose CSO, a method for IDE that starts from a U-OOD detector that is agnostic to the OOD distribution and slowly refines it during deployment using observed unlabeled data. CSO uses a new U-OOD scoring function that combines the Mahalanobis distance with a nearest-neighbor approach, along with a novel confidence-scaled few-shot OOD detector to effectively learn from limited OOD examples. We validate our approach on a dedicated benchmark, showing that our method greatly improves upon strong baselines on three medical imaging modalities.

SAM-DA: Decoder Adapter for Efficient Medical Domain Adaptation

This paper addresses the domain adaptation challenge for semantic segmentation in medical imaging. Despite the impressive performance of recent foundational segmentation models like SAM on natural images, they struggle with medical domain images. Beyond this, recent approaches that perform end-to-end fine-tuning of models are simply not computationally tractable.

To address this, we propose a novel SAM adapter that minimizes the number of trainable parameters while achieving comparable performances to full fine-tuning. The proposed SAM adapter is strategically placed in the mask decoder, offering excellent and broad generalization capabilities and improved segmentation across both fully supervised and test-time domain adaptation tasks. Extensive validation on four datasets showcases the adapter's efficacy, outperforming existing methods while training less than 1% of SAM's total parameters.

GEYEDANCE: An OCT-Enhanced Multi-Modal Feedback Platform for Robot-Assisted Ophthalmic Surgery

Vitreoretinal surgery includes a group of highly complex microsurgical procedures that demand precision. Robotic systems can enhance surgical performance, particularly for novice surgeons, while ensuring patient safety through advanced sensing capabilities. Optical Coherence Tomography (OCT), commonly used for eye anatomy imaging, is typically implemented via microscopes or diagnostic devices. This paper introduces the GEYEDANCE system, a bilateral teleoperated microsurgery platform integrating OCT directly at the end-effector of its remote manipulator, offering multi-modal feedback. The system enables intraoperative global eye modeling and surface reconstruction by exploiting a neural network-based tool-to-tissue distance estimation module. Its performance was validated in the operating room using ex vivo eyes, effectively simulating the surgical steps of various vitreoretinal procedures.

Fast and user-friendly multi-spectra Mueller matrix polarimeter for fresh tissue biopsy imaging

Mueller Matrix polarimetry (MMP) characterizes changes in light polarization after interacting with a medium, providing insights into tissue microstructure. Combined with multispectral (MS) imaging cameras, MS-MMP offers a novel way to quickly and safely acquire tissue surface information. Machine learning methodologies enable new diagnostic methods by automating tasks on fresh tissue biopsies, though this requires extensive and diverse data. To achieve this, we propose a user-friendly MS-MMP imager with a simple interface and fast acquisition time operated by laboratory technicians and residents. We show that our system, when operated by laboratory staff over several months, yields high-quality data in large amounts and with positive feedback of its inclusion in a clinically compliant workflow. This positive outcome is promising for such systems to be used for large data collection initiatives.
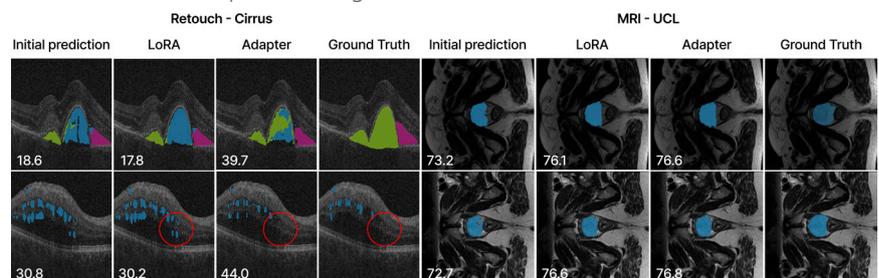

Fig. 4: Qualitative results on eight randomly selected in-domain test samples for our SAM-DA model.

Selected Publications
1. Paulo Sampaio, Davide Scandella, C.H. Lucas Patty, Pablo Márquez-Neila, Heather DiFazio, Martin Wartenberg, Federico Storni, Brice-Olivier Demory, Daniel Candinas, Aurel Perren, and Raphael Sznitman. "Mueller matrix polarimetry for fresh ex-vivo cancerous tissue segmentation," Proc. SPIE 13606, Applications of Machine Learning 2025.
2. Doorenbos, L., Sznitman, R., Márquez-Neila, P. (2026). Iterative Deployment Exposure for Unsupervised Out-of-Distribution Detection. In: Medical Image Computing and Computer Assisted Intervention–MICCAI 2025.
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Cardiovascular Engineering

Dominik Obrist, Head of Research Group
E-mail: dominik.obrist@unibe.ch
Phone: +41 31 684 14 22, +41 31 684 14 00

Research Partners
Prof. Matthias Siepe, Department of Cardiovascular Surgery, Inselspital Bern
Prof. Hendrik von Tengg, Department of Radiology, Inselspital Bern
Prof. Stephan Windecker, Department of Cardiology, Inselspital Bern

Dominik Obrist

Karoline-Marie Bornemann

Aurelia Bucciarelli

Lorenzo Ferrari

Silje Ekroll Jahren

Valérie Kulka

Chryso Lambride

Ali Mokhtari

Yannick Rösch

Franca Schmid

Nataliya Sevryugina

Gaia Stievano

Ross Straughan

Till Zeugin

Shaokai Zheng

Research Profile

The Cardiovascular Engineering Group (CVE) develops diagnostic and therapeutic technology for cardiovascular diseases. Our research aims to improve the durability and biocompatibility of cardiovascular devices and to establish novel diagnostic tools. These translational research projects address unmet clinical needs that were identified with our clinical partners who are closely integrated in our research teams from start to finish.

CVE operates a modern Biomedical Flow Lab with state-of-the-art measurement technology to simulate physiological conditions in the cardiovascular system and to measure hemodynamic parameters. This includes highspeed cameras and laser-based methods for flow quantification. In addition to the experimental facilities, CVE develops and uses custom-tailored computer models of cardiovascular flows, including fluid-structure interaction and turbulent blood flow. Large-scale flow simulations are enabled by using the high-performance computing infrastructure at the Swiss Supercomputing Center CSCS. For the development of patient-specific models, we work closely with radiologists to integrate clinical image data into experimental and computational models.
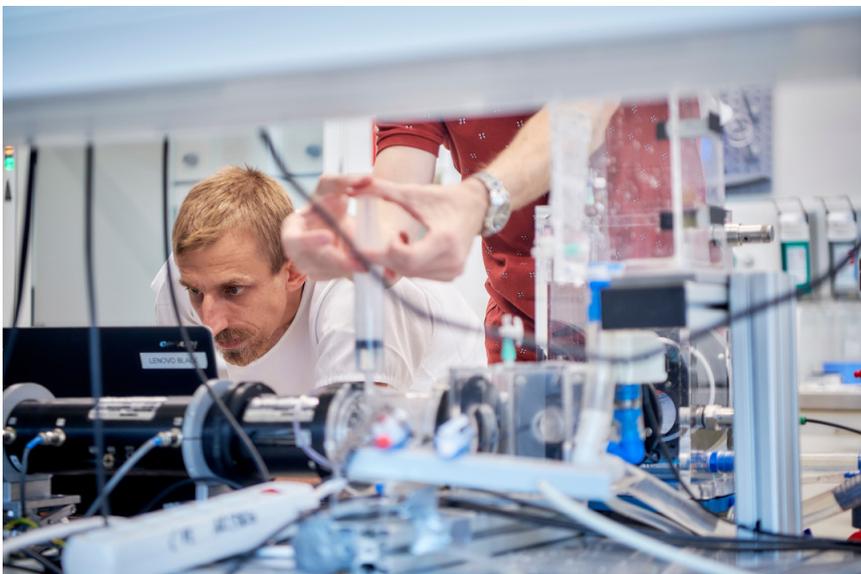

Fig. 1: Testing of heart valves in the Cardiovascular Flow Lab.

Heart Valve Replacement

Insufficient durability and biocompatibility of heart valve prostheses are limiting factors for their clinical use. In an ageing society where patients expect to be able to continue their active lifestyle after heart valve replacement, these limiting factors represent an unmet clinical need.

A detailed understanding of hemodynamic mechanisms governing valve tissue deterioration and blood trauma paves the way for the design of more durable and biocompatible devices. To this end, we have developed a sophisticated experimental and computational infrastructure for the study of heart valves. This includes mock loops replicating pulsating blood flow, silicone phantoms of large blood vessels, and modern measurement technology for quantifying complex three-dimensional turbulent blood flow fields (Fig. 1). This experimental expertise allowed us to support the development of a non-thrombogenic, durable heart valve prosthesis (TRIFLO by Novostia SA, Epalinges, Switzerland) which has been implanted for the first time in patients in December 2023.

Our experimental work is complemented by high-fidelity computer models for turbulent flow and fluid-structure interaction in cardiovascular systems. Together with the Swiss Supercomputing Center CSCS, we have optimized these models for high-performance GPU-accelerated supercomputing platforms, which allows us to study complex turbulent flow phenomena in the human body at unparalleled levels of detail, enabling us to gain new insights into disease mechanisms (Fig. 2). In recent studies, we established a direct connection
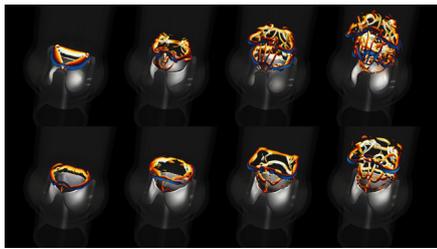
Fig. 2: Onset of turbulent flow in a fluttering (top row) and non-fluttering (bottom row) bioprosthetic valve.

→ between turbulent blood flow and aortic valve calcification, and we investigated the relation between valve design, patient-specific anatomy and the formation of blood clots. This information is used to design better heart valve prostheses with higher durability and lower thrombogenicity. These efforts resulted in the spin-off company ValTech Lifesciences GmbH which promotes a novel valve design to improve prosthetic valve performance.

Aortic assist device

Together with the Center for Artificial Muscles from EPFL, we are working on a novel cardiac assist device in a project supported by the Werner-Siemens Stiftung. In contrast to classical ventricular assist devices (VADs) that use rotary blood pumps, the Dielectric Elastomer Actuator (DEA) device directly compresses and dilates a section of the aorta to support the function of the heart by reducing the afterload. We have developed an in vitro benchtop model with a circulatory mock loop to optimize the design and actuation pattern of the DEA device, and we are conducting in vivo trials at the experimental surgery laboratory of the University of Bern to test and enhance its efficiency.

Computer-augmented 4D-Flow-MRI for plaque rupture

4D-Flow-MRI is a method for non-invasive and non-ionizing measurement of blood flow patterns in large blood vessels. It has great potential to be used for the diagnosis of cardiovascular diseases such as carotid stenosis. However, the lack of sufficient spatial resolution limits the applicability of this imaging modality in the clinic, and it is known that luminal wall-shear stress (an important factor in atherosclerotic plaque progression) is underpredicted by 4D-Flow-MRI. We combine data from 4D-Flow-MRI with advanced computational models to enhance the predictive quality of these measurements. This includes classical CFD models which are used to regularize the measured flow fields and statistical machine learning models which are trained with CFD data to yield very fast and accurate predictions of luminal wall-shear stress patterns that can be used in clinical practice.

Microvascular Obstruction

In myocardial infarction (heart attack), the supply of the heart muscle with oxygen and nutrients is blocked by an obstruction of a coronary artery. Even after re-canalization of this artery, secondary obstructions in the cardiac microcirculation (Microvascular Obstruction, MVO) may lead to local underperfusion of the heart muscle negatively affecting the long-term patient outcome. MVO is an underdiagnosed condition because it cannot be detected during acute treatment in the catheter lab. Moreover, there exists no established treatment for MVO. We are addressing this unmet clinical need in collaboration with the Swiss med-tech start-up

Fig. 3: Drug transport in a microfluidic model of the cardiac microcirculation with microthrombi.

CorFlow Therapeutics. We have developed a multi-scale benchtop model of the coronary circulation which allows us to study the pathophysiology of MVO and to develop novel diagnostic and therapeutic approaches for MVO. This model comprises a microfluidic chip mimicking the cardiac microcirculation (Fig. 3). We are using this model to enhance the efficiency of drug-based treatment of MVO and we were able to show that microvascular thrombi may be resolved by micro-doses of thrombolytic drugs. This clinically important result opens a new field of therapeutic options because the use of high-dose thrombolytic drugs is very limited by adverse side effects such as bleeding.

Microvascular Blood Flow Regulation

Oxygen and nutrient exchange between blood and surrounding tissue takes place in the capillary networks of the microcirculation. They comprise capillaries as small as 5 micrometers, such that red blood cells must squeeze through these vessels. In contrast to blood flow in larger blood vessels, capillary blood flow follows different physical laws and the mechanics of red blood cells plays a dominant role. We study blood flow in complex capillary networks as they may be found, for instance, in the brain, and investigate how the network topology affects the distribution of red blood cells in the network and how the system reacts to local vasodilation and obstructions. We use computational and experimental models to better understand the complex interactions of blood flow, red blood cell mechanics and metabolic exchanges with the parenchyma.

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Computational Bioengineering

Philippe Büchler, Head of Research Group
E-mail: philippe.buechler@unibe.ch
Phone: +41 31 684 14 10

Research Partners
Prof. Moritz C. Deml, University Clinic for Orthopedic Surgery, Inselspital, Bern
Dr. Patrick Goetti, Dr. Fabio Becce, Lausanne University Hospital, Lausanne
Prof. Carol Hasler, Dr. Daniel Studer, University Children's Hospital (UKBB), Basel
Dr. Jay Levin, Rothman Orthopaedic Institute, Philadelphia, USA
Prof. Georg Rauter, Department of Biomedical Engineering, University of Basel
PD Dr. Stefan Schmid, Spinal Movement Biomechanics Group, Berner Fachhochschule BFH
Dr. Theodor Seiler, Ophthalmology Clinic, University Hospital, Inselspital, Bern
Dr. Alexandre Terrier, Ecole polytechnique fédérale de Lausanne (EPFL), Lausanne
Dr. Bernhard Weisse, Swiss Federal Laboratories for Materials Science and Technology (EMPA), Dübendorf

Philippe Büchler	Beatriz Izquierdo Real
Miguel Ángel Ariza Gracia	Sabine Kling
Philippe Bähler	Kim Lieball
Laura Barberán-Bernardos	Till van der Reijden
Noelia Bracher	Tim Schär
Dong Chu	Osman Berk Şatır
Salvatore Conticello	Vahoura Tahsini
Yannic Eltschinger	Damien Vallélian
Matteo Frigelli	

Research Profile

The Computational Bioengineering Group (CBE) develops computational models to address clinical challenges in ophthalmology and orthopedics. We combine clinical imaging with ex vivo and in vivo experimental data to build accurate, physics-based representations of patient-specific tissue biomechanics. A key focus of our work is the development and validation of non-invasive methods to obtain biomechanical data in vivo, supporting the creation of digital twins that reflect individual patient conditions. This integrative approach advances understanding of disease mechanisms, enables treatment simulation, and contributes to more personalized therapies.
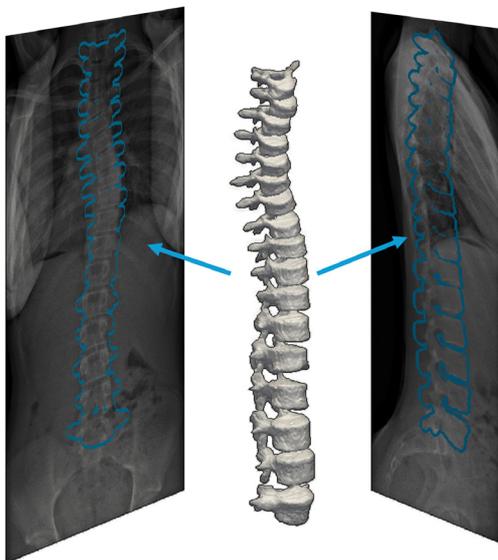

Fig. 1: Full 3D reconstruction of vertebral positions from low-dose biplanar X-ray images, showing an articulated spine model fitted in standing condition.

A preoperative spinal stiffness test for adolescent idiopathic scoliosis

A detailed understanding of spinal biomechanics is crucial for planning scoliosis surgery and for characterizing degenerative spinal disorders. Current clinical assessments do not measure true mechanical stiffness because they only quantify displacement, without considering the force needed to deform the spine. To overcome this limitation, we developed a spinal traction device compatible with low-dose biplanar X-ray imaging. The system delivers controlled axial traction through a head halter, while a force-sensor platform records both load and displacement, allowing a quantitative evaluation of spinal deformation under traction.

Accurate stiffness characterization requires precise 3D vertebral positions in both standing and traction conditions (a 30% unloading of body weight). An ultrashort MRi sequence supplies high-resolution 3D vertebral geometry, which is integrated into an articulated model of the full spine. This model is fitted to the biplanar X-ray data for each condition, producing full 3D reconstructions from which intervertebral motion can be quantified (Fig. 1). Comparing the two configurations reveals how each vertebra responds to traction, enabling patient-specific biomechanical assessment.
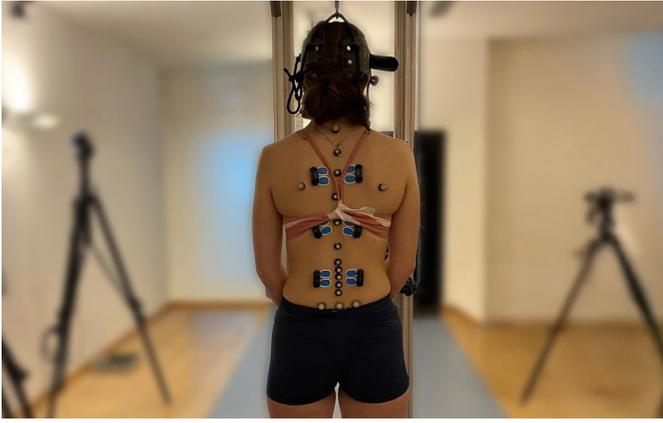
Fig. 2: Setup for monitoring trunk muscle activation during the preoperative axial traction text in a healthy volunteer.
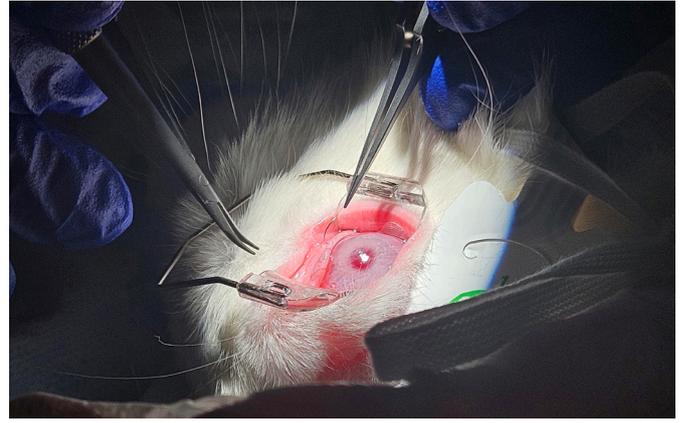

Fig. 3: The stability of hydrogel injections for correcting hyperopia was demonstrated in an animal model.

→ The ability of this traction test to isolate passive spinal behavior was confirmed in an adolescent subject who maintained low trunk muscle activity during cervical traction, as measured with surface EMG (Fig. 2). This demonstrates that the method captures passive properties without significant muscular interference.

This platform is particularly relevant for adolescent idiopathic scoliosis, where individualized stiffness characterization is essential for optimizing surgical planning and guiding the development of motion-preserving treatment strategies. By capturing true 3D deformation between baseline and traction, the approach provides a more reliable preoperative evaluation of spinal flexibility and mechanical behavior.

Intraoperative quantification of spinal stiffness

Degenerative and deforming spinal conditions impose a substantial socioeconomic burden. Current treatments such as spinal fusion often compromise mobility and long-term function. To support the development of novel solutions, precise characterization of the biomechanics of deformed and degenerated spinal segments is required.

In collaboration with the University of Basel, we are developing a system capable of measuring three-dimensional segmental stiffness directly in patients during surgery. The system relies on a parallel-kinematic robotic device that applies controlled loads to adjacent vertebrae while a force-torque sensor records the resulting mechanical response. Ex vivo evaluations are conducted to verify the accuracy and repeatability of these measurements. In parallel, we are developing patient-specific finite element models of the motion segment that will incorporate the intraoperative measurements. This integrated approach deepens our understanding of spinal biomechanics and supports the development of next-generation motion-preserving treatments.

Hydrogel microinjections for vision correction

By 2050, more than five billion people are expected to be affected by refractive vision disorders such as presbyopia, myopia and astigmatism. Current surgical options rely largely on laser procedures that reshape the cornea by removing tissue. Although effective in many cases, these techniques reduce corneal strength and carry a risk of complications. They are also unsuitable for patients with thin corneas or high refractive errors. To respond to these limitations, we are developing a novel treatment based on hydrogel injections into the cornea to correct hyperopia while preserving corneal integrity. This approach represents a promising alternative for individuals who are not eligible for conventional laser surgery.

Our technique improves vision through highly controlled microinjections of hydrogel that form implants inside the corneal stroma. These implants remodel the cornea and reinforce its structure at the same time.

We demonstrated in an in vivo animal study the feasibility of the procedure. The treatment successfully corrected large refractive errors, showed good long-term stability of the hydrogel, and revealed no signs of adverse reaction or hydrogel opacification (Fig. 3). This study provides strong support for the future translation of the technology.

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Gerontechnology and Rehabilitation

Tobias Nef, Technical Head of Research Group
René Müri, Clinical Head of Research Group
Urs Mosimann, Clinical Head of Research Group

Research Partners
Prof. Urs Fischer, Prof. Andrew Chan, Prof. Bogdan Draganski, Prof. Simon Jung,
 Prof. Georg Kägi, Prof. Paul Krack, Prof. Iris-Katharina Penner, Prof. Olivier
 Scheidegger, Prof. Kaspar Schindler, Department of Neurology, Inselspital Bern
Prof. Stefan Klöppel, University Hospital of Old Age Psychiatry, Bern
Prof. Thomas Nyffeler, Department of Internal Medicine, Luzerner Kantonsspital
Prof. Matthias Wilhelm, Department of Cardiology, Inselspital Bern

Tobias Nef	Nora Geiser
Noora Angelva	Stephan Gerber
Diana Bethge	Sarah Mischler
Lena Bruhin	Kevin Moeri
Nicola Brunello	Manuela Pastore-Wapp
Alessia Carlucci	Hugo Saner
Matilde Castelli	Michael Single
Aaron Colombo	Tim Vanbellingen
Michael Falkner	Emilie Zitzmann

Research Profile

The interdisciplinary Gerontechnology and Rehabilitation Research Group (GER) is a collaborative research effort with the goal of developing and evaluating novel, flexible, and cost-efficient technologies to improve diagnostics, monitoring, and therapies of neurological and psychiatric disorders in the hospital, in the instrumented apartment and at home. Core methodologies include digital biomarkers for motor function, cognition and mood, telemonitoring and telerehabilitation technology. The research group partnered with the Department of Neurology (Prof. U. Fischer) to establish the NeuroTec Loft, which is an instrumented apartment within the sitem NeuroTec to monitor human behavior and investigate how neurological and psychiatric disorders influence daily life.

Implementation Partners:
Alzheimer Schweiz
Bewelab
Biogen
Calicarpa
Hirncoach
Ikerian
machineMD
Magnes
Microsoft Schweiz
Post Sanela Health
QuantActions
QUMEA
WELL Gesundheit

Fig. 1: Academic and implementation partners of the AI for BrAIn Health Flagship Project. Awarded under the Innosuisse 'AI in health' call (PIs: T. Nef & B. Draganski; 9.6 Mio CHF), this five-year project begins in 2026. Collaboration involves partners from ETHZ (J. Vogt & E. Vavena), EPFL (M. Salathé), CHUV (J. Fellay), HSLU (A. Paice), HES-SO (A. Kucharavy), and 13 implementation partners.

AI for BrAIn Health Flagship – Towards Personalized Brain Health in Switzerland

The cautious projections of double-to-triple increase of dementia cases in Switzerland by 2050 amount to estimated CHF 25.4 billion p.a. health care costs. Meta-analytic evidence demonstrates that 45% of dementia risk is linked to modifiable lifestyle factors, which call for efficient and cost-saving preventive strategies.

The Swiss BrAIn Health Flagship will develop an AI system for personalized dementia risk reduction targeting individuals with Subjective Cognitive Complaints – early indicators in the Alzheimer's disease continuum. This system complements human expertise with AI capabilities, integrating clinical evaluation with continuous lifestyle assessment via digital wearables.

Building on an integration of brain health trajectories derived from Swiss longitudinal epidemiological data with clinical expertise, the system generates individually tailored dementia risk profiles identifying modifiable factors (e.g., cardiovascular risk, physical inactivity, depression). Digital therapeutic interventions support patient adherence while enabling out-of-hospital continuous monitoring and coaching.

Clinical utility validation is conducted at Inselspital's Brain Health Clinic, providing the canvas for future Brain Health Centers. The NeuroTec Loft (Figs. 2 and 3) provides a realistic test environment for validating sensor-based digital biomarkers designed to assess real-life behavioral patterns.
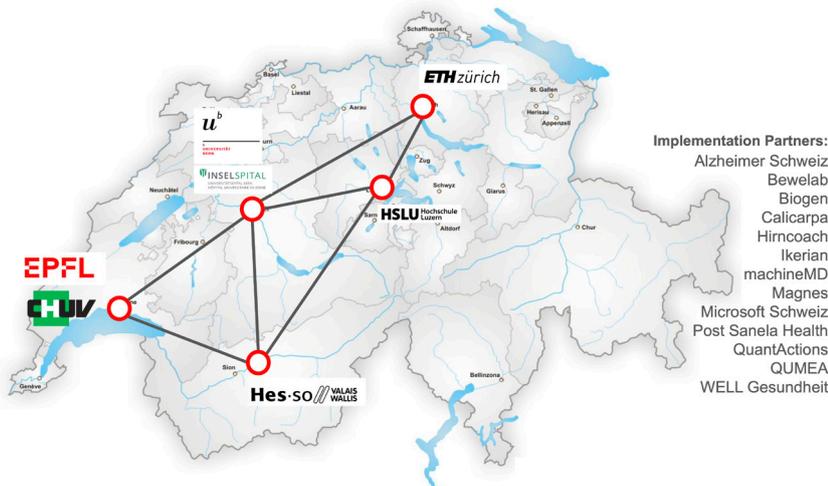
Fig. 2 and 3: The NeuroTec Loft is a state-of-the-art, sensor-equipped three-room apartment featuring a kitchen, living room, bathroom, and bedroom. Designed to study behavioral aspects of neurological and neuropsychiatric disorders, this unique facility provides a setting that closely replicates natural living conditions. Equipped with 300 sensors, it enables precise quantification of motor function, cognition, and mood. Additionally, the Loft serves as a testing environment for innovative technological developments. The NeuroTec Center is an integral part of the Department of Neurology, and it is operated by Profs. Schindler (Neurology) and Nef (ARTORG Center).

→ The cost-benefit analysis is compelling: achieving just 20% risk reduction in 30% of at-risk patients would yield CHF 750 million in annual savings. Implementation partners project to generate at least 548 million additional revenue in Switzerland (2026-35).

The project addresses current healthcare infrastructural constraints by empowering self-management while providing actionable recommendations to clinicians. The breakthrough potential for a paradigm shift in disease prevention builds on integrating novel digital biomarkers and therapeutics for AI-supported brain health risk assessment and dementia risk reduction to ensure scalable low-cost development in the Swiss healthcare ecosystem.
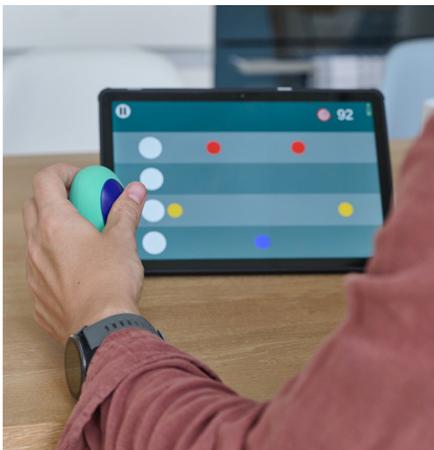

Fig. 4: A healthy participant plays a motor-cognitive game. Sensors in the silicone egg measure the pressure applied by each finger as well as the movement of the wrist, which control the computer game. This is used both as a digital biomarker for fine motor function and cognition and for training purposes.

Pocket-size device to measure and train fine-motor function and cognition

The Smart Sensor Egg (Fig. 4 and 5) is a newly developed device to assess and train fine finger movement and cognitive abilities for patients with neurodegenerative diseases and brain injury. It is a pocket-sized, sensor-based tool designed to enhance dexterity (coordinated finger movements) and hand function (grip and grasp), which are often impaired in this patient population. In an initial study, the first prototype of the Smart Sensor Egg, equipped with a gyroscope, an accelerometer, and four pressure sensors was evaluated. Participants, supervised by a clinician, successfully used the device, which was connected to a laptop running a single game. The device was well-received, and the gamified environment proved motivating for training hand function. To enable the use of this innovative device in a home-based setting, further development is ongoing, both in the technical design of the device and the accompanying game-based software.

Alongside the technical developments and clinical evaluation, the transition to market implementation is underway with the establishment of the new ARTORG spin-off company GoRehab.

Fig. 5: Nine participants with Parkinson's disease trained their finger dexterity using the smart sensor egg for a total of five hours distributed over three weeks. Analysis of the DextQ-24 questionnaire scores revealed a significant reduction in mean finger dexterity impairment.

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Hearing Research Laboratory

Philipp Aebischer, Head of Research Group
E-mail: philipp.aebischer@unibe.ch
Phone: +41 31 684 14 25

Research Partners
Prof. Georgios Mantokoudis, Department of Ear, Nose and Throat Diseases, Head and Neck Surgery, Inselspital Bern
Prof. Martin Kompis, Audiology, Inselspital Bern
Prof. Raymond van de Berg, Department of Ear, Nose and Throat, Head and Neck Surgery, Maastricht University Medical Center, Netherlands
Prof. Wilhelm Wimmer, Technical University of Munich, Germany
Cochlear AG, Basel, Switzerland
MED-EL GmbH, Innsbruck, Austria

Philipp Aebischer	Francis Liechti
Raphael Andonie	Jiayi Ma
András Bálint	Giuliano Martinelli
Walter Bernardi	Alexandra Nuoffer
Benjamin Bircher	Christoph Schmid
Nathalie Buser	Stephan Schraivogel
Marco Caversaccio	Stefan Weder
Katharine Keller	

Research Profile

The Hearing Research Laboratory (HRL) develops precision instruments and data-driven methods to improve treatments in otology and neurotology. We adopt a translational approach, transferring findings from basic research into clinical practice, to ensure that our solutions meet real clinical needs.

In collaboration with clinicians at the Inselspital, our multidisciplinary team develops artificial anatomical models, sensor-based monitoring systems and computer-assisted methods to gain quantitative insights into surgical procedures.

Fig. 1: Trajectory planning for minimally invasive vestibular access. The visualization shows how different entry points and approach angles influence access to the semicircular canals, highlighting regions that allow safe and precise robotic drilling.

Robotic Access to the Vestibular System

Vestibular surgery is challenging because the labyrinth provides no reliable navigational landmarks. This limits the precision of procedures such as superior canal dehiscence syndrome plugging or vestibular neurectomy, and increases their invasiveness. Image-guided robotic systems can help to overcome this limitation. In a feasibility analysis, we evaluated keyhole trajectories for robotic drilling to the semicircular canals, optimizing safety margins and geometric access. These methods enabled the world's first robotic vestibular surgery, demonstrating that accurate, minimally invasive access to the labyrinth is clinically achievable. This work establishes a foundation for the targeted, minimally invasive treatment of vestibular disorders.

Quantitative Insights for Surgical Training

The delicate microanatomy of the cochlea leaves little margin for error. To study the effect of surgical techniques on the inner ear and enable surgeons to refine their skills, we develop high-fidelity artificial temporal bone models that replicate human anatomy and mechanical ➔
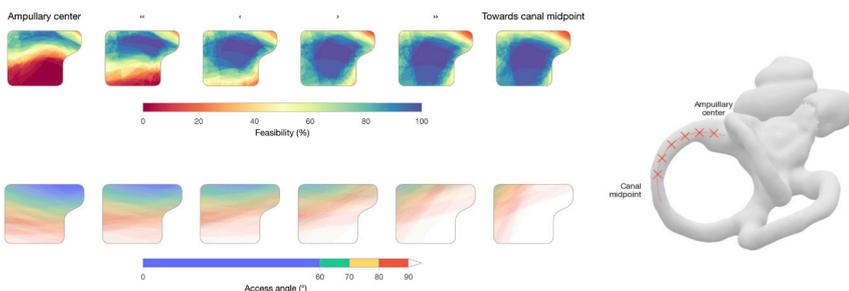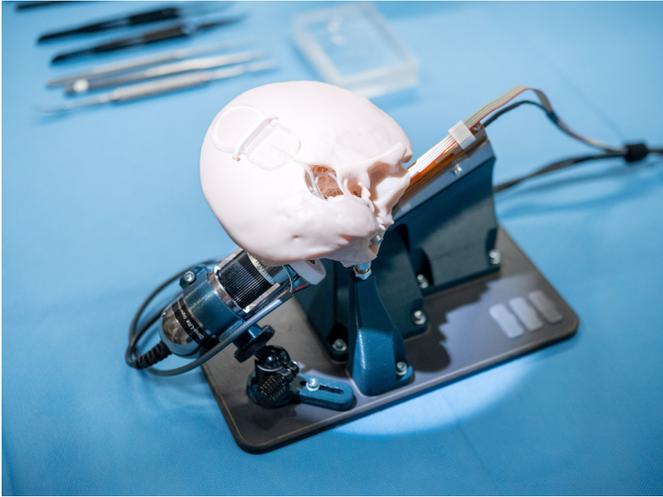
Fig. 2: A high-fidelity temporal bone model for cochlear implant surgical training. This model provides a realistic anatomical environment paired with detailed, evidence-based feedback on the microstructural effects of surgeons' actions, allowing them to refine their techniques in a controlled environment.

→ properties. These models are equipped with a comprehensive sensing system and provide quantitative feedback on surgical actions and their microstructural impact.

Modular components enable training in a variety of clinical scenarios, including malformations and age-related anatomical variations. Compared with cadaveric specimens, our models offer a more controlled, consistent and ethical environment in which to research and practice cochlear implant surgery.

Intraoperative Cochlear Health Monitoring

Electrocochleography (ECochG) is increasingly becoming an important tool to monitor cochlear function during the implantation. By combining objective signal analysis with precise knowledge of where responses originate inside the cochlea, we gain a clearer picture of how well the inner ear continues to function throughout surgery. Recent work from our group shows that stronger cochlear microphonic responses and clearer tonotopic patterns are associated with better residual hearing in CI recipients. These insights support the use of ECochG as a biomarker for cochlear health.

Radiation-Free Localization of Implanted Electrodes

Impedance telemetry is routinely used to assess electrode function in cochlear implants. We showed that impedances also offer valuable information about the spatial position of implanted contacts. Building on our previous work, we use impedance-based models to estimate electrode location without the need for postoperative CT imaging. Recent results show that this approach can achieve sub-millimeter accuracy and reliably identify positioning patterns even in challenging cases, such as partial insertions.

Imaging Brain Plasticity in Response to Cochlear Implantation

Alongside these surgical aspects, rehabilitation is an essential component for successful outcome of cochlear implantation. The adaptation to cochlear implant stimulation is critical to hearing rehabilitation, with cortical plasticity playing a central role. Our recent fNIRS imaging work shows that good-performing cochlear implant users display activation patterns similar to normal-hearing individuals during listening tasks, indicating effective auditory adaptation, whereas poorer performers rely more strongly on visual cues and recruit additional cortical regions to support speech processing.

These patterns clarify how the brain adapts to electric hearing and inform more targeted approaches to CI therapy and follow-up.

Selected Publications
1. Aebischer, P., Gawliczek, T., Loos, E., Wagner, F., Weder, S., Caversaccio, M., and Mantokoudis, G. "Robotic keyhole access to the semicircular canals for vestibular implantation: an anatomical feasibility study," European Archives of Oto-Rhino-Laryngology, 2025.
2. Bálint, A., Wimmer, W., Rummel, C., Caversaccio, M., & Weder, S. "Linking brain activation to clinical outcomes: an fNIRS study in cochlear implant users and normal hearing individuals," Neurophotonics, 2026.
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4. Schraivogel, S., Weder, S., Mantokoudis, G., Caversaccio, M., & Wimmer, W. "Predictive Models for Radiation-Free Localization of Cochlear Implants' Most Basal Electrode using Impedance Telemetry," IEEE Transactions on Biomedical Engineering, 2025.

Medical Image Analysis

Mauricio Reyes, Head of Research Group
E-mail: mauricio.reyes@unibe.ch
Phone: +41 31 632 75 74

Clinical Partners
Prof. Daniel Aebersold, Department for Radiation Oncology, Inselspital Bern
Prof. Alex Pöllinger, Department for Diagnostic, Interventional, and Pediatric
    Radiology, Inselspital Bern
Prof. Roland Wiest, Department of Diagnostic and Interventional
    Neuroradiology, Inselspital Bern
Prof. Jan Gralla, Department of Diagnostic and Interventional Neuroradiology,
    Inselspital Bern
Prof. Andreas Raabe, Department for Neurosurgery, Inselspital Bern
Dr. Philippe Schucht, Department for Neurosurgery, Inselspital Bern

Mauricio
Reyes

Freddy
Guebely De la Hoz

Amith J.
Kamath

Fabricio
Kirchhofer

Luc
Lerch

Jihe
Li

Haozhe
Luo

Michael
Müller

Francesco
Nitti

Albora
de Pablo Pena

Marvin
Schmid

Shelley Zixin
Shu

Nirosh
Sivanesan

Erika
Spada

Joseph
Weibel

Research Profile

The Medical Image Analysis Group (MIA) develops advanced AI-based image analysis technologies and translational biomedical engineering solutions to quantify, diagnose, and monitor diseases. Our core expertise lies in multimodal image segmentation and longitudinal analysis for brain tumors (glioblastoma, brain metastases, ischemic stroke), as well as deep learning for thoracic imaging.

The research aims to identify robust, non-invasive imaging biomarkers to characterize disease evolution, guide therapy, and support clinical decision-making in radiology, neurosurgery, and radiotherapy. Underpinning this work is a commitment to robustness, trustworthiness, and clinical translation. A major focus is on the interpretability and transparency of AI systems, embedding this directly into model design and linking predictions to clinically meaningful reasoning patterns. The overall goal is to bridge the gap between high-performance AI algorithms and their safe, effective adoption in healthcare settings.

AI-based Brain MEtastases TraCking and SegmentatiON - A-BEACON

A-BEACON
- Multicenter-based data-centric AI
- Zero-miss Brain MET detection
- Active TTA for system adaptability
- Interpretability-guidance and reporting
- All-In-One-View Expert review
- Brain METs Radiomics
- Functional Atlas based reporting
- DICOM-RT compatibility

Improvements
User corrections

Active Test-Time-Augmentations
ACTTA

- Interpretability-based TTA:
  → Class-specific saliency distinctiveness
  → Saliency/Feature alignment
- TTA reporting
  → Interpretability of improvements
  → Improved transparency & trustworthiness

Fig. 1: Proposed A-BEACON for automated brain metastases segmentation, detection and tracking. Listed main features and contributions under a multi-lateral and multi-disciplinary consortium..
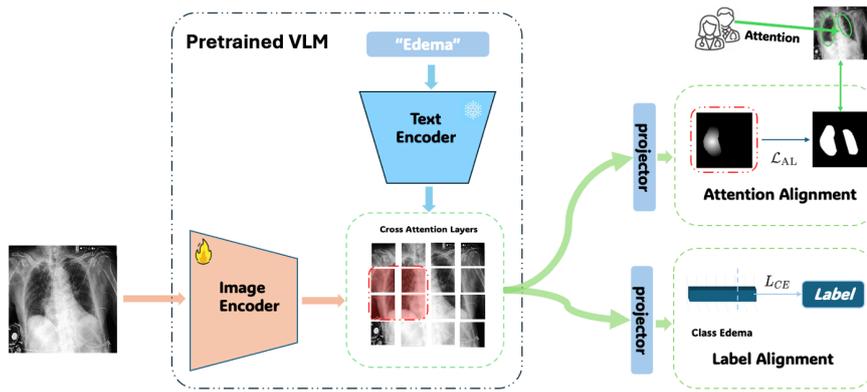
Accurate, Robust and Clinically Translated AI-based Quantification in Medical Image Computing

Magnetic Resonance Imaging (MRI) remains the cornerstone of brain tumor assessment. Extracting its full diagnostic and prognostic value increasingly requires advanced AI tools for detection, segmentation and longitudinal quantification. Over the last years, the MIA group has co-developed AI models for automated brain tumor segmentation that led to clinically deployed software in collaboration with Neosoma Inc., including FDA-cleared solutions for glioma segmentation.

Building on this foundation, 2025 marks an important strategic development: the creation of Neosoma GmbH in Bern. In this new structure, the relationship has evolved from "we license a first-class technology to Neosoma" to "we serve as the Swiss-based hub for all current and future AI developments of Neosoma Inc.". Neosoma GmbH is now working in close partnership with the University of Bern and Inselspital, strengthening Switzerland's position as a global innovation site for AI brain oncology.
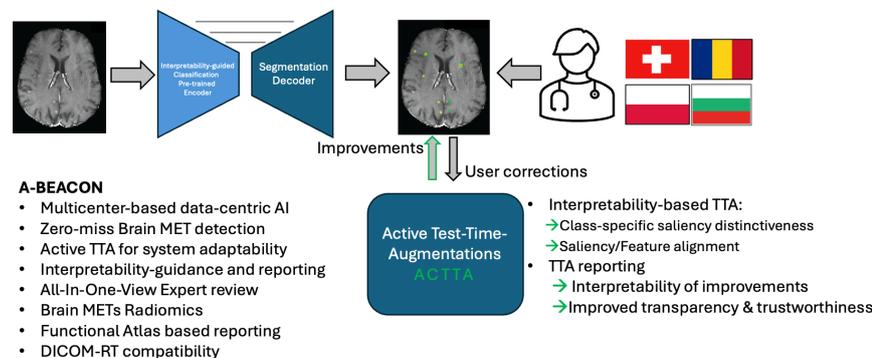
SNSF–MAPS: A-BEACON Project

A major highlight this year is the award of the SNSF Multi-Area Projects in Science (MAPS) grant for A-BEACON, *AI-based Brain Metastases Tracking and Segmentation*. This international consortium aims to address a critical unmet need: consistent, accurate and comprehensive identification and monitoring of ➔

Fig. 2: Human-AI Alignment flow chart. The approach is based on Visual-Language-Model (VLM) fusing image and language embeddings via cross-attention. The model is trained sequentially for each class per epoch, with the disease name as a prompt (e.g., "Edema"). Two projector heads are used to (i) optimize Human-AI alignment, and (ii) perform disease classification.

brain metastases across longitudinal MRI timepoints. A-BEACON develops a "zero-miss" AI system focused on: high detection sensitivity, reliable tumor volume quantification, precise longitudinal lesion tracking, and seamless integration into clinical workflows.

The project brings together partners from Switzerland, Poland, Romania and Bulgaria, establishing a diverse evaluation ecosystem that will accelerate clinical translation and generalization across healthcare settings.

AI in Radiotherapy

The group continues to advance AI methods that directly incorporate clinical dosimetric relevance into segmentation evaluation and contouring workflows. Recent work includes:

(i)   a multifaceted AI contouring evaluation framework benchmarking geometric and dosimetric performance for clinical readiness,

(ii) dose-prediction models that provide radiotherapy-aware quality assurance, and

(iii) automated systems for ranking segmentation variants based on dosimetric impact.

These developments help ensure that segmentation accuracy is assessed not only geometrically but also in terms of actual clinical consequences.

Interpretability of Deep Learning-based Medical Image Analysis

Trustworthy AI in medicine requires models that not only achieve high performance but also provide transparent,

human-aligned decision pathways. The MIA group has long led research in this domain, and 2025 marks significant developments across modalities

A central theme this year is the advancement of human-aligned learning frameworks, where models are trained to attend to radiologically meaningful patterns and follow clinically coherent reasoning structures. This includes methods

that integrate explanation-guided learning, self-supervised strategies and transformer-based attention mechanisms to ensure that internal representations are interpretable and aligned with clinical expectations. This approach reduces hidden failure modes, improves robustness across diverse patient populations, and supports fairer, more trustworthy AI systems. We also address the interplay between interpretability, fairness and performance trade-offs, contributing conceptual and methodological insights into how transparent models can be designed without compromising clinical utility.

These advances extend beyond neuro-oncology into thoracic imaging, where the group develops interpretable, data-efficient methods for multi-label chest X-ray classification. Here, attention-guided and alignment-driven strategies ensure that performance gains remain closely tied to medically meaningful explanations, thereby strengthening clinician trust and facilitating adoption.

Our interpretability research is now embedded into major applied initiatives, including A-BEACON, contributing to AI systems that are safe-by-design, clinically explainable and reliable over time.

Selected Publications

1. Amith J. Kamath, Jonas Willmann, Nicolaus Andratschke, and Mauricio Reyes. The impact of U-Net architecture choices and skip connections on the robustness of segmentation across texture variations. *Computers in Biology and Medicine*, 197(Pt B):111056, 2025.

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3. Ezequiel de la Rosa, Mauricio Reyes, Sook-Lei Liew, Alexandre Hutton, Roland Wiest, Johannes Kaesmacher, and colleagues. DeepISLES: a clinically validated ischemic stroke segmentation model from the ISLES'22 challenge. *Nature Communications*, 16(1):7357, 2025.

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9. Jianning Li, Zeyu Zhou, Jun Yang, Alessandro Pepe, Christian Gsaxner, Gjis Luijten, Chenxia Qu, Tianyi Zhang, Xiaoyan Chen, Wenjia Li, Mateusz Wodzinski, Patrick Friedrich, Kai Xie, Yihuang Jin, Nakulan Ambigapathy, Enrico Nasca, Nihat Solak, Giovanni M. Melito, Van Duong Vu, and colleagues. MedShapeNet – a large-scale dataset of 3D medical shapes for computer vision. *Biomedical Engineering / Biomedizinische Technik*, 70(1):71–90, 2025.

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Medical Sensing Laboratory

Brice-Olivier Demory, Head of Research Group
E-mail: brice-olivier.demory@unibe.ch
Phone: +41 31 632 51 57

Clinical Partners
Aurel Perren, Institute of Tissue Medicine and Pathology, University of Bern
Prof. Daniel Candinas, Dept. of Visceral Surgery and Medicine, Inselspital Bern

Brice-Olivier Demory

Gaëlle Nivlet

Lucas Patty

Research Profile

The Medical Sensing Laboratory (MSL) develops novel imaging modalities focusing on real-time, non-invasive diagnostics used for tissue medicine, pathology and surgery. One key objective is to design and build instruments fitting in the operating room to improve the detection of tumors during surgery. Our research activities currently focus on the development of bench-top Müller matrix polarimeters for pathology assessment, design of compact sensor-heads using liquid-crystal technology and polarimetry-enabled endoscopy for broad clinical applications.
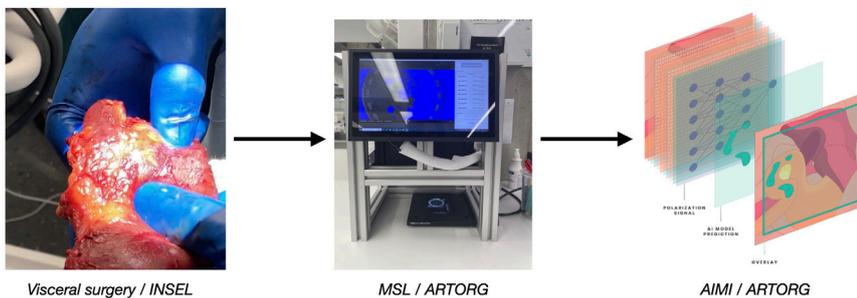

Visceral surgery / INSEL   *MSL / ARTORG*   *AIMI / ARTORG*

Fig. 1: The whole exceeds the sum of its parts. Here is an example of the workflow between a pancreatic tissue and a prediction map of its nature.
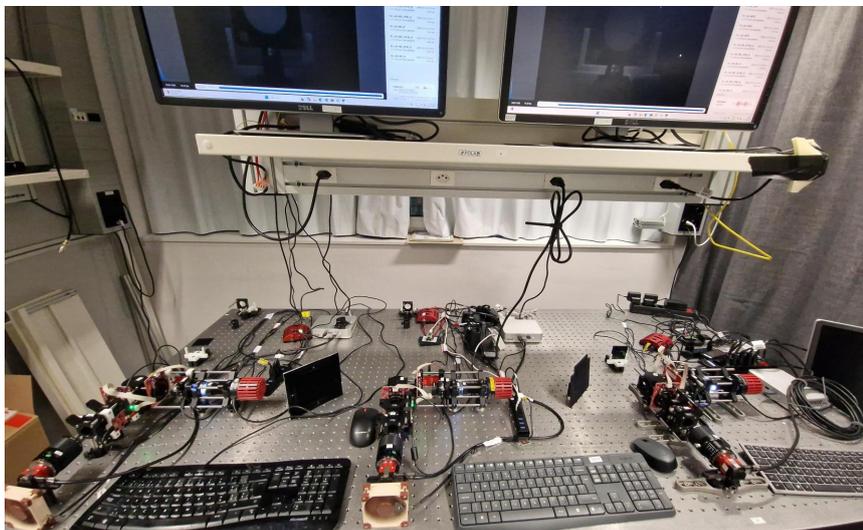

Fig. 2: Optical table in the MSL lab featuring three Müller matrix polarimeters purpose-built for tissue diagnostics. These devices are designed to have a compact volume to be fitted in settings with restricted space availability (e.g. operating rooms or pathology labs).

Cancer detection in fresh pancreatic tissues with multispectral Mueller matrix polarimetry

The treatment of tumors is a clinical challenge whose success critically hinges on early detection and complete surgical resection to minimize recurrence. For many tumor types however, the distinction between healthy tissue and tumors can be difficult during surgery because of the differences that can be indistinguishable visually.

Through a collaboration with the Artificial Intelligence in Medical Imaging Laboratory (AIMI) and the Neuro Robotics Group (NRG), the Medical Sensing Laboratory (MSL) develops purpose-built instrumentation that exploits the polarization of light to increase the contrast between healthy and non-healthy tissues and achieve higher success rate in cancer surgery.

Figure 1 shows an example of a workflow between a pancreatic tissue and a prediction map of its nature (e.g. cancerous vs. non-cancerous) utilizing Müller matrix polarimetry. After sampling in the operating room by clinical partners from Visceral Surgery at Inselspital, the Müller matrix polarimeter developed at MSL analyzes how the light's polarization is modified by the tissue's structural organization. The data are then processed by an AI model developed at AIMI to convert the polarization signal into a prediction map informing pathologists and/or surgeons about the nature of the tissue. Different instrumental devices developed at the Medical Sensing Laboratory (MSL) are now in operation with our research and clinical partners, notably at the Institute of Tissue Medicine and Pathology at the University of Bern.

Musculoskeletal Biomechanics

Philippe Zysset, Head of Research Group
E-mail: philippe.zysset@unibe.ch
Phone: +41 31 684 14 87

Research Partners
Prof. Dieter Bosshardt, Dental Clinics of the University of Bern (ZMK), Bern
Prof. Serge Ferrari, University Hospitals Geneva (HUG), Geneva
Prof. Johannes Bastian, Prof. Johannes Heverhagen, Prof. Christian Jackowski,
    Prof. Kurt Lippuner, Prof. Simon Steppacher and Prof. Marcel Zwahlen,
    Inselspital (IS), Bern
Prof. Marianne Liebi, Paul Scherrer Institut (PSI), Villigen
Prof. Dieter Pahr, Vienna University of Technology (VUT), Vienna
Prof. Michael Pretterklieber, Medical University Graz (MUG), Graz
Dr. Jakob Schwiedrzik and Prof. Johann Michler, EMPA, Dübendorf & Thun
Dr. Peter Varga, AO Research Institute (AO), Davos
Prof. Bettina Willie, Shriners Hospital for Children and McGill University (MG),
    Montréal
Prof. Andrew Minor, Lawrence Berkeley National Laboratory (LBNL), Berkeley

Philippe Zysset	Yvan Gugler
João Alves	Tatiana Kochetkova
Michaël Angéloz	Jonas Peter
Alexander Bieri	Alexia Pollaci
Stefan Bracher	Simone Poncioni
Sudeesh Dass	Romane Roux
Alice Delaloye	Osman Berk Şatır
Amin Dolati	Mathieu Simon
Daniela Frauchiger	Christina Wapp
Matteo Frigelli	Patrik Wili
Gabriela Gerber	Jianzhong Xu

Research Profile

Motivated by prevention, diagnosis, and treatment of degenerative diseases, the research of the Musculoskeletal Biomechanics Group (MSB) focuses on multi-scale structure-function relationships of bone from the extracellular matrix to the organ level. Combined theoretical, experimental, and numerical approaches are applied to model, validate, and simulate the mechanical behavior of bone tissue and bone-implant systems during growth, aging, disease and treatment. The group supervises Master theses, provides biomechanical testing services, and cooperates with local, national as well as international partners from academia, hospitals, and industry to help reduce the burden of bone diseases and failure of the bone-implant interface.
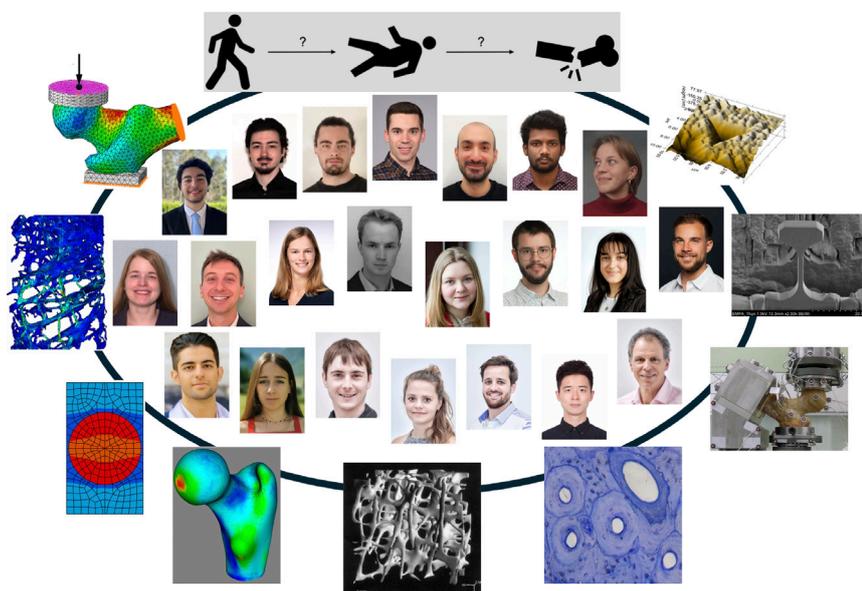

Fig. 1: The Musculoskeletal Biomechanics (MSB) research team combining experimental, imaging, computational and clinical studies.

Contribution of Bone Tissue Properties to Strength of the Ageing Human Hip *(SNF grant # 200365 with EMPA, PSI, VUT & MUG)*

To better understand age-related bone fragility, we examine multi-scale and multimodal tissue properties in the proximal femur. At the microscale, we define the tissue's complete mechanical profile (elastic, yield, and post-yield) using nanoindentation and state-of-the-art high-throughput micropillar compression. Enhancing the collected dataset with microradiography measurements provides information on the mechano-mineral interplay. Collaborative synchrotron measurements with PSI enabled us to further investigate the relationship between bone ultrastructure and mechanical properties at the femoral neck, analyzing local variations ➔
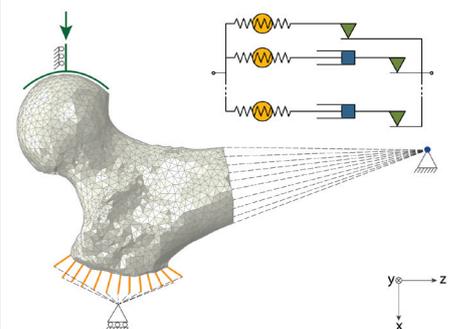

Fig. 2: Finite element model of the human proximal femur in a sideways fall configuration and rheological representation of a strain rate-sensitive constitutive model for bone.

within bone quadrants and among donors. These experimental approaches were complemented by a computational study at the whole bone level, incorporating strain rate-sensitive material properties into finite element models of the proximal femur. By including strain rate sensitivity in models representing a fall from standing height, the quantitative agreement between simulation and experiment was improved considerably.

HR-pQCT-Based Diagnosis of Osteoporosis *(with IS & MG)*

Recently, novel diagnostic tools have been developed to predict the mechanical strength of distal bone sections using homogenized finite elements (hFE) based on high-resolution peripheral computed tomography (HR-pQCT). These tools have lowered repeatability errors for improved longitudinal assessments compared to the gold standard dual X-ray absorptiometry (DXA).

The average spatial distribution of bone damage induced by compressive overloading was recently evaluated in a large healthy cohort (n=381, 20-92y) using statistical shape modeling (SSM). Results showed that in the radius damage primarily at the lunate joint within the trabecular compartment, no damage was detected in the cortex. In the tibia, most damage accumulated in the proximal trabecular region, which is characterized by a lower bone volume fraction and a higher cortical thickness. The multi-stack acquisition protocol (20 and 30 mm for radius and tibia, respectively) proved less sensitive to boundary conditions than the standardized single-stack acquisition (10 mm). These findings suggest the potential of hFE-based SSM for understanding bone failure patterns in a population-wide context.
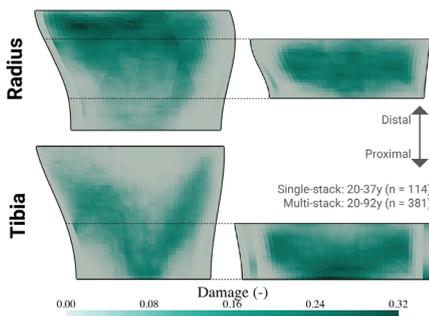
Average Damage Distribution

Fig. 3: Comparison of the statistical distribution of damage in single versus multiple sections of HR-pQCT-based hFE models of the distal radius and tibia.

A Fragility Fracture Integrative Risk Model for CT Recycling *(SNF grant # 183584 with HUG, IS, & MUG)*

In the previous year, the development of the required submodels for the novel integrative risk model was completed. The calculator has been implemented as a python pipeline, and the next logic step is its validation using external clinical datasets. Suitable datasets such as the Study of Osteoporosis Fractures (SOF) or the MrOS are currently used to calibrate the model and assess its predictive performance. Preliminary results show that the model performs at least as good as a BMD from DXA alone. Further adjustments to improve the model's calibration are currently under investigation. Next to that, the follow-up of our own clinical study is in its final stage, and the last follow-up calls are planned for June 2026.

Improving Primary Stability of Total Hip Arthroplasty *(with MUG & industry partners)*

Variability of the proximal femoral medullary canal plays a crucial role in cementless femoral stem design and placement in total hip arthroplasty and was quantified using statistical shape modeling based on computed tomography data from 763 femora.
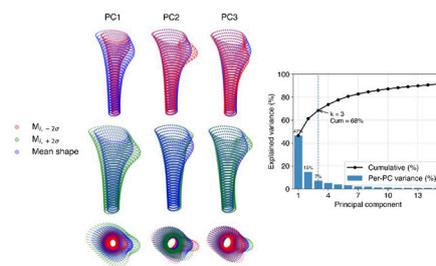

Fig. 4: Left: Anterior and superior views of mean medullary canal (blue) and deformations along the first three PCs at ± 2 SD. Right: scree plot for the first 15 PCs.

Biomechanical Stability of Dental and Orthopaedic Implants *(with AO, ZMK & industry partners)*

The bone sets the tone for implant stability and surgical success. Finite element simulation combined with CT imaging enables the virtual reconstruction and analysis of a patient's heterogeneous bone structure, providing insight into the mechanics underlying bone-implant stability. Research in this area advances through experimental investigations and multi-scale FE modeling.

Studies on carbon fiber-reinforced PEEK pedicle screws revealed their toggling behavior and mechanical performance in spinal fixation. Comparative analyses of micro- and homogenized FE models showed that homogenized simulations can efficiently predict the load-bearing capacity of bone screws. In dental implant surgery, the integration of experimental data with cone beam CT-based FE analyses substantially improved the prediction of primary implant stability in human jawbones. This approach shows potential for clinical implementation, allowing dentists to virtually assess bone quality and optimize implant placement before surgery, thereby improving patient outcomes.
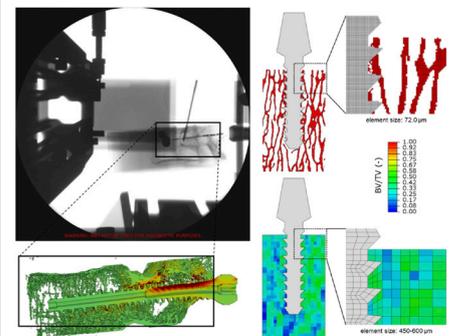

Fig. 5: Left: Toggling experiment and FE simulation of a PEEK pedicle screw. Right: Comparison of a microFE with a homogenized FE model.

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Neuro Robotics Group

Manuela Eugster, Head of Research Group
E-mail: manuela.eugster@unibe.ch
Phone: +41 31 684 14 27

Research Partners
Prof. Andreas Raabe, Department of Neurosurgery, Inselspital Bern
Prof. Georg Rauter, Department of Biomedical Engineering, University of Basel
Prof. Stefan Weber, University of Bern
Brütsch Technology AG, Schaffhausen

Manuela Eugster	Timon Mettler
Marcel Allenspach	Inês Salema
Thomas Bucher	Kajetan Sandorski
Cedric Frenzer	Raphael Schranz
Iona Guth	Daniela Zenklusen

Research Profile

The Neuro Robotics Group (NRG) focuses on the development of surgical instruments for neurosurgery based on robotics and micromechatronics technology. Our goal is to develop innovative robotic systems and mechatronic devices to improve the precision, efficiency, and safety of neurosurgical procedures. At the core of our work is the close collaboration with medical professionals, emphasizing the crucial synergy between technological innovation and clinical expertise. This partnership ensures that our developments are seamlessly aligned with the clinical need of neurosurgery.
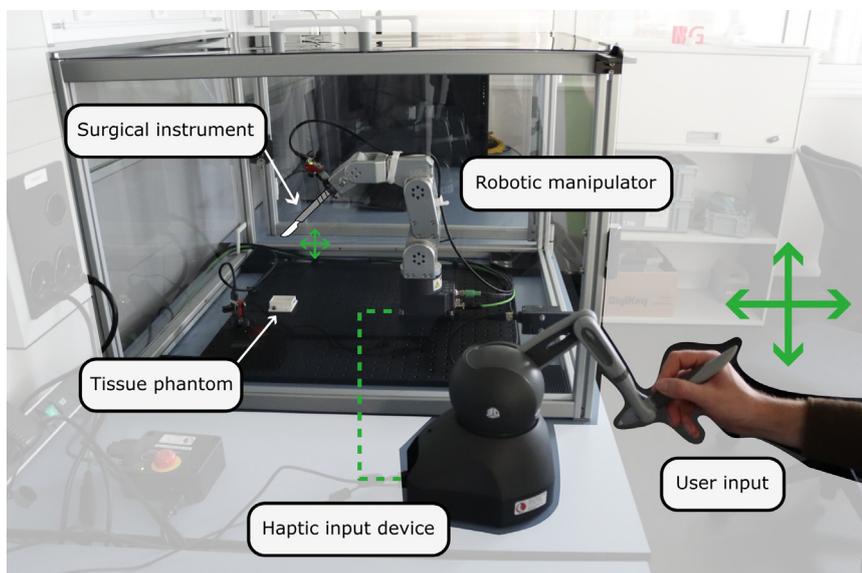

Fig. 1: Teleoperation setup used in our experiments: a haptic input device operated by the user controls a robotic manipulator.

Teleoperation for Neurosurgery

In several surgical robotic systems, surgeons control the robot indirectly through dedicated input devices. These teleoperation setups offer significant advantages, including the ability to miniaturize the robotic components that interact directly with patient tissue, as well as to incorporate advanced features such as force feedback, tremor suppression, and motion scaling. These capabilities can enhance precision and enable finer manipulation of surgical instruments. We design and optimize these features to better address the specific requirements of neurosurgical procedures.

Improving the outcomes of Spontaneous Intracranial Hypotension (SIH) interventions

The brain and the spinal cord are embedded in around 140 ml of cerebrospinal fluid (CSF). The presence of this fluid is relevant for the metabolism of the nerve cells as well as for the protection against external mechanical influences and acceleration forces, such as vibrations. Around 500 ml of this fluid is produced and reabsorbed every day. In case of a CSF loss syndrome also known as spontaneous intracranial hypotension (SIH) cerebrospinal fluid is lost through a lesion. A standing position of the affected person results in a sagging of the brain, which causes various symptoms from mild headaches to impairment of consciousness. The lesion must be located ➜
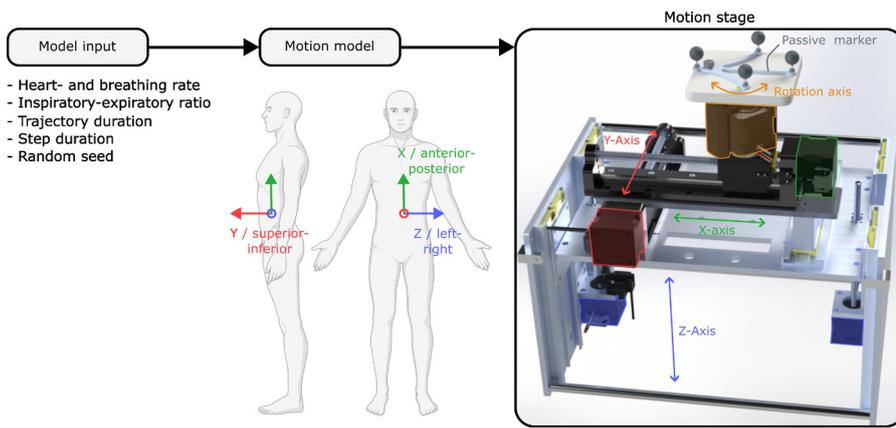
Fig. 3: Motion model and motion stage designed to replicate pancreatic movement generated by cardiac and respiratory activity during surgical procedures. Human depiction created with BioRender.com.

and closed to prevent severe consequences like chronic pain and potential paralysis. The treatment of spontaneous intracranial hypotension (SIH) is a poorly addressed clinical challenge. We are developing technological solutions to improve the outcomes of SIH interventions together with our implementation partner Brütsch Technology AG.
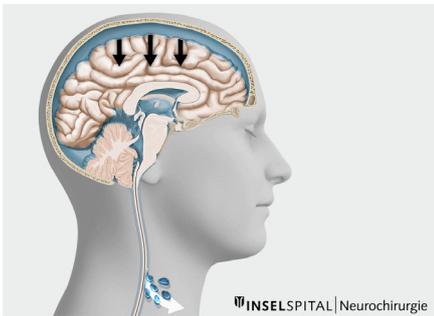

Fig. 2: A cerebrospinal fluid (CSF) leak in the spinal column. Image: Universitätsklinik für Neurochirurgie, Inselspital Bern © CC BY-NC 4.0.

Bulk tissue classification based on Müller Matrix Polarimetry

Pancreatic cancer is a leading cause of cancer-related death with surgical resection representing the only potentially curative treatment. In this context, precise intraoperative identification of tumor margins is essential to maximize resection success and improve patient outcomes. Müller Matrix Polarimetry (MMP) has emerged as a promising optical technique capable of differentiating malignant from healthy pancreatic tissue. However, its effectiveness can be compromised by organ motion during open-abdomen procedures. We are addressing this challenge in collaboration with the Artificial Intelligence in Medical Imaging Group (Prof. Sznitman) and the Medical Sensing Laboratory (Prof. Demory).

We developed a comprehensive motion simulation framework to support the development and validation of MMP based intraoperative imaging devices. The framework consists of two key components: (i) a pancreatic motion model that generates realistic three-dimensional organ trajectories observed during open abdominal surgery, and (ii) a high-precision motion stage capable of reproducing these trajectories with controlled accuracy.

We completed integration and testing of this system. The motion stage achieved accuracy and repeatability in the submillimeter range across the translational axes. The results confirmed that both the motion model and the motion stage offer the precision and reproducibility required to emulate physiological pancreatic motion. By providing a controlled, near-realistic testing environment, this platform enables systematic evaluation of MMP-based devices under conditions that closely mimic the challenges of live surgery. This represents a significant step toward advancing optical guidance technologies and improving intraoperative tumor detection capabilities in pancreatic cancer surgery [1].

ARTORG Services

The ARTORG Center offers a range of services to the research community of the Bern Biomedical Engineering Network. The Neuro Robotics Group manages two of these facilities.

Electronics laboratory

Electronics are an integral part of many devices in medical technology. These devices include, for example, a large number of sensors for evaluating patients' health parameters. In order to create a workplace where electrical and electronic prototypes can be produced to high-quality standards, the electronics laboratory has been professionally refurbished and expanded.
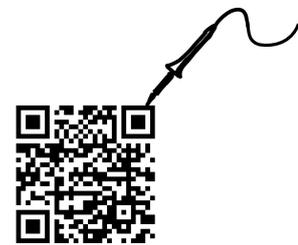
3D printing laboratory

The 3D printing facility has already facilitated many groundbreaking projects, including customized patient-specific skull implant molds, models for perioperative planning of complex aortic arch surgery, liver resection planning models, and aneurysm models for surgical coiling and surgical clipping. The facility has been expanded with further state-of-the-art additive manufacturing systems to continue to offer these possibilities.
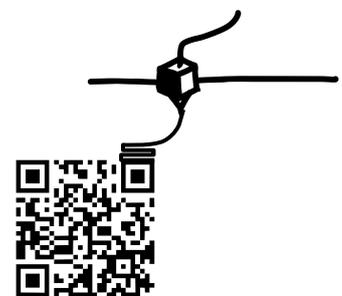
Selected Publications

1. Allenspach, M., Sznitman, R., Eugster, M. "Simulating pancreatic tissue motion to study the performance of polarimetry-based intraoperative cancer detection," at - Automatisierungstechnik, vol. 73, no. 12, 2025, pp. 922-933. https://doi.org/10.1515/auto-2025-0111.
2. Parduzi, Q., Wermelinger, J., Alvarez Abut, P., Eugster, M., Raabe, A., Schneider, C. and Seidel, K. "Safety through automation: advancing intraoperative neurophysiological monitoring to preserve motor function," at - Automatisierungstechnik, vol. 73, no. 12, 2025, pp. 911-921. https://doi.org/10.1515/auto-2025-0090.

Organs-on-Chip Technologies

Olivier T. Guenat, Head of Research Group
E-mail: olivier.guenat@unibe.ch
Phone: +41 31 632 76 08

Research Partners
Prof. Dr. med. Thomas Geiser, Pulmonary Medicine, Inselspital Bern
Prof. Dr. med. Patrick Dorn, PD Dr. Thomas Marti, Thoracic Surgery, Inselspital Bern
Dr. Nina Hobi and Dr. Arunima Sengupta, AlveoliX AG, Bern
Prof. Dr. Carole Bourquin, Institute of Pharmacology, University of Bern
Prof. Dr. Cornelia Halin Winter, Pharmaceutical Immunology, ETHZ
Prof. Dr. Wolfgang Kuebler, Charité – Universitätsmedizin Berlin, Germany
Prof. Dr. Vinicio de Jesus Perez, Stanford University Medical Center, CA, USA
Prof. Dr. Deborah Stroka and Prof. Dr. Stephanie Ganal-Vonarburg, DBMR, University of Bern
Prof. Dr. Patric Eberle, HSLU, Luzern, Switzerland
Prof. Dr. Nadia Mercader, Anatomy Institute, University of Bern
Prof. Dr. Carmen Faso, Cell Biology Institute & IFIK & MCID, University of Bern
Prof. Dr. Volkner Heussler, Cell Biology Institute, University of Bern
Prof. Dr. Reiner Wiest, Gastroenterology Clinic, Inselspital Bern
Dr. Simon Häfliger, Medical Oncology, Inselspital Bern

Olivier T. Guenat	Christian Moser
Denise Ackermann	Urs Mumenthaler
Mahsa Asgari	Joanne Nikles
Mahsa Babaie	Mattia Panza
Francesco Bonollo	Daniela Schmidt
Ina Brodbeck	Karin Schmid-Rechberger
Marc Favrod-Coune	Sabine Schneider
Johannes Fehr	Negar Vahdani
Amin Hajari	Tobias Weber
Elvar Ingason	Claude Wenger
Kwun Wai DeDe Man	Soheila Zeinali
Sepehr Mohseni	

Research Profile

The Organs-on-Chip Technologies Group (OOC) develops advanced in-vitro models designed to replicate key functional units of human tissues by mimicking their cellular composition and microenvironment. Our work focuses on modeling the lung and microvasculature in health and disease through multidisciplinary research in cell biology, biomechanics, microtechnology, and microfluidics. These systems support precision medicine by enabling therapy testing on patient-derived cells. This year's report presents three projects combining organ-on-chip and organoid technologies: two show how breathing-related mechanical forces shape cellular responses, and one examines how flow profiles influence immune cell behavior.

Fig. 1: Differential gene expression after 24h of unidirectional (pump) versus bidirectional (rocker) flow. Volcano plot highlighting 761 differentially expressed genes: 310 upregulated and 451 downregulated (Ref.1).

Flow Dynamics as a Driver of Endothelial Gene Regulation

Rocking-platform perfusion systems rely on hydrostatic pressure differences to drive flow in organ-on-chip devices. Their tubing-free design enables easy parallelization, making them widely used in drug discovery, precision medicine, and academic research. However, these platforms typically generate bidirectional flow, which does not accurately reflect the unidirectional shear stresses experienced by endothelial cells (ECs) in the microvasculature. Pump-based systems can provide unidirectional flow but require external tubing, limiting their scalability.

In this study, we compared endothelial transcriptomic responses under matched average flow rates generated by either a rocking platform or a peristaltic pump. The two flow modalities produced distinct transcriptional signatures, with hundreds of genes differentially expressed. After 4 hours of flow, pathways including NF-κB, ERK, BMP, and MAPK were enriched. After 24 hours, we observed significant regulation of genes involved in immune cell migration, angiogenesis, and vascular and extracellular matrix remodeling (Fig. 1). These results highlight how the nature of flow—pump-driven versus rocker-induced—shapes endothelial behavior at the molecular level (Ref.1).
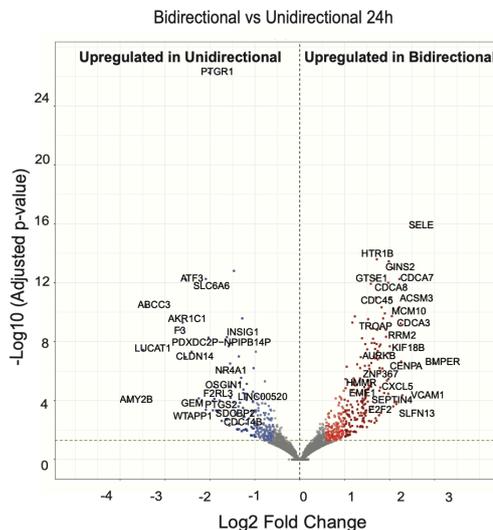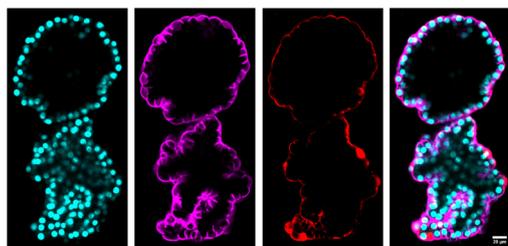
Fig. 3: Immunostained alveolospheres (alveolar epithelial organoids) showing epithelial cells (EpCAM, magenta), cell nuclei (Hoechst, blue), transitional AT0 cells (KRT8, red). Scale bar: 20μm (Ref. 2).
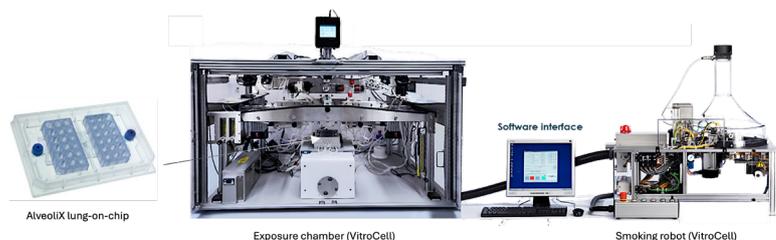

Fig. 4: Experimental set-up of the smoking robot connected to the dilution system and VitroCell exposure chamber, where smoke is diluted, guided through the exposure head, and delivered to the 12-well lung-on-chip system (AX12, AlveoliX) for cell exposure, before being exhausted via a vacuum-driven outlet (Ref. 3).

→ Integrating Organoids with Organ-on-Chip Technology to Model Human Alveoli

We developed an alveoli-on-chip (AOC) platform (Fig. 2) that recreates arrays of alveoli at near-in vivo scale and applies 3D cyclic stretching to mimic breathing. Its open 24-well format simplifies handling and supports medium-throughput experimentation. This work uniquely integrates two powerful technologies—organs-on-chip and patient-derived organoids. Lung organoids were generated from AT2 cells isolated from surgical lung tissue and maintained their epithelial identity, including AT2, AT1, and transitional AT0 subtypes (Fig. 3). After expansion, organoids were dissociated, and cells from three patients were cultured on the AOC under static or cyclic stretch conditions. Bulk RNA sequencing showed that mechanical stimulation significantly altered gene expression. Cyclic stretch activated pathways related to autophagy, cell-cycle regulation, and mTORC1 signaling, revealing key molecular responses of the alveolar epithelium to physiological mechanical cues (Ref. 2).
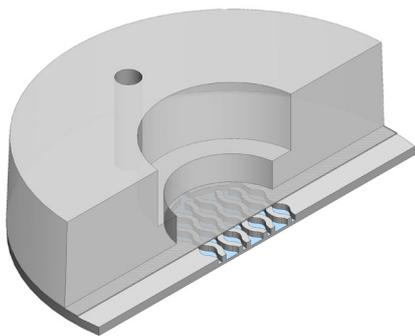
Modeling Cigarette Smoke Exposure Under Physiological Lung Conditions

With our spin-off AlveoliX, we investigated the effects of cigarette smoke on human lung epithelial cells using a lung-on-chip model. This work was conducted in collaboration with Vitrocell (Germany), whose smoke exposure system directly accommodated the AlveoliX lung-on-chip (Fig. 4).

Cigarette smoke (CS) is a major driver of severe respiratory diseases, yet existing animal models and traditional in-vitro system often fail to replicate the mechanical and biological complexity of the human lung.

To address this gap, we developed a smoke inhalation-based lung-on-chip system (CFAX12) that exposes human alveolar epithelial cells, lung microvascular endothelial cells, and macrophages to continuous smoke under air-liquid interface (ALI) conditions combined with breathing-like cyclic stretch. We found that cellular sensitivity was highest—and barrier disruption most pronounced—when smoke exposure occurred under air-liquid interface (ALI) together with mechanical stretch, closely reflecting in vivo physiology (Fig. 5). These responses were far stronger than those induced by standard cigarette-smoke extract in submerged cultures. The addition of pulmonary surfactant on the apical surface

suggested a protective effect, reducing cytotoxic and oxidative stress responses.

This study highlights the importance of combining realistic exposure, ALI culture, and breathing motions to accurately model smoke-induced injury. To our knowledge, it is the first distal-lung in-vitro smoke exposure platform integrating continuous smoke delivery with cyclic stretch, offering a more predictive tool for studying disease mechanisms and evaluating therapeutic strategies.
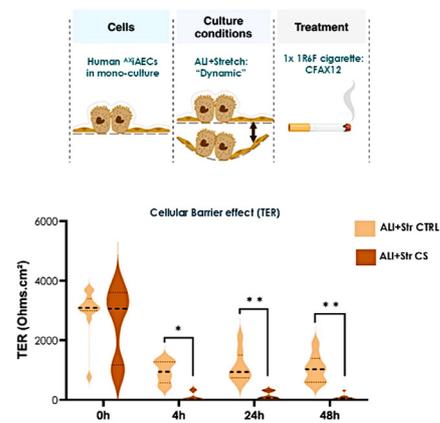
Fig. 5: Breathing motions (Str) and the air-liquid interface (ALI) increase alveolar barrier vulnerability to cigarette smoke (CS). After 4h, TEER measurements show barrier disruption (Ref. 3).

Fig. 2: Schematic of the alveoli-on-chip featuring a sinusoidal channel pattern (500μm - 150μm) designed to generate spatially varying pressure on the overlying flexible membrane where cells are cultured.

Selected Publications:
1. Vahdani, N, Arora P, van Os L, Ackermann D, Mercader N, Guenat OT. Rocker or pump? Transcriptomic response of endothelial cells exposed to peristaltic pump-based unidirectional flow vs. rocker-induced bidirectional flow. Lab Chop. 2025 Oct 7;25(20):5129-5140. doi: 10.1039/d5lc00553a. PMID: 40746301.
2. Hajari MA, Schulte J, Principi D,, Schnidrig D, Schneider S, Weber T, Lee JH, Dorn P, Zamprogno P, Marti TM, Guenat OT. A novel alveoli-on-chip platform for modeling cyclic stretch in patient-derived alveolar epithelial cells cultured from organoids. Lab Chip. 2025 Nov 7. doi: 10.1039/d5lc00473j. Epub ahead of print. PMID: 41200831; PMCID: PMC12593192.
3. Sengupta A, Schmid S, Grangier N, Dorn A, Hebestreit M, Hugi A, Žajdlíková K, Herbst, A, Losada-Oliva P, Ortolf-Wahl H, Krebs P, Stucki JD, van der Velpen V, Perez-Gil J, Krebs T, Hobi N, Guenat OT. A next-generation system for smoke inhalation integrated with a breathing lung-on-chip to model human lung responses to cigarette exposure. Sci Rep. 2025 May 25;15(1):18181. doi: 10.1038/s41598-025-00438-z. PMID: 40414911; PMCID: PMC12104466.

Urogenital Engineering

Francesco Clavica, Head of Research Group
E-mail: francesco.clavica@unibe.ch
Phone: +41 31 684 14 28

Francesco Clavica	Federica Magnano
Cornel Dillinger	Sofia Melone
James Fox	Pedro Pereira Amado
Nuofan Gao	

Research Partners
Prof. Beat Roth, Dept. of Urology, Inselspital Bern, CH
Prof. em. Fiona Burkhard, University of Bern, CH
Prof. Daniel Fuster, Dept. of Nephrology and Hypertension, Inselspital Bern, CH
Prof. Markus Drake, Dept. of Urology, Imperial College, London, UK
Prof. Dirk Lange, Stone Center, University of British Columbia, Vancouver, CA
Prof. Dominik Obrist, Prof. Daniel Ahmed, ARTORG Center, University of Bern, CH
Swiss Paraplegic Center, Nottwil, CH
URODEA AG, Biel, CH

Research Profile

The urinary tract (UT) consists of two kidneys, two ureters, the bladder and the urethra. For normal urination to occur, all components must function in a coordinated and efficient manner. The Urogenital Engineering Group (UGE) develops innovative, biomedical engineering-based solutions to improve the understanding, diagnosis, and treatment of UT diseases, many of which have a substantial impact on health and quality of life.

Our primary research areas include urinary obstructions (e.g., kidney stones), underactive bladder, overactive bladder and urinary incontinence. Our work integrates fundamental science with translational research: we investigate the basic mechanisms underlying urinary tract function while also optimizing existing medical devices and developing novel technologies to address unmet clinical needs, identified in close collaboration with our clinical partners. We apply advanced biomechanics approaches, combining computational and experimental methods, along with machine learning methods to investigate biofluid dynamics and key behaviors that influence urinary tract functionality.
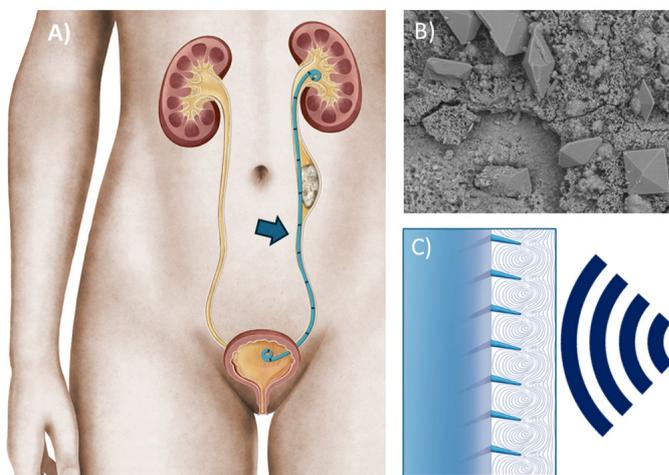

Fig. 1: Ureteral stents (arrow) are tubes used to bypass urinary obstructions (A). They can become blocked by biofilm and encrustation (B). Our novel ureteral stents feature surface microstructures activated by ultrasound to enable non-invasive cleaning through acoustic streaming (C).

Biofilm and encrustation on urinary stents and catheters

One of our primary research foci is improving the urine-drainage performance of urinary stents (small tubes placed from the kidneys to the bladder to bypass obstructions) and urinary catheters (tubes extending from the bladder to the outside of the body). Once implanted, both devices are prone to blockage due to encrustation and biofilm formation, which also increases the risk of urinary tract infections. Although many antimicrobial coatings have been investigated, none has demonstrated effectiveness against the combined, synergistic effects of crystals and bacteria.

Understanding the location and extent of encrustation and biofilm formation on ureteral stents across different diseases provides valuable insights for patient management.

In this context, our current projects include: (i) using micro-computed tomography (µCT), combined with semantic segmentation, to quantify encrustation and biofilm volume on ureteral stents retrieved from patients, and (ii) applying scanning electron microscopy (SEM) together with energy-dispersive X-ray spectroscopy (EDX) for detailed morphological and chemical characterization of crystals. These investigations aim to identify stent regions most susceptible to encrustation and to correlate these regions with local fluid mechanical conditions.

A central part of our expertise is the optimization of existing stent and catheter designs and the development of novel ➜

solutions. In this direction, we are creating the first non-invasively cleanable ureteral stent, which integrates ultrasound technology with artificial micro-cilia positioned both inside and outside the stent (Fig. 1). These cilia are hair-like structures inspired by those found in the respiratory system and inner ear. When exposed to ultrasound, the micro-cilia vibrate at high frequencies, each generating a pair of vortices. Collectively, the vibrating cilia produce a directed fluid jet known as acoustic streaming. Our goal is to utilize this acoustic streaming to effectively clean encrusted stents.

Urinary Tract Modeling

A thorough understanding of normal urinary tract (UT) function (and how it is altered by various pathologies) is essential for developing innovative medical devices that can effectively support patients. To this end, we have developed advanced platforms that integrate in-silico, in-vitro and ex-vivo models for bio-fluid-mechanical investigations within the UT. These platforms enable detailed characterization of fluid dynamics (Fig. 2) and allow systematic testing of a wide range of medical devices, including those designed for urinary incontinence, urinary retention and obstructions. They also provide a controlled environment for assessing device-tissue interactions (Fig. 3) and predicting long-term behavior under realistic physiological conditions. Quantitative measurements under both physiological and pathological conditions are crucial for validating our

Fig. 2: Example of our in-vitro platform mimicking the fluid dynamics in UT with artificial urine and programmable bladder emptying.
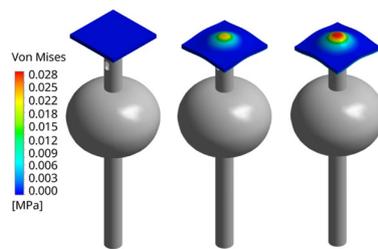

Fig. 3: Computational modeling of bladder-catheter interaction during bladder emptying. High von Mises stress is associated with increased risk of bladder trauma.

models and platforms. In this context, we are investigating the use of Magnetic Resonance Imaging (MRI) and Phase-Contrast MRI to obtain accurate measurements of tissue and organ deformation, as well as urine velocity, within the UT. These imaging techniques offer non-invasive, high-resolution insights that can enhance model accuracy and guide future device optimization.

Overactive Bladder and Incontinence

Patients suffering from overactive bladder (OAB) live with a continuous urge to urinate even at low bladder filling volumes, often leading to urinary incontinence. OAB has an enormous impact on the quality of life of affected patients. Despite its high prevalence, the understanding of the mechanism underlying OAB remains limited and, as a consequence, treatment options are scarce. UGE has developed several tools that aim to identify specific patterns in bladder pressure and bladder nerve signals associated with overactive bladder. For example, we have developed an algorithm that generates alarms before the start of an unwanted bladder contraction. The algorithm was successfully tested first in rats and then in patients using classical urodynamic signals.

It could be used to warn the patient about an impending bladder contraction (to act against incontinence) and/or to trigger conditional sacral nerve stimulation. Moreover, our group has recently shown that pressure-volume catheters, designed to measure cardiac pressure and volume, could be used in urology to better diagnose and treat lower urinary tract dysfunctions. These catheters could enable the evaluation of the bladder contractile function and the identification of local changes of bladder volume (e.g., associated with non-voiding bladder contraction which are typical in OAB patients) for more tailored treatment options.

Impedance pumping for urinary retention

Patients suffering from urinary retention are unable to empty their bladder because of either a weak bladder muscle and/or a bladder outlet obstruction.

To date, catheters are the most common therapy for bladder emptying. However, catheters are invasive and frequently cause urinary tract infections, making a non-invasive bladder-emptying solution highly desirable. Our approach to urinary retention uses the impedance pump principle, a valveless mechanism that generates directed flow through impedance mismatch: externally applied, rhythmic compression of an elastic tube creates traveling waves that are reflected and interact to produce net flow. Applied to the urethra, this principle can support urine flow and bladder emptying without direct infection risk.

A first prototype has been developed and tested in 10 male patients, and we are currently working on a dedicated version of the device for women. URODEA AG, a spinoff of the ARTORG Center, is advancing this technology toward clinical use.

Selected Publications
1. Amado P., Dillinger C., Chaimae B., Hashemi G.A., Obrist D., Burkhard F., Ahmed D., Clavica F. "Ultrasound-activated cilia for biofilm control in indwelling medical devices", Proceedings of the National Academy of Sciences, vol. 122, no. 18, p. e2418938122, May 2025, DOI:10.48620/88212.
2. Amado P., Zheng S., Burkhard F., Obrist D., Clavica F., "Rethinking ureteral stent design: Do more side holes improve performance?", Computers in Biology and Medicine, vol. 196, no. Pt C, p. 110895, Aug. 2025, DOI:10.48620/90635.
3. Fox J., Jahren E.S., Drake M.J., and Clavica F., "Choosing the optimal urethral Catheter: A computational comparison", Continence, vol. 16, Dec. 2025, DOI:10.48620/92306.
4. Gammie A., Clavica F., Gray T., Hassani F., Solomon E., Song Q., Speich J., Valentini F., Harding C., "How Can Urodynamic Innovations be Better Integrated Into the Clinical Pathway?: ICI-RS 2025", Neurourology and Urodynamics. Wiley, Nov. 06, 2025, DOI:10.48620/92422.
5. Drake M., Clavica F., Murphy C., Fader MJ 'Innovating Indwelling Catheter Design to Counteract Urinary Tract Infection' European Urology Focus 2024, DOI:10.1016/j.euf.2024.09.015.
6. Jahren S.E., Obrist D., Haenggi M., Burkhard F., Clavica F. 'Can Cardiac Pressure-Volume Catheters Improve Urodynamic Assessment? An Ex-Vivo Proof-of-Concept.' Frontiers in Urology 2023, 3, DOI:10.3389/fruro.2023.1258649.
7. Zheng S., Amado P., Obrist D., Burkhard F., Clavica F., 'An in vitro bladder model with physiological dynamics: Vesicoureteral reflux alters stent encrustation pattern' Frontiers in Bioengineering and Biotechnology, 2023. DOI:10.3389/fbioe.2022.1028325.

Mechanical Design and Production

Ralf Kreienbühl, Head of Workshop
E-mail: ralf.kreienbuehl@unibe.ch
Phone: +41 684 14 17

Ralf Kreienbühl

Simon Balz

Lio Ritschard

Fabio Spena

Amiel Zaugg

Research Profile

The primary function of the Mechanical Design and Production Group (MDP) is the co-development and manufacturing of mechanical and electro-mechanical components related to engineering and biomedical research pursuits of the ARTORG Center. The MDP group supports all levels of the design and manufacturing process from idea to production. This includes computer assisted design (CAD) modeling, computer aided modulation (CAM), 3D-printing (filament), CNC-milling up to four axes and CNC-lathe-machining. We also support industrial and academic external research collaborators with their mechanical design and production needs.
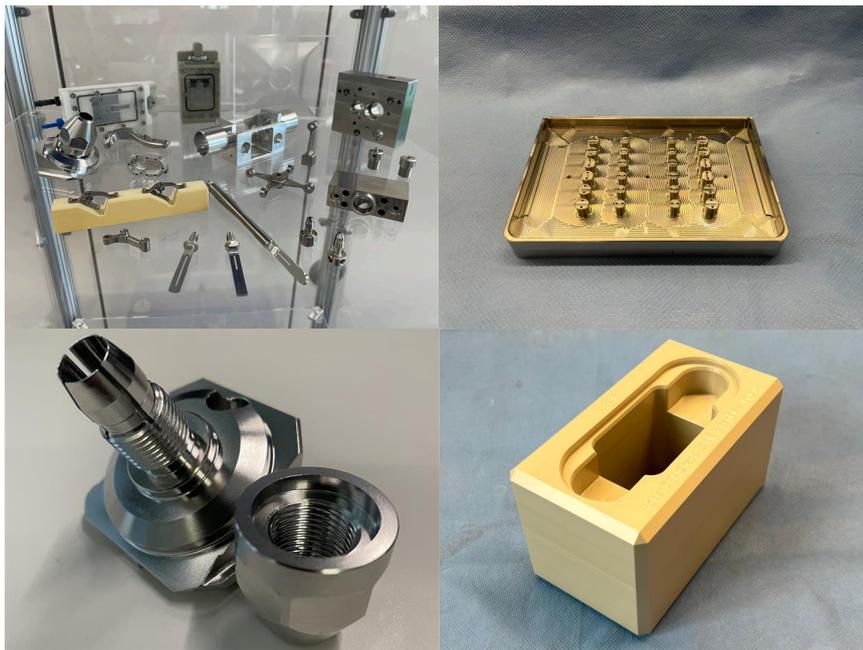

Fig. 1: Examples of parts we manufacture at the MDP Workshop such as a milled part made of stainless steel (top right) or a dental implant holder for load testing in dentistry (bottom left).
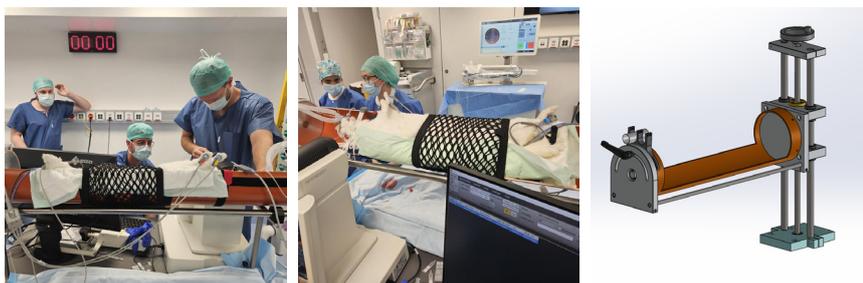

Fig. 2: One of this year's projects, the rabbit holder, in the operating room (left and middle) and its digital model (right).

Research Equipment Design and Manufacturing

The requirements for a workshop that supports research in the field of biomedical engineering are as diverse as the field of research itself. The diversity of topics investigated at ARTORG and by external research partners leads to a range of different design and manufacturing requirements, from prototypes for clinical and surgical instruments to devices for mechanical, biological, and kinematic testing, to accessories for imaging systems and calibration equipment.

Rabbit Holder for Intraoperative Corneal Imaging

Animal experiments pose substantial practical challenges: anatomical variability, sedation, and the natural inability of animals to comply with instructions make precise positioning extremely difficult. Yet, acquiring high-quality images during surgery is essential to verify that new surgical techniques and instruments function as intended.

In collaboration with the Computational Bioengineering Group (CBE), the machine shop designed and fabricated a dedicated rabbit holder to enable accurate measurement of the corneal surface during corneal refractive surgeries. The system centers on a half-cylindrical tube in which the sedated rabbit can safely lie. The tube can rotate 180° in both directions, and the animal is secured using a custom safety net around the body and an adjustable head strap.

A spindle-and-rod mechanism allows controlled elevation of the tube, while a robust clamping system anchors the entire device to the operating table. Once the rabbit is positioned and secured, the tube can be raised and tilted with precision so that the eye aligns correctly with the optical coherence tomography system, which allows precise measurement of the eyeball's geometry. This controlled positioning enabled reliable, repeatable ➜

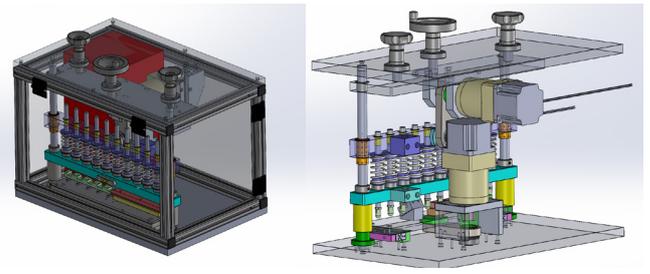**Fig. 3:** Front-left and front view of the finished Chewing Simulator.   **Fig. 4:** CAD-Model of the Chewing Simulator developed for ZKM.

Fig. 5: HR-pQCT Phantom Bone with layered structure, and individual bone samples in the PMMA tube (right).

acquisition of postoperative corneal scans directly in the operating room. The resulting device significantly improved the consistency and quality of intraoperative imaging, demonstrating the essential role of the machine shop in supporting complex surgical research.

Training and Education

The MDP group has a secondary role in training. This training encompasses the skills required to safely and proficiently operate machine shop tooling and equipment, the knowledge required to achieve the best results with a variety of materials and the skills needed to efficiently manage the design and production workflow.

In June 2025, our third-year apprentice Lio Ritschard, successfully passed his intermediate examination as a polymechanic with a grade of 5.6. We congratulate him on this excellent achievement.

In August 2025, Amiel Zaugg began his four-year apprenticeship as a polymechanic. For the first eight months, he will receive practical basic training in the Exact Sciences workshop under the supervision of Heinz Tschumi. In May 2026 he will then join the MDP workshop, completing our team and continuing his apprenticeship with us. We welcome him.

Developing and manufacturing a new Chewing machine simulator for the ZMK

The Clinic for Conservative Dentistry, Preventive Dentistry, and Pediatric Dentistry has two pneumatically driven chewing simulators with a vertical axis.

In January 2025, we were commissioned by ZMK to design and manufacture a new chewing simulator with an electric drive in the vertical and horizontal axes to simulate improved chewing motion. Ten dental implants can be tested simultaneously on the new chewing simulator. The drives and the machine's design are configured so that the implants can be loaded with a force of 50N to a maximum of 250N at a frequency of 1.5 Hz. The test cycles range between $1*10^6$ to $5*10^6$ repetitions. Under this load, the implant is additionally moved by 0.7 mm in the horizontal axis to simulate improved chewing movement.

We would like to take this opportunity to thank Mr. Leuch from UIKER, who has provided us with excellent support in selecting all the electronic components and implementing the control software.

ISO – 13485 Certification

The ARTORG QMS ISO 13485 is being established with the workshop included within its scope.

HR-pQCT Phantom (Musculoskeletal Biomechanics MSB)

The global prevalence of obesity has almost tripled over the past four decades. The resultant weight-loss treatments can lead to a substantial loss of adipose tissue. Such longitudinal changes may compromise the accuracy of volumetric bone mineral density (vBMD) as measured by high-resolution peripheral quantitative CT (HR-pQCT) imaging. To quantify the non-linear impact of beam hardening caused by soft tissues, a custom-made

phantom was manufactured to accommodate embedded distal bone sections for HR-pQCT scanning. A crescent-shaped PMMA element was fixed to the innermost cylinder to ensure reproducible radial positioning. Successively, several discs of PMMA of increasing thickness (in 5 mm increments) were placed over the outer diameter of the samples to simulate the effect of soft tissues surrounding the bone. The two ends of the phantom were made compatible with the XtremeCT II fixation system (Scanco Medical AG, Brüttisellen, Switzerland).

Retirement and new leadership in the MDP-workshop

After 34 years as workshop manager at the MDP-workshop, Urs Rohrer took his well-deserved retirement at the end of June 2025. At this point, the MDP team wishes him much happiness and good health for the next stage of his life. Thank you very much for the cooperation, which has enabled the workshop to continue running smoothly.

His successor, Ralf Kreienbühl, took over management of the workshop on July 1, 2025. Ralf is a trained Polymechanic with many years of experience in CAD-, CAM- and CNC-manufacturing and operational maintenance, and training of apprentices.

He acquired his skills in managing a workshop through, among other things, a two-year advanced training course in his former profession, qualifying as a "Federally certified printing industry specialist." He also brings leadership experience from previous positions as workshop manager.

Dissertations

Osman Berk Şatir

Computational Bioengineering

Deep learning for automatic characterization of shoulder bone and muscle morphology and degeneration from CT images

Mathieu Simon

Musculoskeletal Biomechanics

Multi-Scale Bone Morphology Property Relations in Ageing and Disease

Matteo Frigelli

Computational Bioengineering

Localized Corneal Stiffening for Refractive Correction: Experiments and Computational Analysis

Michael Single

Gerontechnology and Rehabilitation

Digital Biomarkers to Characterize Motor Functions of People with a Neurodegenerative Disease

Christina Wapp

Musculoskeletal Biomechanics

The Development of a Personalised Fragility Hip Fracture Risk Calculator

Aurelia Bucciarelli

Cardiovascular Engineering

Dynamics of Red Blood Cell Partitioning and Flow in In Vitro Microvascular Networks: The Roles of Lingering Red Blood Cells and Pericyte

Lorenzo Ferrari

Cardiovascular Engineering

Experimental Flow Field Assessment of Surgical Valve Prostheses with Tomographic Particle Image Velocimetry: Impact of Model, Size and Cardiac Output

Fei Wu

Artificial Intelligence in Medical Imaging

Alleviating the Issue of Annotation Scarcity in Semantic Segmentation using Active Learning

Vahoura Tahsini

Artificial Intelligence in Medical Imaging / Computational Bioengineering

Material characterization of the cornea, lens, and sclera in healthy eyes with age

Tobias Weber

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