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An African spurred tortoise with a wound on the plastron. The tortoise was examined using our photon-counting detector CT and came from the Tropicarium next to Kolmården Wildlife Park.

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Facts and figures of the fiscal year of 2024.



s we look back on 2024, we do so with a sense of pride and inspiration. This year has marked significant progress for CMIV, driven by curiosity, collaboration, and a shared commitment to advancing medical imaging science.

A particularly encouraging development has been the growing interest from clinicians in referring patients for cutting-edge photon-counting CT examinations. This increasing clinical engagement highlights the translational strength of our research and the confidence in new imaging technologies to improve diagnostics and patient outcomes.

Our research community continues to thrive. Through our research school, we've seen remarkable engagement and productivity. A highlight of the year was the retreat in Söderköping – two days filled with insightful dialogue and knowledge exchange between our scientific council and PhD students, reinforcing the strong academic spirit that defines CMIV.

Among this year's standout achievements are two flagship projects: Abbreviated MRI to Screen for Hepatocellular Carcinoma and AI Quantification of SCAPIS Calcium Score CT. Both represent our ambition to turn complex research into practical tools that benefit patients. Another highlight has been the success of our unique initiative: the Research School Run by the PhD Students Themselves – a testament to the energy and ownership within our next generation of researchers.

To meet the growing demand for MRI-based research and address the shortage of radio-graphers with MR expertise, the CMIV Board made the strategic decision to directly employ research radiographers. In August, we welcomed two highly skilled professionals to our team.

Additionally, with increasing research and research exam bookings, we have strengthened our administrative capacity by hiring both a finance administrator and a research booking administrator – two valued team members whose professionalism and initiative have quickly become essential to our daily operations.

Throughout 2024, we have remained steadfast in our mission: to improve patient care and individual health through excellence in medical image science and visualization. None of this would be possible without the continued collaboration between the university, healthcare providers, industry, and our invaluable support staff.

Together, we have made 2024 a year of growth, innovation, and meaningful progress – cementing CMIV's role as a center of scientific excellence and a beacon for future medical breakthroughs.

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Anders Persson
DIRECTOR OF CMIV





CMIV Affiliated Researchers Recognized at the Spring Academic Ceremony

CMIV was prominently represented at Linköping University's Spring Academic Ceremony. Milda Pocevičiūtė was conferred her doctoral degree and received the traditional hat and diploma, while Petter Dyverfeldt was formally installed as professor. PhD student Twan Bakker contributed musically, performing fanfares for all newly installed professors, graduates, and award recipients. CMIV Director Professor Anders Persson also took part in the celebration.

A special highlight of the ceremony was the recognition of Professor Tino Ebbers, affiliated with CMIV and a researcher in physiological measurements at the Faculty of Medicine and Health Sciences, who received the 2024 Onkel Adam Prize for his pioneering work at the intersection of medicine and technology. He is recognized for his groundbreaking research on quantifying and visualizing physio-

logical processes in the cardiovascular system. His contributions have been instrumental in developing techniques that enhance the understanding of the human body, some of which are now implemented in healthcare. This award highlights the impact of his work on both research and clinical practice. Acting University Director Professor Per-Olof Brehmer presented the award.



Professor Per-Olof Brehmer and Professor Tino Ebbers

Collaboration with Mayo Clinic on 4D Flow CT

Mayo Clinic, whose main facility is located in Rochester, Minnesota, is ranked as one of the most esteemed hospitals and healthcare organizations in the world. In 2022, Mayo Clinic employed 76,000 people and served more than 1.3 million patients from all 50 states and 138 countries

The CT Clinical Innovation Center (CT-CIC) at Mayo Clinic was established in 2004 in partnership with Siemens Healthineers.

The center was formed under the leadership of Drs. Cynthia H. McCollough and J.G. Fletcher to advance the field of CT imaging by developing and validating CT applications directly relevant to the diagnosis, understanding, and treatment of disease. CT-CIC was one of the early adopters of Photon-Counting Detector CT (PCD-CT) and has been an important research and validation partner in industrial development.

After several successful collaborations between CT-CIC and CMIV, Jonas Lantz and Linus Ohlsson from CMIV were invited to spend the fall at CT-CIC as Visiting Scientists. The aim of their visit was to combine knowledge and experience in PCD-CT from the two centers to evaluate and quantify the geometry and motion of the mitral valve. Results were then used to perform functional fluid quantifications with 4D Flow CT – a framework that was invented and is continuously developed at CMIV and the Cardiovascular Imaging and Modelling Cluster (CIM).

The project showed that, using optimized PCD-CT images of mitral valves, it is possible to extract the complex motion pattern of the annulus and leaflets both before and after mitral valve interventions. Functional and hemodynamic quantifications were shown to be similar to clinical measurements with MRI and echocardiography. This paves the way for future methodological development of 4D Flow CT for cardiac applications, which could enhance patient-specific optimization of treatment options and interventional planning.



Linus Ohlsson and Jonas Lantz.

CMIV Researchers at the ISMRM in Singapore

Three CMIV researchers presented their work at the 2024 Annual Meeting of the International Society for Magnetic Resonance in Medicine (ISMRM) in Singapore. PhD students Chiara Trenti and Shan Cai gave power pitches on referenceless 4D Flow MRI for cardiac imaging and 3D MR elastography for liver disease, respectively. Postdoc Sohaib Ayaz Qazi presented a digital poster on deep learning-reconstructed 4D Flow MRI. Additional posters covered topics such as wall shear stress and liver fat quantification, highlighting CMIV's strong contributions to advanced imaging and AI in clinical research.



Chiara Trenti, Sohaib Ayaz Qazi and Shan Cai at ISMRM in Singapore.

Showcasing Swedish AI in Healthcare at House of Sweden

CMIV was honored to be part of the "Artificial Intelligence IRL – How Sweden is Putting AI to Good Use" exhibition at House of Sweden in Washington, D.C. Highlighting Sweden's innovative use of AI, CMIV was showcased as a leading example in medical research, where AI-driven applications and entrepreneurship have resulted in several spin-off companies. CMIV Director Anders Persson attended the opening in March 2024. The exhibition runs until June 2025.



One of the examples of the use of AI in medicine from CMIV at House of Sweden in Washington.

CMIV and MARS Bioimaging Partner to Advance Medical Imaging

CMIV has entered a new collaboration with MARS Bioimaging, a leader in spectral photon-counting CT (SPCCT) technology. This partnership aims to push the boundaries of medical imaging by exploring new applications for photon-counting CT, particularly in cancer research and precision medicine.

The collaboration, led by CMIV Director Professor Anders Persson and MARS Chief Medical Officer Professor Anthony Butler, will focus on refining imaging techniques to enhance material differentiation in complex biological samples. With the potential installation of a MARS scanner at CMIV, this partnership represents an important step toward more advanced diagnostics and improved healthcare outcomes.



Lee Jollans Wins Prestigious Award for Cardiac CT Research

At the ISCT (International Society for Computed Tomography) meeting in Toronto this September, CMIV researchers Erik Tesselaar, Bente Konst, Anders Persson, and Lee Jollans presented their latest scientific work. We are especially proud of Lee, who was awarded first place for their outstanding presentation, "Efficient Fully 3D Segmentation of Cardiac CT using Vision Transformers". This recognition highlights Lee's significant contributions to the field of medical imaging and AI-driven analysis. Congratulations, Lee, on this well-deserved achievement!



Lee Jollans with the diploma.

AI-Enhanced Mammography – A Research Breakthrough

CMIV PhD student Pantelis Gialias and researcher Håkan Gustafsson are leading a project exploring how artificial intelligence can support radiologists in mammography screening. The study, conducted at Linköping University Hospital, has gained significant attention for demonstrating that AI-assisted image analysis can enhance diagnostic accuracy while reducing workload.

The research, involving 15,500 cases, found that AI and radiologists largely agreed on identifying healthy tissue and potential abnormalities. Further studies suggest AI could even handle initial screenings, allowing radiologists to focus on complex cases. This approach may improve early cancer detection and optimize healthcare resources.



Pantelis Gialias and Håkan Gustafsson next to a mammography unit used for breast imaging.





oday, CMIV conducts focused front-line research within multidisciplinary projects providing solutions to tomorrow's clinical issues. The mission is to develop future methods and tools for image analysis and visualization for applications within health care and medical research.

CMIV has a unique structure in which research at the university provides health care with the opportunity of clinical benefits, while the industry gain from the research with such as spin-offs. The activities aim to balance different demands: the university focuses on publishing in high-quality journals and developing new products, while Region Östergötland expects the research and development to benefit patients. CMIV's organization, fully integrated within in the university hospital, provides the foundation to successfully meet these requirements. Basic research outcomes at the university can be applied in clinical research, leading to scientific publications and advancements in patient care.

The CMIV research projects can be described as links in a sequential imaging chain. Projects move dynamically through the chain and researchers from different disciplines work together to reach the goal of patient benefit. Currently, artificial intelligence and precision medicine are integrated parts of the imaging chain.

We are in the midst of a paradigm shift in healthcare. While focused research and development in every step of the chain remain crucial for continuous improvements in the quality of care, it is equally important to embrace new possibilities and allow research to extend into new dimensions. This adaptability is essential for maintaining a leading position in medical imaging, a principle CMIV is currently incorporating into its research strategies.

The advancements in precision medicine result from rapid developments in several ground-breaking areas. However, the impact of these advancements can be significantly enhanced when strategically combined. These areas encompass molecular biology, large-scale genetic sequencing, and artificial intelligence. CMIV is actively positioning itself at the forefront of this development, recognizing the synergies that can arise from integrating these diverse yet interrelated fields.

Precision medicine can be defined as a set of clinical, therapeutic, and diagnostic methods tailored for optimal disease management, taking into account individual variations among patients, often incorporating a genetic profile. Its primary goal is to offer more effective treatments, reduce adverse effects, and improve overall survival rates.

Furthermore, precision medicine extends its advantages to increased possibilities for identifying and, subsequently, preventing or mitigating diseases at an early stage. It enhances disease management for patients and contributes to the reduction of hospital stays.

The CMIV projects defy easy categorization as they dynamically traverse various research areas, consistently seeking inspiration from diverse fields. To visually represent the CMIV research landscape, we have created an overview table based on projects from the annual report. The table identifies key areas of involvement, classifying them into three main research domains: imaging data source, biomedical research area, and technical research area. Each of these main areas comprises several subareas, capturing the multidisciplinary nature of CMIV's research endeavors.



Marjan Firouznia.

IMAGING DATA SOURCE

Traditionally, the predominant data source at CMIV has been magnetic resonance imaging (MRI). This method's versatility allows for extensive opportunities in project-specific development. An additional advantage lies in the use of volunteers without restrictions imposed by radiation dose.

In the realm of computed tomography (CT), the advent of low-dose CT has facilitated larger prospective studies, and clinical examinations can be utilized for potent simulations. Since 2020, CMIV has stood as one of the few clinical research centers worldwide with access to the cutting-edge photon-counting CT technology. The latest photon-counting CT, now clinically approved, features two X-ray tubes and two detectors, offering unprecedented possibilities.

While MRI remains a major data source, there has been a rapid increase in data from digital pathology and photon-counting CT. The researchers' growing need to amalgamate data from diverse sources places substantial demands on infrastructure, particularly for data storage and access to computing power.

CMIV is currently engaged in several exciting studies across these fields. Another emerging area with a growing contribution is microscopy, where the ongoing digitization of clinical routines has paved the way for new applications in image analysis and deep learning.

BIOMEDICAL RESEARCH AREA

CMIV has a rich tradition in cardiovascular and neurology research, with other robust areas including musculoskeletal and gastrointestinal research. However, with new collaborative constellations emerging, projects are shifting away from a singular focus on individual organs, adopting a more holistic approach.

TECHNICAL RESEARCH AREA

A key aspect of CMIV is in its comprehensive approach, covering all technical areas within the imaging chain. This cross-disciplinary strategy ensures that scientific endeavors in one technology domain at CMIV benefit from in-depth knowledge of the characteristics of preceding steps and the subsequent utilization of results later in the chain.

The overview reveals a well-balanced distribution of CMIV projects in terms of technical contribution. This spans from data generation through acquisition and simulation to a diverse array of analytics and visualization methods.

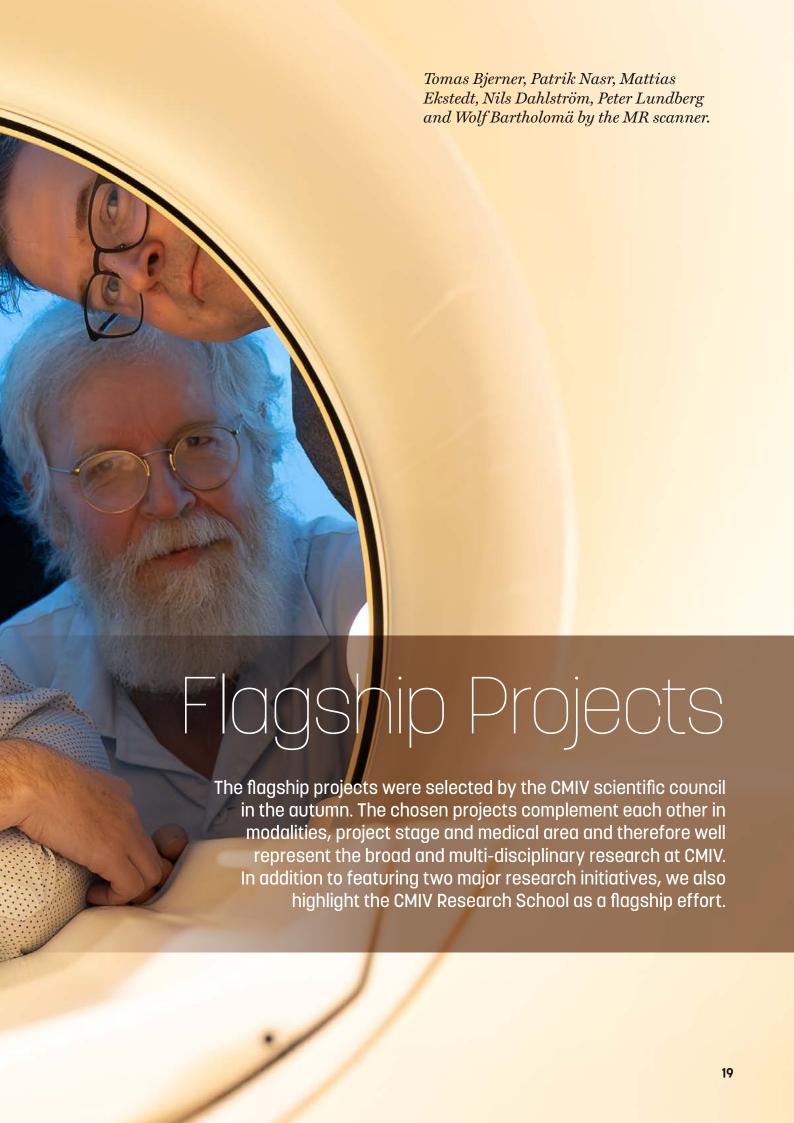
A SELECTION OF CMIV PROJECTS DIVIDED BY RESEARCH AREA

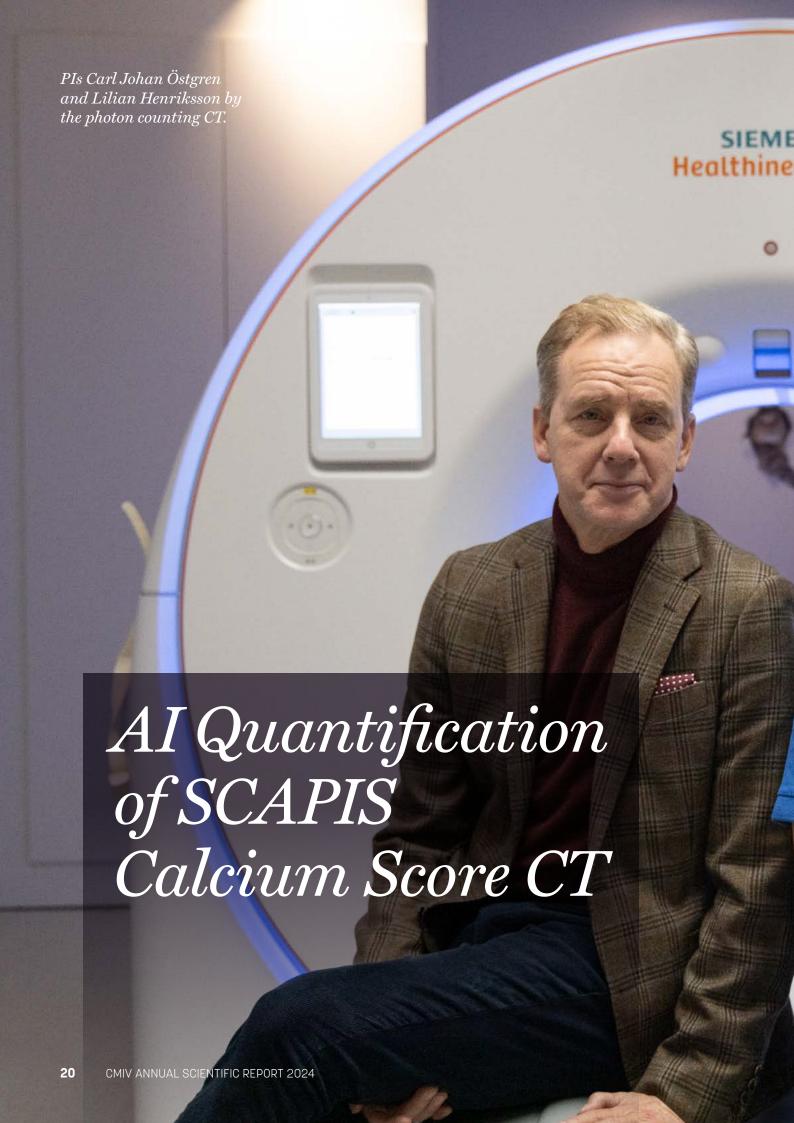
	Computed Tomography	Magnetic Resonance Ima	Digital Microsec	Ultrasound	Other	
Opportunistic AI Screening for Osteoporotic Vertebral Fracture Detection						
Bone Analysis for Reducing Fractures						
The NACOX-Study						
Photon-Counting CT of the Wrist						
Photon-Counting CT for Improved Prosthesis Imaging						
Aortic Stenosis - Calcium Burden and its Impact on Left Ventricular Function						
Novel Markers and Risk Factors for Ascending Aortic Dilation						
Predictive Value of Carotid MRI						
MR Turbulence Angiography						
Evaluating Antithrombotic Treatment Post-Coronary Artery Bypass Grafting with CT						
Chronic Coronary Syndrome in Swedish Primary Care						
4D Flow CT						
AIDA - Analytic Imaging Diagnostic Arena						
Evaluating Prevalence and Severity of NAFLD in Primary Care						
The ACCESS-ESLD Study						
AiMPLANTAI-Based Medical Record Screening for Patient-Safe MRI Examination						
Health Effects of Resistance Training in Postmenopausal Women						
Detect and Monitor Domain Shift						
Precision Panorama						
Bigpicture						
Spectral Photon-Counting CT Radiotherapy						
Medical Digital Twin						
BrAlnScap: Substudy Brain in Scapis 2						
Post-COVID, Chronic Fatigue, and Exhaustion						
Automatic Ventricle Segmentation Using 3D Quantitative MRI						
Localization of Seizure Onset Zone in Focal Epilepsy						
Detection and Neurological Effects of Manganese						
Improved Diagnosis of Pediatric Brain Tumours Using Al-Based Digital Pathology						
Ketamine Reduces Neural Self-Other-Distinction of Affective Touch						
Schizophrenia's Altered Sense of Self						
Spinal Cord Activity during Touch from Self and Other						
PoCo-19: a Multidisciplinary Study on Fatigue in Patients with Post-Covid Condition						
Evaluation of Reconstruction Methods in CT						
Elastography of the Liver						
Assessment of Hepatic Function in Health and Disease						
Artificial Intelligence in Mammography Screening						
MR-Mammography 3.0						

IMAGING DATA SOURCE

BIOMEDICAL RESEARCH AREA								-	TECHNICAL RESEARCH AREA								
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MIV PhD student Lilian Henriksson, who successfully defended her thesis in December, conducted an AI evaluation of calcium score CT as part of her research. Her study was based on data from participants in the SCAPIS study. SCAPIS – the Swedish CardioPulmonary bioImage Study – is a globally unique research project on the heart, blood vessels, and lungs, with Professor Carl Johan Östgren as the principal investigator in Linköping. The goal is to predict who is at risk of suffering a heart attack or stroke and to treat them before illness occurs.

The first phase of SCAPIS was completed in 2018, when 30,000 randomly selected Swedes aged 50–64 underwent comprehensive health examinations (including blood tests, questionnaires, and CT scans) at six locations in Sweden. Now, in SCAPIS 2, half of the participants are undergoing follow-up examinations. This time using a photon counting detector CT system.

Calcium scoring is a method used to measure the amount of calcification in the coronary arteries. By assessing this, a risk evaluation can be performed to estimate an individual's likelihood of developing CAD.

"Traditionally, CAD risk assessments are based on factors such as age, gender, smoking, and obesity. However, these provide a probability based on population statistics rather than individual data. With a calcium score, the evaluation is specific to the individual, offering a more accurate risk assessment," Lilian Henriksson explains.

In SCAPIS, calcium score evaluations were initially performed using traditional methods, where cardiologists and radiologists conducted a semi-automated assessment. A post-processing program automatically segmented all pixels in the CT images that could represent coronary calcifications. The reviewer then manually se-

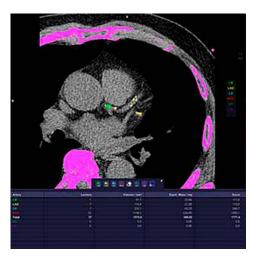
lected which of these pixels belonged to coronary calcifications. This process, conducted by either a cardiologist or a radiologist without a second review, required the reviewer to have completed the American Heart Association's basic coronary assessment training. Additionally, annual meetings were held to standardize the evaluation process.

CAD refers to atherosclerosis in the coronary arteries, where plaque builds up. These plaques can consist of various components, including fat and fibrosis. The process begins with fat deposition in the arterial wall, and over time, different mechanisms determine how the plaque evolves. "A fully calcified plaque is essentially scar tissue from a ruptured and healed plaque, similar to how skin heals from a wound," Lilian continues.

While calcified plaques do not necessarily block blood flow, an increase in plaque formation raises the risk of arterial obstruction. In some cases, plaques grow gradually, leading to angina (chest pain). In more severe cases, a ruptured plaque can cause a blood clot that completely blocks the artery, resulting in a heart attack or even sudden cardiac death. Many patients who suffer such serious events have had no prior symptoms, underscoring the need for reliable risk assessment tools.

Calcium scoring is primarily intended as a screening method for asymptomatic individuals with certain risk factors.

"Among the 5,056 patients examined in Linköping, more than half had no coronary calcifications. The participants, aged 50–64, displayed varying levels of calcification, which is common at that age. The greatest strength of calcium scoring is its ability to provide highly reliable predictions for individuals with no detected calcifications. These have a very low risk of coronary events within the next five to ten years," adds Lilian.



Expert thoracic radiologists or cardiologists traditionally perform calcium scoring evaluations using semi-automatic software, which involves manual identification and marking of CAC lesions. Advancements in artificial intelligence (AI) in radiology have emerged offering the possibility of assisting or potentially replacing human readers in this task. Thus, presenting an opportunity to alleviate clinical workload and enhance overall efficiency.

Unlike the traditional semi-automated review process, AI-based analysis evaluates the images independently. The software which is approved for clinical use automatically identifies coronary calcifications and presents the calcium score to the reviewer. AI can in this way serve as a first-line assessment, allowing the human reader to merely confirm or correct the results.

For this study, AI evaluations were conducted on the same dataset as the initial SCAPIS CSCT assessments, and the results were compared. The AI model's findings closely matched those of human reviewers. Discrepancies were found and analyzed in 402 (8.8 %) of the included cases. This revealed that the human reviewers had made errors in 80 of these, mainly due to failure in detection of existing calcifications. AI contributing to the remaining errors, on the other hand, rarely missed calcifications but tended to misidentify image noise or artifacts as calcifications.

"Implementing AI in calcium scoring evaluations offers both efficiency and quality improvements. A first assessment by AI could streamline the evaluation process, making it easier for human reviewers to provide fast and accurate assessments. A more reliable calcium score also strengthens clinical decision-making," Lilian concludes.



Lilian Henriksson, looking at the coronary arteries.

Computed Tomography | Cardiovascular | Acquisition | Al/Data analytics | Visualization | Imaging Biomarkers

Project information

PROJECT NAME

Al Quantification of SCAPIS Calcium Score CT.

PROJECT LEADER

Lilian Henriksson, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.
Carl Johan Östgren, Department of Health, Medicine and
Caring Sciences, HMV, Division of Prevention, Rehabilitation and Community Medicine.

MAIN PROJECT PARTICIPANTS

Anders Persson, Mårten Sandstedt, Patrik Nowik, Jan Engvall, Tino Ebbers, Mischa Woisetschläger.

GRANTS

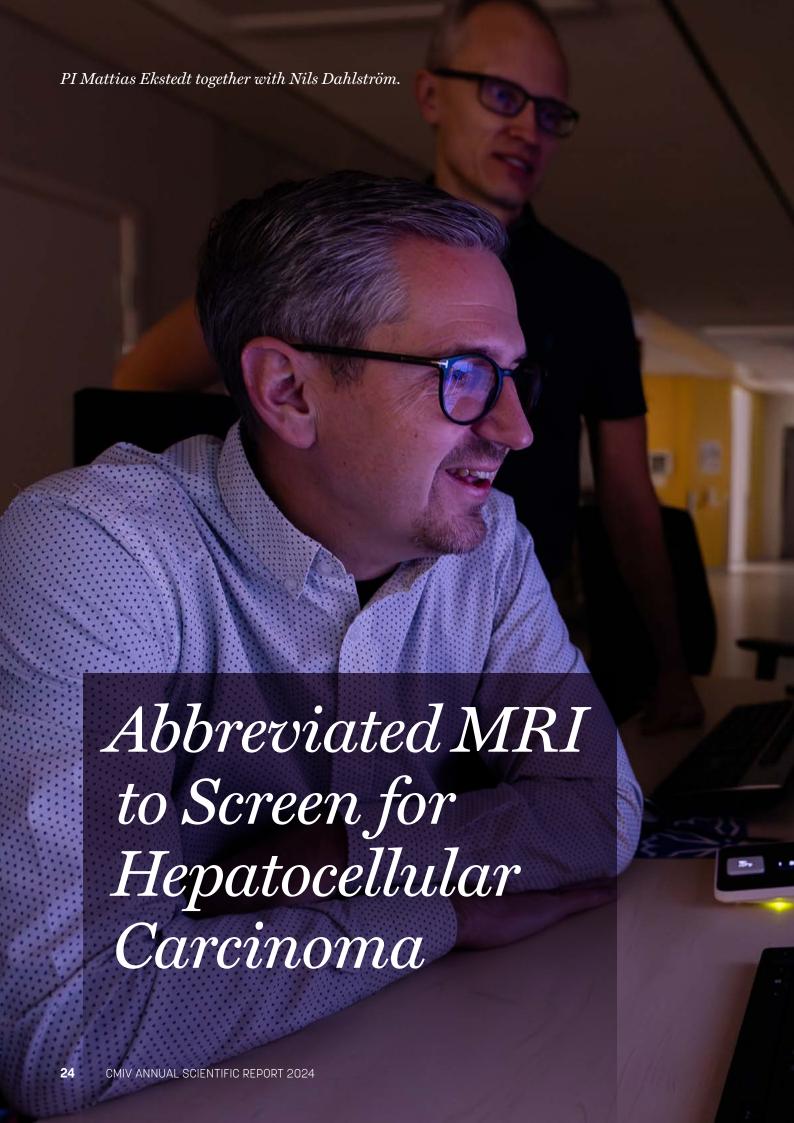
Local and Development Council in Östergötland

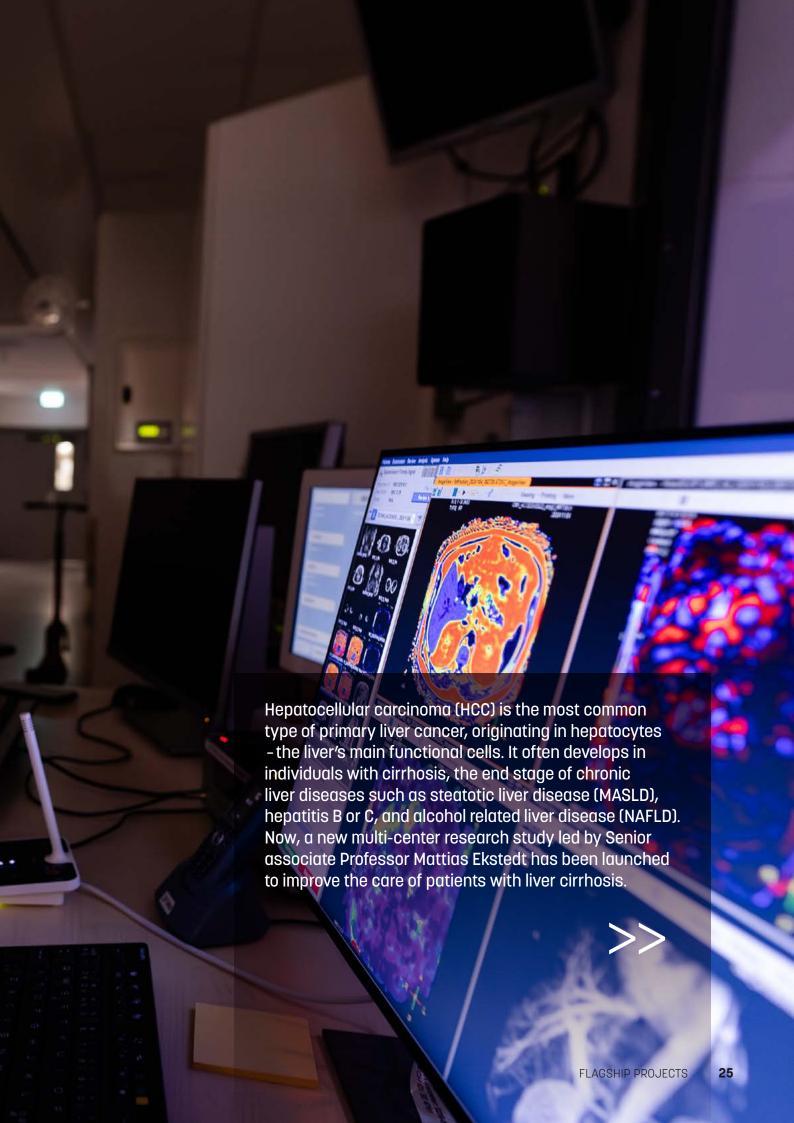
KEY PUBLICATIONS

Bergström G, Persson M, Adiels M, Björnson E, Bonander C, Ahlström H, Alfredsson J, Angerås O, Berglund G, Blomberg A, Brandberg J, Börjesson M, Cederlund K, de Faire U, Duvernoy O, Ekblom Ö, Engström G, Engvall JE, Fagman E, Eriksson M, Erlinge D, Fagerberg B, Flinck A, Gonçalves I, Hagström E, Hjelmgren O, Lind L, Lindberg E, Lindqvist P, Ljungberg J, Magnusson M, Mannila M, Markstad H, Mohammad MA, Nystrom FH, Ostenfeld E, Persson A, Rosengren A, Sandström A, Själander A, Sköld MC, Sundström J, Swahn E, Söderberg S, Torén K, Östgren CJ, Jernberg T. Prevalence of Subclinical Coronary Artery Atherosclerosis in the General Population.
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Sandstedt M, Henriksson L, Janzon M et al (2020) Evaluation of an Al-based, automatic coronary artery calcium scoring software. Eur Radiol DOI: 10.1007/s00330-019-06489-x.

Henriksson L, Sandstedt M, Nowik P, Persson A. Automated Al-based coronary calcium scoring using retrospective CT data from SCAPIS is accurate and correlates with expert scoring. Eur Radiol 2024 Oct 18. doi: 10.1007/s00330-024-1118-3.





SLD stands for End-Stage Liver Disease, which refers to the final, most severe phase of chronic liver disease. Patients with ESLD typically experience severe liver dysfunction, which can lead to life-threatening complications.

The DETECT-HCC-ESLD study (the DETECtion of HepatoCellular Carcinoma End-Stage Liver Disease) is a groundbreaking initiative aimed at improving the care of patients with liver cirrhosis. Led by Principal Investigator Senior Associate Professor Mattias Ekstedt, the study spans across 15 hospitals in Sweden, including all university hospitals. Finland and Iceland are also participating in this significant research effort.

Liver cirrhosis represents the final stage of chronic liver disease, marked by severe scarring that disrupts the organ's normal function. The primary culprits include alcohol-related liver disease, metabolic fatty liver disease, viral hepatitis, and autoimmune hepatitis. Cirrhosis develops gradually over decades, and while many patients remain asymptomatic, some experience severe liver failure and succumb to the disease within two years.

"One of the major challenges in managing liver cirrhosis is that it often remains undetected until it reaches an advanced stage. At this point, prognosis is extremely poor," Mattias says. Cirrhosis significantly increases the risk of liver cancer, with a 2–6% risk of developing cancer each year.

The primary goal of DETECT is to enhance diagnostic methods to identify liver cancer earlier and more effectively.

"Currently, cirrhosis patients undergo ultrasound screenings every six months to detect liver cancer. However, this method frequently fails to identify tumors in time. One reason for this is that the altered structure of a cirrhotic liver makes imaging challenging," Mattias continues. An alternative being explored is Magnetic Resonance Imaging (MRI). Traditional liver MRIs are lengthy and expensive, but recent research suggests that a shortened MRI protocol could be just as effective, or even superior, to ultrasound.

The DETECT study evaluates both ultrasound and an abbreviated MRI protocol on the same day to determine which method yields better results. At some hospitals, patients undergo a 45-minute MRI scan, while others receive a streamlined 30-minute protocol. At CMIV, the longer protocol is implemented. The study also investigates experimental imaging techniques, including Magnetic Resonance Elastography (MRE). MRE assesses liver stiffness by measuring vibrations within the organ, providing critical insight into disease progression.

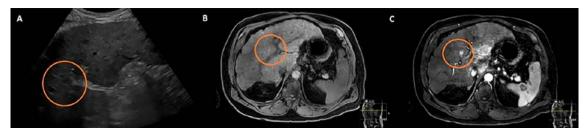
A key collaboration in the study is with AMRA Medical, which specializes in body composition and muscle health analysis. Since cirrhosis patients frequently suffer from muscle loss, or sarcopenia, the study examines how muscle deterioration correlates with liver disease progression. Another partner, Antaros Medical, is responsible for processing and analyzing imaging data from all participating hospitals. Additionally, pharmaceutical company Takeda supports the study.

Patients included in the study are those already being treated for liver disease at participating hospitals. Cirrhosis, though not exceedingly rare, is becoming more prevalent due to rising obesity rates and the increasing incidence of fatty liver disease.

If the DETECT study proves successful, the next step will be to standardize MRI as a routine screening tool for liver cancer. Researchers also aim to determine optimal screening intervals – potentially reducing the frequency of scans from semiannual to annual screenings while maintaining or improving diagnostic accuracy. The ultimate goal is to influence global guidelines for cirrhosis management and cancer detection.



Wolf Bartholomä and Patrik Nasr by the MR scanner.



HCC-surveillance of a patient with liver cirrhosis with ultrasound (A), non-ceMRI (B), and ceMRI (C). As noted the HCC-lesion is only visible on the MRI-scans.

Beyond improving cancer detection, DETECT aims to enhance overall patient care for cirrhosis sufferers. "Historically, these patients have been an overlooked group in medical research, despite their severe illness and poor prognosis. Additionally, the stigma associated with liver disease, particularly its link to alcohol abuse, has contributed to the neglect of cirrhosis patients in scientific studies. By focusing on this patient group through an ambitious and high-profile research initiative, DETECT also seeks to challenge and reduce the stigma surrounding liver disease," concludes Mattias.

With its comprehensive approach, innovative imaging techniques, and international collaboration, the DETECT study has the potential to revolutionize the diagnosis and management of liver disease, offering new hope for patients worldwide.



Project information

PROJECT NAME

Comparison between abbreviated MRI and ultrasound for the surveillance of HCC in patients with cirrhosis – The DETECT-HCC-ESLD-trial.

PROJECT LEADER

Mattias Ekstedt, Department of Health, Medicine, and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

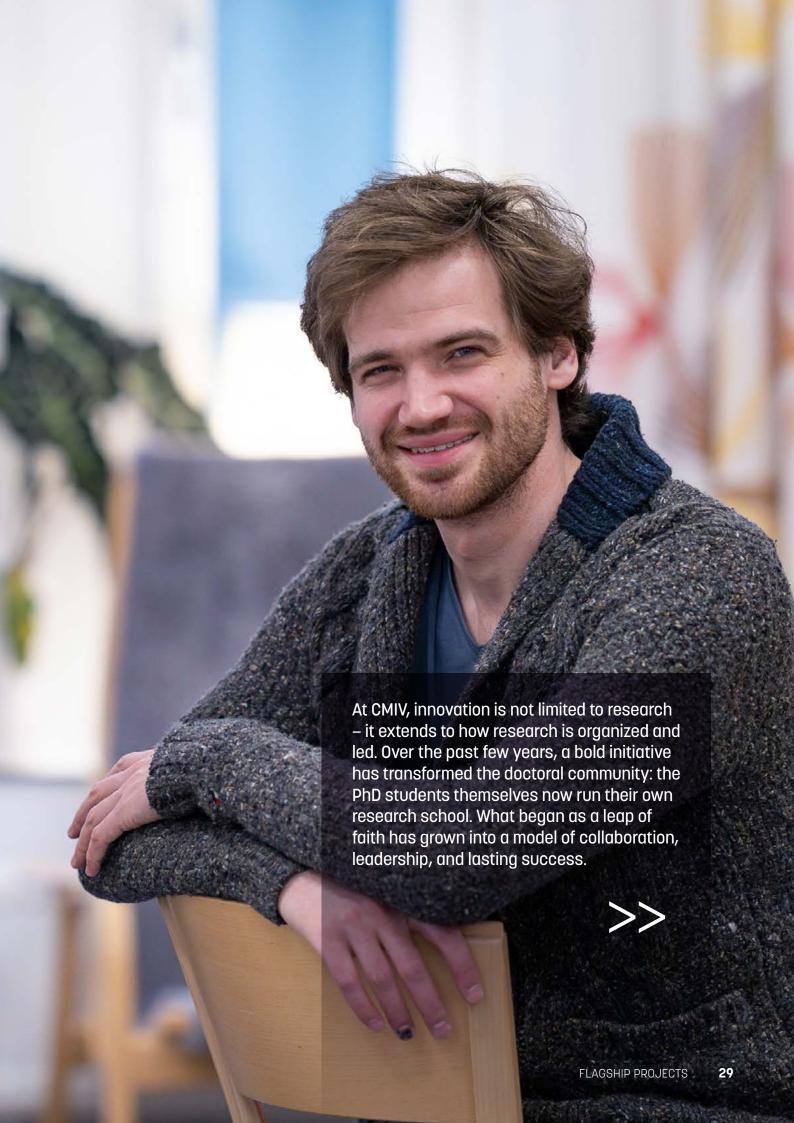
Patrik Nasr, Stergios Kechagias, Peter Lundberg, Wolf Bartholomä, Nils Dahlström, Tomas Bjerner, Mikael Forsgren, Olof Dahlqvist Leinhard, Signe Swerkersson Cecilia Jönsson.

GRANTS

Cancerfonden Al F PhD students Christoforos Spyretos and Twan Bakker.



A Research School
Run by the PhD
Students Themselves
- A Success Story



or nearly 25 years, CMIV has hosted a research school for PhD students across both medicine and engineering. Over the years, 87 PhD students have successfully defended their theses.

In the early days, the research school was managed by appointed directors of studies. But in late 2020, a new chapter began when the PhD students themselves proposed a bold idea to the Scientific Council: they wanted to take on greater responsibility for running the school. The council welcomed the initiative – and the rest is history.

What followed has proven to be a true success story. PhD students Sophia Bäck and Milda Pocevičiūtė were appointed chair and vice chair, respectively, and were also invited to join the Scientific Council to report on progress and receive guidance. Despite the challenges of the pandemic and remote working, they succeeded in strengthening the doctoral student community and organizing monthly research school seminars.

The proposal approved by the council outlined key responsibilities for the chair and vice chair: to host regular meetings and seminars, keep PhD students informed about activities at CMIV, organize the annual research school retreat, and a dedicated workshop in the spring of 2021. Since then, the chair and vice chair teams have organized a wide range of workshops at the annual retreats – covering topics such as crafting compelling graphical abstracts, effective visualization techniques, and how to capture and hold an audience's attention during presentations.

In 2022, Milda took over as chair while Sophia stayed on as vice chair for the first half of the year. Together, they began planning for a smooth handover by identifying the next candidate for the vice chair role. In mid-2022, Gustav Magnusson stepped into that role. Around this time, a new model was introduced: a staggered leadership structure where each vice chair would become chair in the second half of their one-year term. This system has worked remarkably well.

After Milda's term, Gustav became chair and was succeeded by Linus Ohlsson as vice chair. Half a year later, Linus stepped into the chair position and Anna Ljusberg became vice chair. As of 2024, leadership continues to evolve. In March, Twan Bakker joined as vice chair. In September, following the annual retreat, Anna stepped down and Christoforos Spyretos assumed the vice chair role. In March 2025, he will become chair as Twan completes his term.

CMIV has become a vibrant meeting point for doctoral students with diverse research interests. Currently, our PhD student community represents nine different countries. While we cannot accommodate all students physically at CMIV, many still join our seminars and social events. These gatherings often bring together affiliated PhD students from across Linköping University and have included everything from waffle nights and foosball tournaments to casual afterwork events.

We are not entirely sure what the secret recipe for their success is – but one thing is clear: when PhD students take initiative and support each other, a powerful upward spiral of positive energy is created. We are incredibly proud of what these students have accomplished together and of the strong, welcoming community they have built. Their engagement and leadership continue to enrich CMIV in invaluable ways.



Sophia Bäck and Milda Pocevičiūtė.



Twan Bakker and Anna Ljusberg.



Anna Ljusberg, Linus Ohlsson and Gustav Magnusson.





Opportunistic Al Screening for Osteoporotic Vertebral Fracture Detection

Osteoporotic fractures are very common, serious, and costly. They affect every second woman and every fourth man over the age of 50 and are associated with increased mortality, permanent physical disabilities, and chronic pain. In Sweden, the healthcare costs related to osteoporotic fractures are estimated at 2.3 billion Euros per year. Although effective treatments exist, osteoporosis remains largely underdiagnosed and undertreated.

Vertebral fractures pose a particular challenge, as fewer than one-third of affected patients are identified within today's healthcare system. At the same time, these fractures significantly increase the risk of future osteoporotic fractures. Patients with vertebral fractures have a strong indication for treatment, and available medications effectively reduce the risk of subsequent serious fractures. Opportunistic screening for vertebral fractures has long been proposed as a means to improve detection and treatment rates. However, previous initiatives to bridge this gap have been costly and inefficient. Advances in technology, including AI-supported screening for vertebral fractures, have the potential to be a game changer.

Our research group has been working with AI solutions over the past few years and has recently demonstrated the high accuracy of the AI algorithm "Flamingo" (approved in November, 2023), achieving a sensitivity of 86% and a specificity of 99% in opportunistic vertebral fracture detection (VertAIdo Phase 1). However, for AI to be implemented clinically, it must be carefully integrated into an established clinical workflow, such as a fracture liaison service, involving multiple medical specialties. In this project, we have now integrated the AI algorithm into the clinical system (VertAIdo Phase 2) and will evaluate its clinical effectiveness and health-economic impact (VertAIdo Phase 3).

Computed Tomography Musculoskeletal AI/Data analytics

Project information

PROJECT NAME

Opportunistic Al screening for osteoporotic vertebral fracture detection: The VertAidoproject (vertebral fracture AI detection for better osteoporosis care).

PROJECT LEADERS

Anna Spångeus and Mischa Woisetschläger, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Tomas Bjerner, Maria Lindblom, Evangelia Baldimtsi, Linda Viborg, Erika Gustafsson.

Vinnova/Medtech4Health (2024-2026) Vinnova/AIDA (2022–2024) ALF 2025



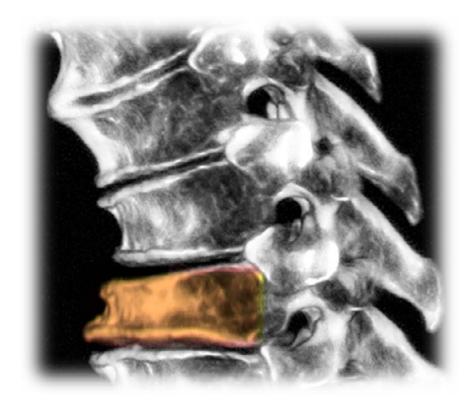


Figure 1: The image shows part of the spine with a vertebral fracture highlighted.

Al for vertebral fracture detection aligned with Fracture liaison services (FLS) Major Routine care Radiologist clinical Excl. incidental findings reading in clinical Clinical Dr CT scan Report handling Handle the major finding (nonflow (eg pneumonia tumouretc) incidental) FLS or AI - clinical flow Radiologist **Primary** Handle the incidental finding (in our "Flamingo Health case verterbal fractures, VF). VF are Dr" led to correct instance directly from care radiology.

Figure 2: Opportunistic screening for vertebral fractures using an Al algorithm (Flamingo). The process involves a parallel workflow for managing vertebral fractures, which includes radiologist confirmation of the Al findings and clinical triaging of the patient through fracture liaison services (FLS), which involve nurses and physicians specialized in osteoporosis.

Bone Analysis for Reducing Fractures

People suffering from osteoporosis have increased risk for fractures. When studying osteoporosis, the amount of mineral in bone is measured. This bone mineral density (BMD) is lower in osteoporotic bone. Research have shown that bone microstructure, seems to be more important for its strength than the reduced mineral content. The internal bone microstructure consists of a network of thin bone structures called trabeculae. This can be measured by different parameters like thickness, number and the distances between them. Measurements of the compact bone structure, with porosities, is also of high importance. Earlier, the 3D microstructure of humans could be studied only by microscopy and by micro-computed tomography (micro-CT) of specimens removed from the body.

This project aims to study the 3D structure of bone structure in living humans, by using clinical methods available in a radiological department, in particular CT devices. Since the bone trabeculae often are less than 0.1 mm thick, the limited resolution of CT may be a problem. We have therefor focused on examinations from CT devices at high resolution. The main goal is to develop automatic image processing techniques for as accurate measurements as possible using these image data sets.

Data from dental cone beam CT (CBCT) shows very strong correlations for bone microstructure when compared

to micro-CT, with many papers from our group published in different journals. Another CT device with high resolution is photon-counting detector (PCD) CT. This is a very novel technique available only in a few radiology departments around the world. One of the devices is installed at CMIV. This technique is very promising since it allows high resolution also of central body parts like the hip and vertebrae where osteoporotic fractures are common.

In our most recent study, which is a clinical study in cooperation with Department of Endocrinology at Linköping University, dental CBCT-data of forearm of 21 patients showed strong correlations with DXA regarding bone mineral content and bone strength. This paper is recently published in "Scientific Reports".

Bone structure and strength is of importance in other diagnostic problems, like i.e., rheumatoid arthritis, dental implant installation and fractures in the facial skeleton. In our research we study bone structure *in vitro* (human and animal specimens) and *in vivo* of bones from different parts of the skeleton.

In the future, we hope that our research and automatic segmentation method will be useful in early detection of osteoporosis. With better tools to bone measurements, it will be possible to diagnose osteoporosis at an earlier stage which will result in reducing the number of future painful fractures.

Computed Tomography Musculoskeletal
Visualization

Project information

PROJECT NAME

Bone microstructure, strength and composition derived from imaging data of different CT devices: relation to osteoporosis and fractures.

PROJECT LEADER

Eva Klintström, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Benjamin Klintström, Mischa Woisetschläger, Örjan Smedby, Rodrigo Moreno, Anna Spångéus, Alexander Malusek, Erik Tesselaar

GRANTS

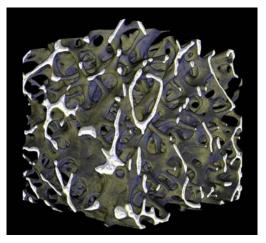
ALF Grants, Region Östergötland

KEY PUBLICATIONS

Yijun Zhou, Eva Klintström, Benjamin Klintström, Stephen J. Ferguson, Benedikt Helgason Cecilia Persson. A convolutional neural network-based method for the generation of super-resolution 3D models from clinical CT images. Computer Methods and Programs in Biomedicine, 2024-03-01, Volume 245, Article 108009, https://doi.org/10.1016/j.cmpb.2024.108009.

Klintström, B., Henriksson, L., Moreno, R.,
Malusek A., Smedby Ö., Woisetschläger
M., Klintström E. Photon-counting detector
CT and energy-integrating detector CT for
trabecular bone microstructure analysis
of cubic specimens from human radius.
Eur Radiol Exp 6, 31 (2022). https://doi.
org/10.1186/s41747-022-00286-w.

Klintström E, Klintström B, Pahr D, Brismar TB, Smedby Ö, Moreno M. Direct Estimation of Human Trabecular Bone Stiffness Using Cone-Beam Computed Tomography. PLoS ONE, Vol. 11, nr 8 2016. https://doi. org/10.1016/j.oooo.2018.03.014.











Upper row: To the left a 3D rendering of a bone specimens from a human forearm and to the right a 3D rendering of a human forearm imaged by CBCT in vivo. Lower row: To the left a 2D image of the right mandible from a patient with osteoporosis with sparse trabecular bone and multiple erosions in the cortical bone. In the middle a jaw joint with erosions in a patient with rheumatoid arthritis. To the right a lamb skull with metal plate in the orbit and many tiny bone structures in the nasal cavity.

The NACOX-Study

Anterior cruciate ligament (ACL) injury in the knee joint can result in joint instability, decreased functional performance, reduced physical activity, and quality of life. Treatment options are rehabilitation alone or combined with ACL reconstruction. The most important long-term consequence is the increased risk of posttraumatic osteoarthritis (PTOA). The underlying mechanisms behind PTOA are not well understood, but altered biological processes due to injury and joint bleeding, as well as concomitant structural injuries to the cartilage and the subchondral bone, have been suggested to be of relevance. Despite the development of new treatment techniques and extensive research, the complex and multifaceted nature of ACL injury and its consequences is yet to be fully understood.

The overall aim of the NACOX study is to evaluate the natural corollaries and recovery after an ACL injury.

The NACOX study is a multi-centre prospective cohort study of patients with acute ACL injury. At seven sites in Sweden, we have included 275 patients aged 15-40 years within 6 weeks after primary ACL injury. Patients complete questionnaires at multiple time points, and a subgroup of 129 patients is followed with extensive imaging modalities, biological samples, and clinical examinations. We have up to 5 years of follow-up. We have 18 publications, and several analyses with a specific interest in imaging have been conducted and are planned. Examples include:

 Diagnostic accuracy of dual-energy CT (DECT) for the detection of bone marrow lesions in the injured knee using MRI as the reference method.

· Quantitative MRI analysis of cartilage matrix organization, as measured by T2 relaxation time, of the tibiofemoral joint cartilage after acute ACL injury, in both the injured and contralateral non-injured knee. Results showed small but statistically significant differences in the subacute phase between the ACL-injured and uninjured knee in cartilage T2 relaxation time and cartilage thickness, some of them related

- to joint loading after the injury and concomitant meniscus and cartilage injuries. Future longitudinal observations of the same cohort will allow for a better understanding of the early development of PTOA.
- Development of a classification score and review of the healing potential of the ACL fibers in the non-reconstructed knee, as well as for concomitant meniscus injuries.

Computed Tomography Musculoskeletal Acquisition Visualization Imaging Biomarkers

Project information

PROJECT NAME

NACOX -Natural Corollaries and Recovery after Acute Anterior Cruciate Ligament Injury.

PROJECT LEADER

Joanna Kvist, Department of Health, Medicine and Caring Science, Division of Prevention, Rehabilitation and Community Medicine

MAIN PROJECT PARTICIPANTS

Håkan Gauffin, Hanna Tigerstrand Grevnerts, Sofi Sonesson, Anne Fältström, Melanie Svensson, Bashir Tajik Edwardsson, Angie Liu, Anders Persson, Ann-Sofi Björkman, Martin Englund, Richard Frobell, Miika Nieminen, Victor Casula, Seppo Koskinen, Nicola Giannotti, Riccardo Cristiani, Leila Hassanlou, Simo Saarakkala, Mike Bowes.

Swedish Medical Research Council (2015-2024) Swedish Research Council for Sport Science (2017-2025) Medical Research Council of Southeast Sweden (2020-2024) ALF Grants Region Östergötland (2018-2024)

KEY DUBLICATIONS

Kvist, J., H. Gauffin, H. Tigerstrand Grevnerts, C. Ardern, M. Hagglund, A. Stalman and R. Frobell (2018). "Natural corollaries and recovery after acute ACL injury: the NACOX cohort study protocol." BMJ Open 8(6): e020543.

Casula, V., Tajik, B. E., Kvist, J., Frobell, R., Haapea, M., Nieminen, M. T., Gauffin H, Englund, M. (2022). Quantitative evaluation of the tibiofemoral joint cartilage by T2 mapping in patients with acute anterior cruciate ligament injury vs contralateral knees: results from the subacute phase using data from the NACOX study cohort. Osteoarthritis and Cartilage. doi:https://doi.org/10.1016/j. joca.2022.02.623.

Cristiani R, van de Bunt F, Kvist J, Stålman A. High Prevalence of Superficial and Deep Medial Collateral Ligament Injuries on Magnetic Resonance Imaging in Patients With Anterior Cruciate Ligament Tears. Arthroscopy 2023 doi: 10.1016/j. arthro.2023.05.029 [published Online First: 20230622].

• Cartilage thickness and bone shape changes were assessed over two years following acute ACL injury using active appearance models for precise measurement of cartilage boundaries and bone surfaces. Results showed increases in femoral cartilage thickness and decreases in patellar and trochlear regions, alongside small expansions in femoral and tibial condyle bone surfaces. These changes were consistent across treatment groups.

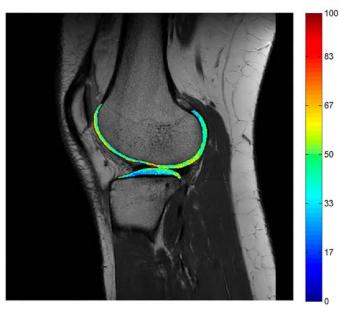


Figure 1: Figure from: Casula, V., Tajik, B. E., Kvist, J., Frobell, R., Haapea, M., Nieminen, M. T., Gauffin, H., Englund, M. (2022). Quantitative evaluation of the tibiofemoral joint cartilage by T2 mapping in patients with acute anterior cruciate ligament injury vs contralateral knees: results from the subacute phase using data from the NACOX study cohort. Osteoarthritis and Cartilage. doi:https://doi.org/10.1016/j.joca.2022.02.623.



Figure 2: Normal ACL. Intact ligament structure and fiber structure. Normal thickness and length of the ligament.



Figure 3: Ruptured ligament. Complete rupture of both ligament structure and fibers, with thickened ligament. Injury located in the middle third of the ligament.

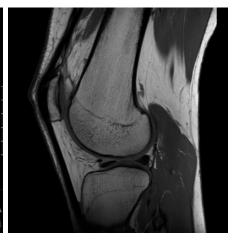


Figure 4: Sagittal T2-weighted MRI of the left knee from a patient with acute ACL injury.



Photon-Counting CT of the Wrist

Medical imaging continues to evolve, driven by our quest to provide more precise diagnoses and safer patient care. One promising development lies in the use of Photon-Counting Detector CT (PCD-CT). Our ongoing research compares PCD-CT to the traditional Energy-Integrating Detector CT (EID-CT) to better understand its applications in musculoskeletal imaging and imaging with metal implants, such as wrist prostheses.

A Clearer Picture of Fractures: Our research has continued to demonstrate the advantages of PCD-CT in assessing bone fractures, specifically scaphoid fractures of the wrist. Accurate evaluation of small bone fractures, like those of the scaphoid, is notoriously challenging due to the bone's shape and location. In our latest study, eight patients with scaphoid fractures were imaged at multiple stages post-trauma using both EID-CT and PCD-CT. The results showed superior image clarity in PCD-CT scans, allowing radiologists to more easily visualize bone structures and fracture lines.

In particular, the sharper details in PCD-CT provided more reliable diagnostic insights during the initial stages of trauma assessment. While both PCD-CT and EID-CT proved equally effective in evaluating the healing progress of the fractures over time, PCD-CT's ability to produce high-resolution images with smaller slice thickness (0.2 mm vs. 0.4 mm in EID-CT) resulted in consistently clearer views of the bone microstructure. This enhanced visibility helps clinicians make more informed decisions, potentially reducing the time patients spend in

New Findings in Dealing with Metal Artifacts: Another study within the project focuses on metal artifacts in CT imaging, which can obscure important de-

tails, especially in patients with implants. Metal artifacts typically manifest as streaks or distortions in the images, often due to the complex interaction between the metal and X-rays. To explore how PCD-CT can overcome these challenges, we conducted a study involving patients with titanium wrist prostheses. Here, we compared PCD-CT and EID-CT in terms of how well they manage metal-induced artifacts.

The findings showed that PCD-CT's virtual monoenergetic images (VMI) at 130 keV effectively reduced metal streak artifacts, significantly improving the visibility of bone near the implant. While PCD-CT polyenergetic images offered the best overall visualization of bone architecture, VMI proved invaluable for minimizing metal artifacts. This suggests that, depending on the diagnostic need, different reconstruction techniques can be used to maximize image quality - a valuable insight for optimizing post-surgery evaluations and ensuring a clear view of implant integrity and bone integration.

Looking Ahead: Our studies underscore the potential of PCD-CT as a promising tool for musculoskeletal imaging. It offers enhanced resolution and image quality, which can make a meaningful difference in both acute fracture diagnosis and long-term management of patients with orthopedic implants. Moving forward, we aim to refine imaging protocols further and continue exploring the capabilities of PCD-CT to visualize the bone-metal interface and to follow-up implant loosening, not only in the wrist but also in the hip and the knee.

The goal remains the same: to offer clinicians the best possible imaging tools to see more clearly, diagnose more accurately, and care for patients with greater confidence.

Computed Tomography Musculoskeletal

Acquisition

Project information

PROJECT NAME

IMPACT and IMPACT-METAL.

PROJECT LEADER

Erik Tesselaar, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Nina Kämmerling, Simon Farnebo, Mårten Sandstedt, Anders Persson.

RFOU Grants, Region Östergötland (2022-2024)

KEY PUBLICATIONS

Kämmerling N, Sandstedt M, Farnebo S, Persson A, Tesselaar E. Assessment of image quality in photon-counting detector computed tomography of the wrist - An ex vivo study. Eur J radiol. 2022 Sep;154:110442, doi: 10.1016/i. ejrad.2022.110442. Epub 2022 Jul 13. PMID: 35849959

Booij R, Kämmerling NF, Oei EHG, Persson A, Tesselaar E. Assessment of visibility of bone structures in the wrist using normal and half of the radiation dose with photon-counting detector CT. Eur J Radiol. 2023 Feb;159:110662. doi: 10.1016/j. ejrad.2022.110662. Epub 2022 Dec 20. PMID: 36565594

Kämmerling N, Tesselaar E, Booij R, Fornander L, Persson A, Farnebo S. A comparative study of image quality and diagnostic confidence in diagnosis and follow-up of scaphoid fractures using photon-counting detector CT and energy-integrating detector CT. Eur J Radiol. 2024 Apr;173:111383. doi: 10.1016/i. ejrad.2024.111383. Epub 2024 Feb 17. PMID: 38377892.

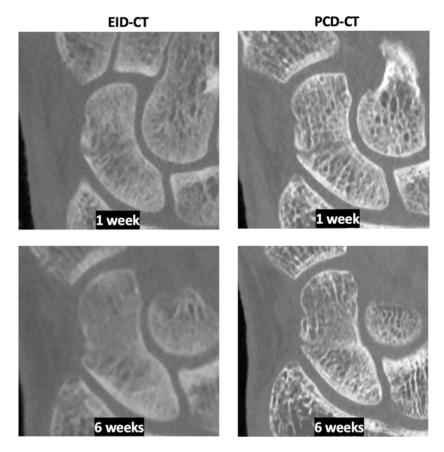


Figure 1. Wrist scaphoid fracture scanned using EID-CT (left) and PCD-CT (right) at 1 day and 6 weeks after injury. Note the better visibility of the fracture line and the trabecular structure on the inside of the bone.



Figure 2. Sagittal reconstruction of a Motec® Wrist Joint Prosthesis acquired using PCD-CT with polyenergetic reconstruction.

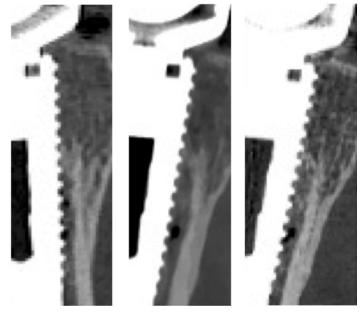


Figure 3. Coronal reconstructions of images obtained using (from the left) EID-CT, PCD-CT VMI and PCD-CT polyenergetic image showing the interface between the metal implant and bone. Streak artifacts are reduced in VMI reconstructions, while the trabecular structure is better visible in the polyenergetic image.

Photon-Counting CT for Improved Prosthesis Imaging

Annually, approximately 20,000 individuals in Sweden undergo hip replacement surgery. Despite the life-enhancing nature of these procedures, a significant challenge persists: ensuring proper integration of the prosthesis with the bone. Improper integration can lead to implant loosening, resulting in pain and necessitating revision surgeries. Early diagnosis of loosening or identification of other pain sources is crucial for timely intervention and patient care. Traditional radiographs, while effective for detecting severe loosening, lack the sensitivity to identify early issues of prosthetic loosening or differentiate between loosening and other causes of pain.

Photon-counting detector computed tomography (PCD-CT) represents a groundbreaking technology that with the potential to significantly enhance image resolution and reduce interference from metal implants. This project aims

to evaluate the potential of PCD-CT to improve diagnostics for prosthesis loosening and osseointegration. By providing sharper images and more precise material differentiation, this advanced imaging method could revolutionize patient care, enabling earlier and more accurate diagnoses while reducing unnecessary surgeries and patient suffering.

The study involves 35 patients who have suspected issues with their hip replacements. These patients will undergo both conventional CT (EID-CT) and PCD-CT scans. By comparing the two types of scans, researchers hope to answer several key questions: Does PCD-CT provide better image quality than EID-CT? Can PCD-CT improve the accuracy of diagnosing loosening and other pain causes? Is it possible to monitor bone healing around the prosthesis using PCD-CT?

Computed Tomography Musculoskeletal Acquisition Visualization

Project information

PROJECT NAME

Photon-Counting CT for Improved Prosthesis Imaging.

PROJECT LEADER

Jörg Schilcher, Department of Orthopedic Surgery and Department of Biomedical and Clinical Sciences, Linköping University Hospital.

MAIN PROJECT PARTICIPANTS

Erik Tesselaar, Ronald Booij, Mischa Woisetschläger.

GRANTS

ALF Grants, Region Östergötland

KEY PUBLICATIONS

Woisetschlager, M., et al. (2023). "Improved visualization of the bone-implant interface and osseointegration in ex vivo acetabular cup implants using photon-counting detector CT." Eur Radiol Exp 7(1): 19.



Figure 1. Retrieved acetabular cup implant (left) with newly formed bone integrated with the porous surface of the implant (middle, with courtesy of Thor Balkhed, Linköping University) and the clinical CT image of the cup acquired using conventional CT before revision surgery (right). Due to the limited spatial resolution, the visibility of the interface between the bone and the implant is not good enough to evaluate whether there is adequate osseointegration.

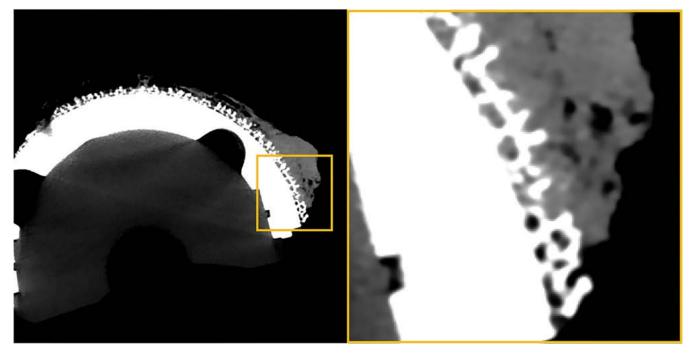


Figure 2. Visualization of the implant-bone interface with PCD-CT. The ingrowth of bone tissue into the porous structure on the implant surface can clearly be seen.

Aortic Stenosis - Calcium Burden and its Impact on Left Ventricular Function

Aortic stenosis (AS) results in a reduction of the valve's opening area. Untreated, this leads to heart failure as the left ventricle (LV) is forced to pump against an increasingly higher pressure. Previously, the treatment of choice was surgical valve replacement. Presently, catheter-based valve replacement, "TAVI", has come to dominate and in 2023, 82% of all valve replacements for AS in the US were TAVI-procedures. Ultrasound is the method of choice to assess both the degree of AS and LV function. Ultrasound allows the calculation of valve area, assesses LV size and function and calculates the deformation of the heart muscle (strain). Computed tomography (CT) is a supporting technique which visualizes the aortic root, the coronary vessels and the aorta and also allows the calculation of the calcium burden of the valve. It is also possible to calculate LV size and function using the same parameters as ultrasound. The latest CT technology uses a photon counting detector which allows a higher spatial resolution and lower noise levels compared to previous multi-detector technology. The aim of the project is to

increase our knowledge about the contribution of calcification to the severity of the aortic valve stenosis in order to improve the timing of catheter-based valve replacement. The goal is to reduce the risk of sudden death or irreversible heart damage through improved diagnostics and treatment, while postponing the risks of surgery and post-operative treatment to the future. We will include a total of 170 patients (study ASCORE 1, 100 + study ASCORE 2, 70) who, based on the recommendation of a multidisciplinary conference, will undergo further investigation in preparation of a possible TAVI procedure. Valve area obtained from the clinical ultrasound investigation is the ground truth to which the valve calcium burden calculated from CT will be compared. Furthermore, we will compare LV size and function obtained from the two modalities (study ASCORE 1). In another group the same parameters will also be studied with the new photon counter CT (study ASCORE 2).

We expect that assessment of calcium burden and LV function from CT, will improve timing for intervention in severe aortic stenosis.

Computed Tomography Cardiovascular

Project information

PROJECT NAME

Aortic Stenosis - Calcium Burden and its Impact on Left Ventricular Function. A Comparison Between CT and Ultrasound in TAVI Patients.

PROJECT LEADER

Lene Rosendahl, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Markus Irding, Peter Blomstrand, Jan Engvall, Mårten Sandstedt, Marcus Lindenberger.

FUTURUM - akademin för hälsa och vård (2022)FORSS-(HT2023) Forskning- och stipendieförvaltningen i Östergötland (HT 2023)

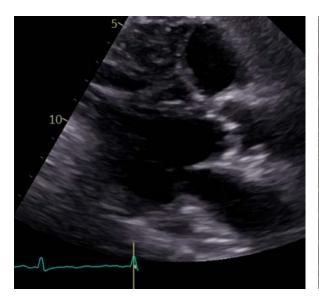


Figure 1. Longitudinal slice of the LV with the echo dense aortic valve with a reduced opening. In addition to the visual impression, the echo operator measures blood flow velocity across the valve. In sever aortic stenosis, velocity exceeds 4 m/s.

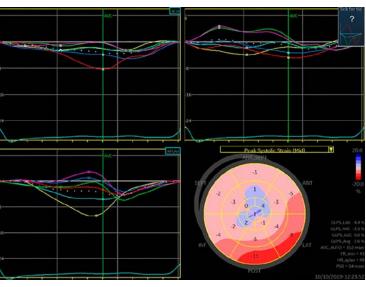


Figure 2. In the echo evaluation of aortic stenosis, it is important to assess systolic function of the left ventricle (LV). Longitudinal strain can be presented in this bull 's eye perspective, with the apex in the middle of the image and the basis of the ventricle at the periphery. Reduced LV function in pink.

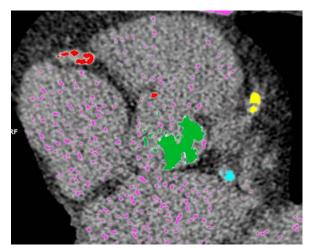


Figure 3. Severe aortic stenosis with atherosclerosis in the aortic valve. Calcifications in aortic valve and coronary arteries color coded to calculate Agatston score separately. Aortic valve color coded green, Right coronary artery red, Left Anterior descending artery yellow and Circumflex artery light blue.

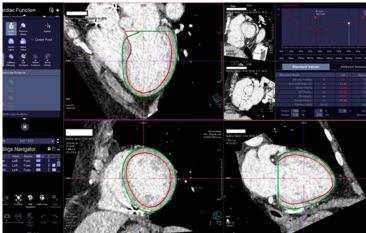


Figure 4. We intend to increase contrast in the CT-image in order to improve on the segmentation of the left ventricle, which will be used to calculate volume, LVEF and circumferential and longitudinal strain in the left ventricle.

Novel Markers and Risk Factors for Ascending Aortic Dilation

Background: Aneurysmal dilation of the ascending aorta (AscAo) is a silent. asymptomatic, disease that is often not detected until a fatal dissection or rupture occurs. While almost certainly multifactorial, basic vessel dimensions are the primary measurement used clinically to risk-stratify patients. But dimensions do not tell the whole story. We and others have previously leveraged the unique assessment of hemodynamics afforded by cardiac magnetic resonance (CMR) imaging to explore the role of abnormal hemodynamics in AscAo dilation. As a result of those previous studies, hemodynamics is increasingly believed to contribute to disease progression in AscAo dilation. However, studies on patient cohorts that are representative of the broader population are needed to further elucidate the role of hemodynamics and circulating biomarkers in AscAo dilation.

Purpose and hypotheses: The overall purpose of this project is to identify novel markers of mild to moderate AscAo dilation and growth with the unique assessment of hemodynamics afforded by cardiac magnetic resonance (CMR) imaging.

We hypothesize that:

- Hypothesis 1. Patients with mild to moderate AscAo dilation are characterized by altered AscAo hemodynamics when compared to matched controls
- · Hypothesis 2. Circulating markers of pathological processes in the vessel wall are a) different in patients with mild to moderate AscAo dilation when compared to matched controls and b) related to abnormal hemodynamics in patients with AscAo dilation
- Hypothesis 3. Growth of AscAo dilation occurs in regions with abnormal hemodynamics

Method: We will investigate our hypotheses by using CMR to comprehensively map AscAo hemodynamics in a unique cohort of individuals with and without mild to moderate AA dilation and analyze plasma samples in the two groups. Progression of AscAo dilation will be monitored on an annual basis and used to establish relationships between abnormal hemodynamics and growth.

Significance: AscAo diameter is a blunt and insufficient measure to appropriately risk-stratify AscAo dilation. Successful accomplishment of this study of a well-defined population-based cohort of individuals with mild to moderate AscAo dilation will contribute to a greater understanding of the role of altered hemodynamics and circulating biomarkers in AscAo dilation. This may facilitate development of best practices and effective clinical guidelines, and in so doing, optimize clinical outcomes for patients with AscAo dilation.

Computed Tomography | MRI | Ultrasound | Cardiovascular | Al/Data analytics

Imaging Biomarkers

Project information

PROJECT NAME

Novel markers and risk factors for ascending aortic dilation using advanced hemodynamics imaging and circulating hinmarkers

PROJECT LEADER

Petter Dyverfeldt, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Chiara Trenti, Filip Hammaréus, Fredrik Nilsson, Marcus Lindenberger, David Kylhammar, Aleksandra Trzebiatowska-Krzynska, Jan Engvall, Lena Jonasson, Eva Swahn.

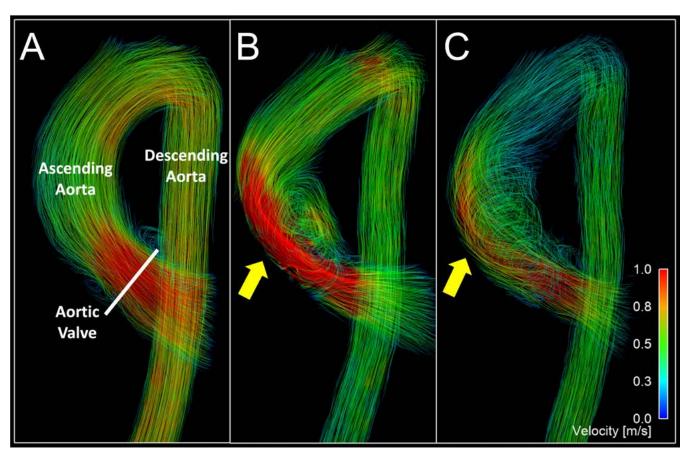
ALF Grant, Region Östergötland Linköping University Strategic Research Area in Circulation and Cardiovascular Metabolic Risk Factors, seed grant Medical Faculty at Linköping University, cofinancing of PhD Student

KEY PUBLICATIONS

Hammaréus F*, Trenti C*, Björck HM, Engvall J, Lekedal H, Krzynska-Trzebiatowska A, Kylhammar D, Lindenberger M, Lundberg AK, Nilsson F, Nilsson L, Swahn E, Jonasson L, Dyverfeldt P. Wall Shear Stress Measured with 4D Flow CMR Correlates with Biomarkers of Inflammation and Collagen Synthesis in Mild-to-Moderate Ascending Aortic Dilation and Tricuspid Aortic Valves. European Heart Journal - Cardiovascular Imaging 2024; 25(10): 1384-1393. * Equal contributions.

Lindenberger M, Ziegler M, Welander M, Ebbers T, Dyverfeldt P. Regional aortic pulse wave velocity in patients with abdominal aortic aneurysm. European Journal of Vascular & Endovascular Surgery 2024; 67(3): 506-513.

Swahn E, Lekedal H, Engvall J, Nyström FH, Jonasson L. Prevalence and determinants of dilated ascending aorta in a Swedish population: a case-control study. European Heart Journal Open 2023; 3:1-8.



Example of systolic hemodynamics in three individuals visualized by flow streamlines color-coded by velocity. A: Normal hemodynamics with highest velocities in the center of the lumen is seen in a 65-year-old male with tricuspid aortic valve (TAV) and normal aortic diameter. B: Deranged hemodynamics with eccentric flow in a 70-year-old male with TAV, severe aortic stenosis and 41 mm dilation in the mid AscAo. C: The same eccentric flow pattern is identified in a 61-year-old male with TAV, no aortic stenosis and 41 mm dilation in the mid AscAo. In B and C, the highest velocities are located at the AscAo wall, resulting in high flow displacement and focally elevated wall shear stress (arrows).

Predictive Value of Carotid MRI

Atherosclerotic plaques in the carotid artery bifurcation is a common cause of ischaemic stroke, a major cause of cardiovascular mortality and morbidity. However, clinical stroke assessment has for many years been based on the degree of lumen narrowing caused by the plaque in the carotid artery. Even if there is a correlation between plaque size and cardiovascular events, this approach risks a consistent misclassification of strokes caused by small plaques. In fact, a large number of strokes tend to be classified as "unknown cause". More research on small plagues is necessary to determine whether small size plagues are a larger problem than previously thought. The necessity to advance our clinical and scientific knowledge in this area is further underscored by the finding that up to 10% of the Swedish population between 50-64 years have asymptomatic carotid plaques >2.7 mm. An improved understanding of such plaques, including the ability of MR imaging to identify plaque features that predict future plaque development and events, can open up for improved selection of patients for thrombendarterectomy and high intensity medical treatment.

The overall purpose of this project is to evaluate carotid magnetic resonance imaging (MRI) in a population-based cohort and explore the natural course of MRI-identified plaque features as well as the capability of MRI-identified plaque features to predict future events such as

stroke. In addition to MRI, we have via the Swedish CArdioPulmonary bioImage Study (SCAPIS) access to data on blood pressure, biomarkers, medical history, lifestyle, coronary computed tomography, etc. in a unique population-based cohort of middle-aged individuals.

In this project, we will investigate baseline characteristics of carotid plaques in our SCAPIS subcohort of 600 middle-aged individuals with asymptomatic carotid plaques. We will also perform a repeat MRI 8 years after the initial MRI to study the natural course of carotid plaques in asymptomatic individuals. Finally, the predictive capability of MRI-based characterization of morphological and compositional plaque features will be explored in relation to events such as stroke and myocardial infarction.

Computed Tomography | MRI | Cardiovascular | Al/Data analytics | Imaging Biomarkers

Project information

PROJECT NAME

Investigating the predictive value of carotid plaque characteristics to evaluate cardiovascular risk in asymptomatic middleaged individuals.

PROJECT LEADER

Petter Dyverfeldt, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine Elin Good, Department of Cardiology.

MAIN PROJECT PARTICIPANTS

Ebo de Muinck, Linda Bilos, Oscar Soto, Tamara Bianchessi, Sofija Bojovic.

GRANTS

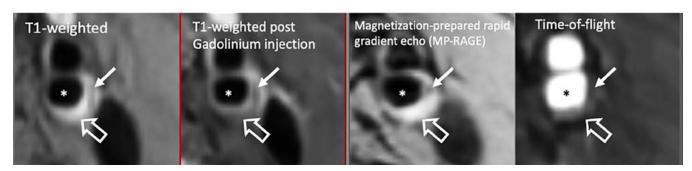
Swedish Brain Foundation ALF Grant, Region Östergötland Henry and Ella Margareta Ståhl foundation Hälsofonden, Linköping University and Region Östergötland Swedish Research Council, project grant

KEY PUBLICATIONS

Good E, Ziegler M, Warntjes M, Dyverfeldt P, de Muinck E. Quantitative magnetic resonance imaging assessment of the relationships between fat fraction and R2* inside carotid plaques, and circulating lipoproteins. Journal of Magnetic Resonance Imaging 2022; 55: 1260-1270.

Ziegler M, Alfraeus J, Bustamante M, Good E, Engvall J, de Muinck E, Dyverfeldt P. Automated Segmentation of the Individual Branches of the Carotid Arteries in Contrast-Enhanced MR Angiography using DeepMedic. BMC Medical Imaging 2021; 21(1):1-10.

Ziegler M, Good E, Engvall J, Warntjes M, de Muinck E, Dyverfeldt P. Towards Automated Quantification of Vessel Wall Composition using MRI. Journal of Magnetic Resonance Imaging 2020; 52: 710-719



MR images in patient with carotid plaque. The images were acquired with T1-weighted, post-Gadolinium contrast T1-weighted, MP-RAGE and time-of-flight MR imaging. Image location is just distal to the carotid artery bifurcation. Asterix: internal carotid artery lumen. Solid arrow: calcification as characterized by low signal intensity in all images. Open arrow: Intraplaque hemorrhage as characterized by hyperintense signal on the T1-weighted and MP-RAGE images in combination with hypointense signal on the post-Gadolinium contrast T1-weighted and time-of-flight images.

MR Turbulence Angiography

The heart's most important function is to pump blood out to the whole body. In healthy individuals, the blood flows in a well-organized and efficient way. When the heart valves that are located between the different parts of the heart become diseased, the flow is affected and transitions to a more chaotic, turbulent state. The presence of turbulent blood flow is therefore a clear characteristic of heart valve diseases. This is actually used during stethoscope examinations when the doctor listens for turbulence in the heart as a sign of heart valve disease. However, there is a lack of a clinical tool that can quantitatively image turbulence in the heart. Such a tool would enable completely new ways to diagnose heart valve diseases earlier and more accurately.

The goal of this project is therefore to develop a method that measures turbulence in the whole heart and with three-dimensional images shows where this turbulence is located.

To achieve this goal, we will develop an advanced method that uses magnetic resonance imaging to measure turbulence in the heart while the patient holds their breath (less than 20 seconds). Previously, similar measurements have taken 5-10 minutes. We will combine the fast image collection with image processing based on artificial intelligence, whereby a computer is trained to find the different parts of the heart. In this way, artificial intelligence can help us to automatically analyze turbulence in the collected images and visualize where and how much turbulence there

is in different parts of the heart for each patient who undergoes the examination. To evaluate and optimize the new techniques that we develop in the project, we will examine 200 patients with the two most common heart valve diseases. In these patients, we will perform several different variants of measurements with the new technique to determine how the technique should be used in the best way. Successful completion of this project

will make it possible to evaluate heart valve diseases in a completely new way. by using a fast magnetic resonance imaging method to quantify and visualize turbulent blood flow. This will improve the diagnosis and affect the assessment of patients with heart valve diseases, with great positive social impact through reduced suffering and death as well as reduced costs for health care.

MRI Cardiovascular Acquisition Al/Data analytics Visualization Imaging Biomarkers

Project information

PROJECT NAME

MR Turbulence Angiography.

DROJECT LEADER

Petter Dyverfeldt, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Sohaib Avaz Oazi, Tamara Bianchessi, Carl-Johan Carlhäll, Marcus Lindenberger.

Co-financing of PhD Student, Medical Faculty at Linköping University (2024 - 2027) ALF Grant, Region Östergötland [2024-2026]

Analytic Imaging Diagnostics Arena (AIDA) Innovation Grant (2023 - 2024) Swedish Research Council, project grant (2022 - 2025)

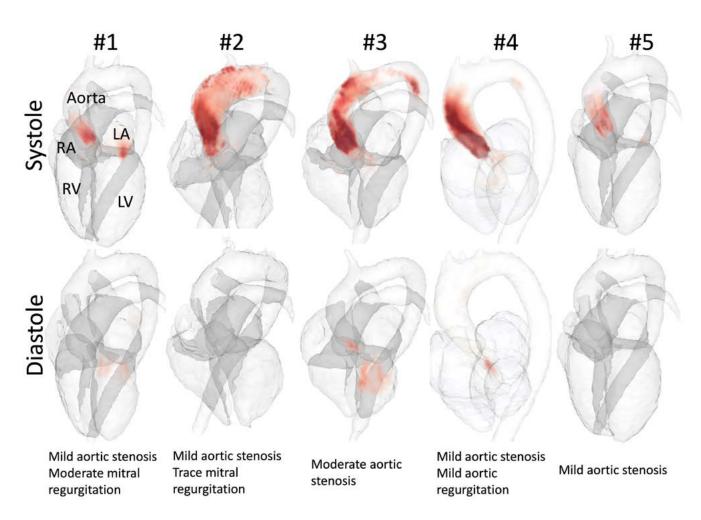
Linköping University Strategic Research Area in Circulation and Cardiovascular Metabolic Risk Factors, Visiting researcher grant (2022 - 2023)

KEY PUBLICATIONS

Dyverfeldt P, Trenti C, Ziegler M, Bjarnegård N, Lindenberger M. Helical flow in tortuous aortas and its relationship to turbulence: A whole-gorta 4D Flow MRI study. Frontiers in Cardiovascular Medicine 2023; 10:1124604.

Riva A, Eriksson J, Viola F, Sturla F, Votta E, Ebbers T, Carlhäll CJ, Dyverfeldt P. Impact of dobutamine stress on diastolic energetic efficiency of healthy left ventricle: an in vivo kinetic energy analysis. Frontiers in Cardiovascular Medicine 2023; 10:1103751.

Dyverfeldt P, Hope MD, Tseng EE, Saloner D. Noninvasive Magnetic Resonance Measurement of Turbulent Kinetic Energy for the Estimation of Irreversible Pressure Loss in Aortic Stenosis. J Am Coll Cardiol Img 2013; 6(1):64-71.



MR turbulence angiograms showing turbulent kinetic energy (TKE) in the whole heart and aorta at systole (top row) and diastole (bottom row). Valvular pathology for each patient is indicated in the bottom of the figure. LV, left ventricle; LA, left atrium; RV, right ventricle; RA, right atrium.

Evaluating Antithrombotic Treatment Post-Coronary Artery Bypass Grafting with CT

Coronary artery bypass grafting (CABG) is the most common cardiac surgery in Sweden. It is employed to restore circulation to the heart muscle in the presence of coronary artery disease. Typically, vessel bridges (grafts) are routinely used to bypass constrictions in the coronary arteries. Sustaining the patency of these grafts over time is crucial for prognostic benefits, preventing new heart attacks, and reducing the risk of heart failure.

Post-surgery, medications are administered to prevent blood clot formation and ensure the long-term functionality of the grafts. The optimal dosage of these drugs, providing effective protection without leading to severe bleeding complications, remains uncertain. Most patients receive one or two antiplatelet medications (ASA and/or ticagrelor).

By assessing the functionality of the grafts through coronary computed tomography angiography (CTA) one year post-operation and comparing it with the antithrombotic treatment the patient has received, we aim to gain insights into different treatment strategies. Through this, we hope to optimize the choice of antithrombotic treatment following CABG. Analytical Method and Data Collection: Patients are evaluated using coronary angiography and coronary CTA according to a protocol developed for the study. Based on the patients' heart rate, the CTA examination is adjusted using "Flash technique" to limit radiation exposure, or spiral technique when Flash technique is not feasible. The radiation dose has been deemed reasonable in relation to the study following ethical approval. To optimize image quality, beta-blockers and nitroglycerin are administered before the examination. Initial assessments are conducted at respective radiology clinics to avoid missing any potential pathological findings. Subsequently, the images are transferred to Linköping US, serving as the core lab for the study. Image interpretation will be carried out by three thoracic radiologists. Participants: We now have six Nordic centers participating in the Co-CAP-study. Sweden: Linköping (primary sponsor site), Gothenburg, Stockholm, Örebro. Norway: Trondheim and Bergen.

Inclusion rate: In our power analysis we have estimated 360 patients for inclusion. Overall we are close to 300 patients included and we hope to have finished the inclusion during 2025.

Computed Tomography Cardiovascular
Al/Data analytics Visualization

Project information

PROJECT NAME

Coronary CT Angio Evaluating Graft Patency in ACS Patients Treated with DAPT or Single ASA after CABG (CoCAP).

PROJECT LEADER

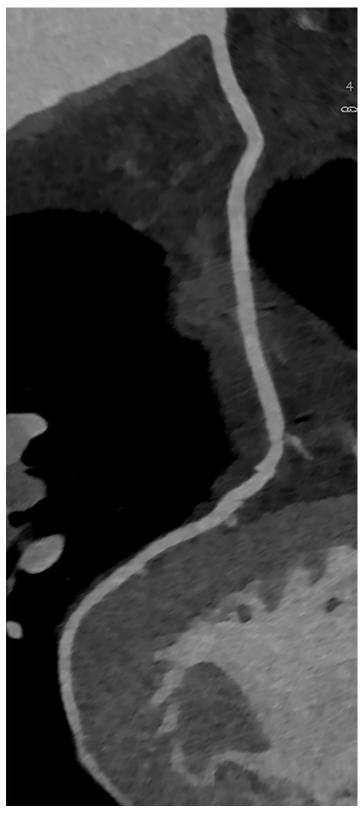
Jonas Holm, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Mårten Sandstedt, Lilian Henriksson, Sofia Sederholm Lavesson, Nina Hallsten.

GRANTS

The Swedish Heart Lung Foundation (2021-2027) ALF grants



The CT image shows a coronary venous graft that was anastomosed to the distal circumflex artery, segmented using curved multiplanar reconstruction.

Chronic Coronary Syndrome in Swedish Primary Care

Guidelines for the investigation and treatment of chronic coronary syndrome were updated in 2024 and put emphasis on individual risk assessment and treatment.

Vascular calcification may function as an extension of traditional markers of cardiovascular risk. The absence of calcification may reclassify some patients to a lower category of risk, and extensive calcification may elevate risk scores, thus changing indications for treatment in the spirit of personalized medicine.

A pre-test probability (PTP) of the presence of coronary artery stenosis is calculated based on the character of chest pain, age, and sex. The new guidelines recommend using additional signs of risk to calculate a risk factor-weighted Clinical Likelihood Ratio to attain a better individualized prediction. For patients in primary care, a stepwise outpatient investigation may take quite a long time, and the delay in arriving at a final diagnosis may cause unnecessary anxiety for the patient and increase the risk of complications.

This study has been ongoing since the end of May 2023 and has the goal of randomizing 500 patients from 18 primary health care centres in Östergötland to use either a same-day application of exercise testing, myocardial perfusion, echocardiography, calcium scoring, and microphone recording using wavelet analysis, or the standard stepwise investigation, in order to study the time delay from visit to a final diagnosis.

The technical developments utilized in this study are: 1. calcium scoring of the coronary arteries to assess cardiovascular risk, 2. the standardized use of ultrasound to rule out other cardiac diseases, and 3. the addition of sound analysis to calculate the likelihood of the presence of a coronary stenosis.

Computed Tomography Ultrasound Other Cardiovascular Imaging Biomarkers

Project information

PROJECT NAME

COSPRI.

PROJECT LEADER

Jan Engvall, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

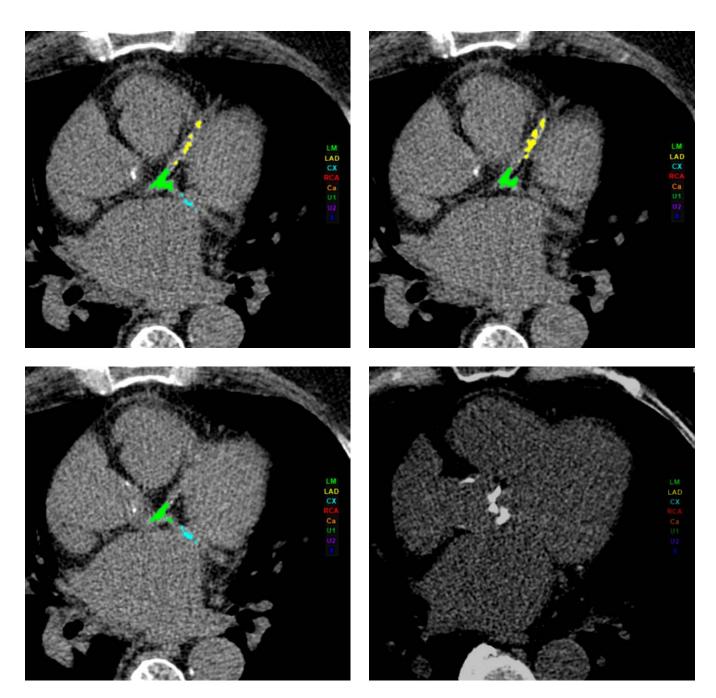
Eva Olsson, Miguel Ochoa, Staffan Nilsson, Fredrik Iredahl, Sofia Sederholm Lavesson, Erik Stertman, Fade Gabro, Mårten Sandstedt, Liselott Yxne, Sara Gifting och Karin Pejic.

GRANTS

ALF/RÖ-991440 (to Staffan Nilsson for 3 years) VR 2024 (to Fredrik Iredahl)

KEY PUBLICATIONS

Nilsson S et al. "Chronic cOronary Syndrome in Swedish PRImary care (COSPRI) - A study protocol for a 5-year cluster randomized controlled trial on a novel package versus standard investigation in patients with suspected chronic coronary syndrome referred from primary health care." Under review 2024.



Composite image of three contiguous slices of the left coronary artery. The software displays image voxels with a Hounsfield value in excess of 130 (indicating presence of calcium) in green when present in the left main coronary artery, in yellow when in the left anterior descending artery and in blue when located in the circumflex artery. The Agatston is in this case 960. Patients with values above 100 carry an increased risk of events over a 10 year period. The fourth image at the lower right shows extensive calcification of the aortic valve that is not colorized and not included in the Agatston score since it is not part of the coronary arterial tree. Aortic calcification in this case indicates a severe aortic stenosis that is also diagnosed by echocardiography as part of the work-up.

4D Flow CT

Advanced computed tomography (CT), including the new photon-counting detector CT modality, allows for excellent visualization of the human body including the beating heart. However, the complex interactions of blood flow, which is crucial in the diagnosis and treatment planning of many diseases, are not fully reflected by these images. Magnetic resonance imaging (MRI) and ultrasound are able to measure functional data like blood flow, but at a low resolution, Furthermore, these techniques are not able to predict the changes in blood flow after or in prior to different treatments and interventions.

This project aims to extract blood flow data from CT images of the heart using image-based simulations. The goal is earlier and more accurate detection as well as improved management of cardiac diseases.

Even though many forms of functional imaging data and modelling approaches are currently available, a gap persists between modelling and experimental research. This project has bridged the gap by developing and evaluating an approach in which intracardiac flow fields are computed based on patient-specific high-resolution cardiac CT data. The heart is segmented quickly with minimal user interaction using novel machine learning techniques, and advanced registration techniques are used to track the heart wall. Using computational techniques usually employed by the automotive or aerospace industry, detailed intracardiac and vascular blood fields are obtained.

The results show that the 4D Flow CT method can produce blood-flow patterns that are qualitatively and quantitatively similar to the current reference standard 4D Flow MRI, but at higher resolution. The high resolution also allows the simulated data to reveal processes that could not be studied before, like the coagulation of blood or the occurrence of turbulence in the blood flow. The approach may also be beneficial in patients who cannot be adequately examined with the other available modalities, such as patients with mechanical heart pumps.

One important clinical application that is explored is in atrial fibrillation. These patients have an increased risk of blood cloths forming in the atrium and by migrating to the brain or coronary arteries they may induce a stroke or heart attack. We are building a model that can identify where the blood cloths are forming. The goal is that the information from this model may be used to identify patients at risk.

The simulation-based approach potentially allows for studies of whatif scenarios where different treatment options can be explored. This is challenging, as the heart is complex and adapts to changes in demand and constrains. A model is a simplified version of reality and there has to be a balance in the amount of details included and clinically usability.



Project information

PROJECT NAME

Simulation of Time-Resolved Three-Dimensional Cardiac Blood Flow from Computed Tomography (4D flow CT).

PROJECT LEADER

Tino Ebbers, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Jonas Lantz, Anders Persson, Carl-Johan Carlhäll, Matts Karlsson, Bente Konst, Lilian Henriksson, Sophia Bäck, André Da Luz Moreira, Linus Ohlsson, Lee Jollans, Twan Bakker, Pontus Benke.

GRANTS

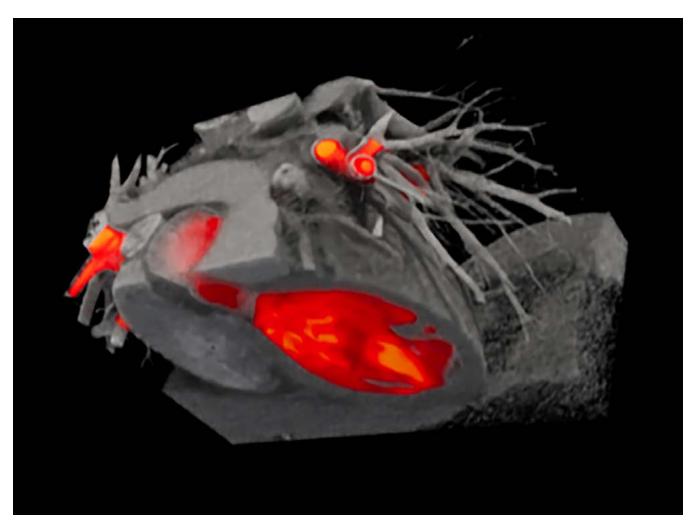
Swedish Heart Lung Foundation (2024-2025) Visual Sweden/MeDigiT (2022-2025) WASP/DDLS (2022-2024) Swedish Research Council (2023-2026) ALF (2024) AIDA (2024-2025) Linköpings Läkarsällskap 2024

KEY PUBLICATIONS

Bäck S, Lantz J, Skoda I, Henriksson L, Persson A, Karlsson LO, Carlhäll CJ, Ebbers T. Comprehensive left atrial flow component analysis reveals abnormal flow patterns in paroxysmal atrial fibrillation. Am J Physiol Heart Circ Physiol. 2024 Mar 1;326(3):H511-H521.

Ohlsson L, Sandstedt M, Papageorgiou JM, Svensson A, Bolger A, Tamás É, Granfeldt H, Ebbers T, Lantz J. Haemodynamic significance of extrinsic outflow graft stenoses during HeartMate 3™ therapy. Eur Heart J Imaging Methods Pract. 2024 Aug 29;2(3):qyae082.

Lantz J, Gupta V, Henriksson L, Karlsson M, Persson A, Carlhäll CJ, Ebbers T. Intracardiac Flow at 4D CT: Comparison with 4D Flow MRI. Radiology. 2018 Oct;289(1):51–58.



Volume rendering of the blood flow in a patient with a dilated left ventricle.

AIDA – Analytic Imaging Diagnostic Arena

Analytic Imaging Diagnostic Arena (AIDA) is a national arena for research and innovation in medical image analysis. AIDA is a cross-disciplinary collaboration aiming for largescale use of Artificial Intelligence (AI) in healthcare. Here, academia, healthcare and industry meet to translate technical advances in AI technology into patient benefit in the form of clinically useful tools. AIDA management resides at CMIV and CMIV is the main physical meeting place of AIDA.

The technical development within AI has been extremely strong in recent years. Modern AI is a toolbox that fits perfectly into the healthcare vision of precision medicine, the fully tailored treatment for each patient. It is, however, difficult for AI solutions to reach actual use in imaging diagnostics. The reason is that the step from experiments to clinical routine entails many challenges. Understanding the targeted clinical workflows and carefully designing user interaction are just as important as the predictive performance of the AI model.

AIDA's objective is to assist taking AI solutions for imaging diagnostics all the way to clinical use. An underpinning fundamental insight is that this complex challenge requires both interdisciplinary and cross-sectoral collaboration.

The AIDA program consists of many types of activities. Most resources are used for innovation projects developing AI methods. These are run by research groups in industry and academia across Sweden, in collaboration with healthcare providers. AIDA also supports clinical competence development in AI, through regularly organizing courses and through supporting clinical fellowship projects.

A cornerstone of the program is the meeting place AIDA organizes, with frequent cross-disciplinary workshops and meet-ups, where knowledge is disseminated and experiences exchanged.

In a special initiative, AIDA acts as an incubator for national AI validation platforms for medical imaging. The aim is to help care providers to take their responsibility to control that the solutions used are safe and effective. Three pilot platforms are being developed, where the one targeting mammography screening, named VAI-B, is the largest and most advanced.

The AIDA operations build on the infrastructure and services provided by AIDA Data Hub. The hub includes a tailor-made technology platform for efficient AI development, with the flagship resource is a heavy-load computational system shared between the groups across the country. A key achievement is the capacity to securely handle sensitive personal data on the system. In 2024, a new generation of the system has been procured, which will be the base for expanded services starting in 2025. AIDA Data Hub also provides sharing services for clinically relevant data available for

Computed Tomography | MRI | Digital Microscopy | Ultrasound | Other | Cardiovascular | Neurology | Oncology | Musculoskeletal | Gastrointestinal | Gynecological | Pulmonary | Al/Data analytics | Visualization |

Project information

PROJECT NAME

Analytic Imaging Diagnostic Arena.

PROJECT LEADER

Claes Lundström, ITN, Media and Information Technology.

MAIN PROJECT PARTICIPANTS

Caroline Bivik Stadler, Joel Hedlund, Catrin Nejdeby, Håkan Gustafsson, Maria Kvist, Gabriel Eilertsen, Betul Eren, Emre Balsever, Varshith Konda, Pontus Freyhult, Erik Ylipää, Minh-Ha Le, Darren Treanor, Petter Dyverfeldt, Neda Haj-Hosseini, Anders Eklund, Tino Ebbers, Martin Lindvall, Karin Stacke, Milda Pocevičiūtė.

GRANTS

VINNOVA Medtech4Health SciLifeLab VINNOVA Precision Health VINNOVA Health Data Demonstrator Europe's Beating Cancer Plan EUCAIM

KEY PUBLICATIONS

Claes Lundström, Martin Lindvall. Mapping the Landscape of Care Providers' Quality Assurance Approaches for Al in Diagnostic Imaging. Journal of Digital Imaging (2023).

Fernando Cossío, Haiko Schurz, Mathias Engström, Carl Barck-Holst, Apostolia Tsirikoglou, Claes Lundström, Håkan Gustafsson, Kevin Smith, Sophia Zackrisson, Fredrik Strand. VAI-B: a multicenter platform for the external validation of artificial intelligence algorithms in breast imaging. Journal of Medical Imaging (2023).

Joel Hedlund, Anders Eklund, Claes Lundström. Key insights in the AIDA community policy on sharing of clinical imaging data for research in Sweden. Nature Scientific Data (2020). AI research, and technical expertise to assist research efforts. Currently 48 datasets with 55 TB of such data are available, so far having been shared with researchers in 42 countries around the world. A notable addition in 2024 is a strategic collaboration with the SCAPIS project, whose images now are shared through the AIDA Data Hub.

The development of the new generation of AIDA Data Hub services are in part carried out within the Vinnova system demonstrator project ASHA (an acronym in Swedish for "using standardized health data as accelerator"). The AIDA Data Hub contribution to ASHA is to provide a health data space for secondary use of multidisciplinary data on its data science platform, for both academic and industrial use. A pilot user is the PULMO project, analysing genetic, microbiome and epigenetic data together with health records, to produce AI based diagnostics tools for multi-systemic diseases like long covid and tuberculosis.

The data science platform is developed in tandem also with the EU project Bigpicture, being co-located with a Bigpicture Federated node, and it also constitutes a data collaboration platform for use cases in the EU project EUCAIM.

AIDA is an initiative within the Strategic innovation program Medtech4Health, jointly supported by VINNOVA, Formas and the Swedish Energy Agency. The AIDA Data Hub is a SciLifeLab Facility within the Bioinformatics Platform (NBIS).



AIDA Day in Lund, where Caroline Bivik Stadler was presenting.



AIDA Day in Linköping at CMIV.

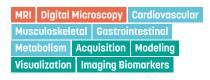
Evaluating Prevalence and Severity of NAFLD in Primary Care

In EPSONIP (Evaluate Prevalence and Severity of Non-Alcoholic Fatty Liver Disease in Primary Care), the latest magnetic resonance imaging (MRI) techniques are used to investigate 400 patients with type 2 diabetes. The patients are identified in primary care, ensuring a representative selection of typical Swedish diabetes patients. The MRI technique can measure body composition and map fat content in various adipose tissues throughout the body, such as intraabdominal and gluteal fat. Moreover, fat content within several internal organs. such as the liver, is measured with great detail.

Fatty liver is the most common liver disease worldwide. One in five individuals has fatty liver, which increases the risk of developing diabetes, cardiovascular disease, and severe liver disease. Fatty liver is the fastest-growing indication for liver transplantation in Sweden.

There is a strong link between diabetes and fatty liver, but it is not known how many diabetes patients are affected. Even though fatty liver is very common, only a minority develop severe liver disease.

Fatty liver is closely related to metabolic syndrome and shares several risk factors with cardiovascular disease. This project will investigate fat infiltration in the heart as well as measure cardiac function using MRI. Through EPSONIP, we will gain a unique insight into the relationship between fat distribution and the development of liver and cardiovascular disease in diabetic patients.



Project information

PROJECT NAME

Evaluating Prevalence and Severity Of NAFLD in Primary care.

PROJECT LEADER

Mattias Ekstedt, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Joakim Alfredsson, Martin Bergram, Carl-Johan Carlhäll, Gunnar Cedersund, Tino Ebbers, Nils Dahlström, Martin Henriksson, Fredrik Iredahl, Stergios Kechagias, Peter Lundberg, Patrik Nasr, Karin Rådholm, Christian Simonsson, Shan Cai, Cecilia Jönsson, Karin Hedin, Markus Holmberg.

GRANTS

Region Östergötland ALF-Grant Mag-tarmfonden Rut och Rikard Juhlin Svenska Läkaresällskapet Bengt Ihre-fonden

KEY PUBLICATIONS

Nasr P, Iredahl F, Dahlström N, Rådholm K, Henriksson P, Cedersund G, Dahlqvist Leinhard O, Ebbers T, Alfredsson J, Carlhäll CJ, Lundberg P, Kechagias S, Ekstedt M. Evaluating the prevalence and severity of NAFLD in primary care: the EPSOMIP study protocol. BMC Gastroenterol. 2021 Apr 20;21(1):180. doi: 10.1186/s12876-021-01763-z. PMID: 33879084; PMCID: PMC8056630.

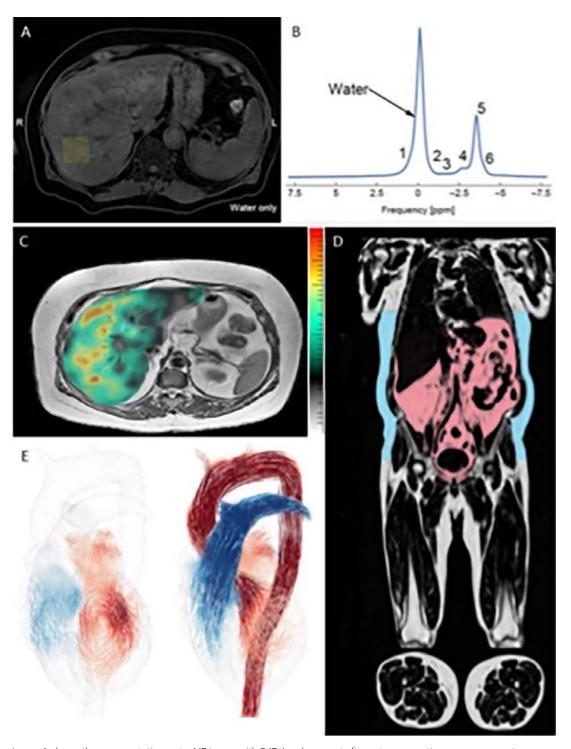


Image A shows the representative water MR image with 547 the placement of a proton magnetic resonance spectroscopy (1 H-MRS) voxel in the right hepatic lobe. Image B shows in vivo 1 H-MRS spectrum for water and fat. Image C shows MRE for a cirrhotic NAFLD patient. Image D shows a whole-body water-fat separated imaging for quantification of visceral and subcutaneous adipose tissue volume. And image E shows a 4D flow image of a healthy heart.

The ACCESS-ESLD Study

The ACCESS-ESLD study represents a significant step towards the early detection, comprehensive understanding, and prevention of complications associated with liver cirrhosis. By leveraging advanced MRI technology, this multi-center prospective cohort study aims to provide profound insights into the changes that occur over time in patients with liver cirrhosis.

In the ACCESS-ESLD study, 150 patients with liver cirrhosis are monitored over a period of 18 months, with regular MRI examinations at 6-month intervals, allowing for in-depth tracking of temporal changes.

The primary aim of the study is to examine whether changes in body composition, particularly muscle volume and muscle fat, can be linked to the progression of end-stage liver disease complications, such as liver decompensation, hepatocellular carcinoma, and sarcopenia.

By combining data from multiple muscle groups, blood samples, and genetic composition, we hope to improve diagnostic yield and identify those patients at the highest risk of severe

The ACCESS-ESLD study includes patients with liver cirrhosis but without a previous diagnosis of hepatocellular carcinoma. All patients will undergo an MR-based body composition profile utilizing the Muscle Assessment Score (MAsS), which includes fat-free muscle volume z-score (FFMV) and thigh muscle fat index (sex-adjusted MFI), using the AMRA® Researcher based on an 8-minute MRI conducted on the same day as the clinical work-up.

The clinical work-up includes comprehensive blood panels, vibrationcontrolled transient elastography for liver stiffness assessment, questionnaires to ascertain health-related quality of life and physical fitness, hand-grip strength to gauge physical frailty, and an assessment of present and past medical history, as well as the absence or presence of liver decompensation and related morbidities.

The ACCESS-ESLD study stands at the forefront of liver cirrhosis research. paving the way for early detection, effective intervention, and improved patient outcomes. The study's holistic approach, from sophisticated imaging to physical assessments, promises a brighter, more informed future for those battling liver cirrhosis.

MRI Musculoskeletal Gastrointestinal Metabolism Acquisition Imaging Biomarkers

Project information

PROJECT NAME

A rapid, non-invasive, Clinical surveillance for CachExia, Sarcopenia, portal hypertenSion, and hepatocellular carcinoma in End-Stage Liver Disease.

PROJECT LEADERS

Mattias Ekstedt and Olof Dahlqvist Leinhard, Department of Health, Medicine and Carina Sciences, Division of Diagnostics and Specialist Medicine

MAIN PROJECT PARTICIPANTS

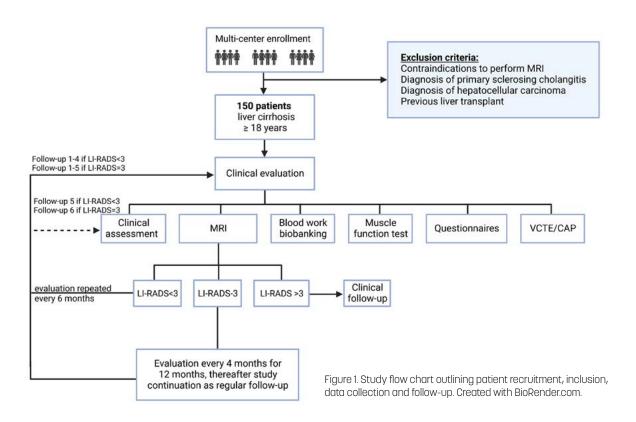
Mikael F Forsgren, Wile Balkhed, Patrik Nasr, Daniel Sjögren, Jennifer Linge, Anna Cederborg, Markus Holmberg, Nils Dahlström, Henrik Stjernman, Martin Rejler, Stergios Kechagias, Peter Lundberg, Wolf Bartholomä.

GRANTS

Region Östergötland ALF-grant **FORSS** Stiftelsen Ruth och Richard Juhlins Fond Svenska läkaresällskapet (SLS) SLS Gastroenterologisk forskningsfond Magtarmfonden Wallenberg centrum för molekylärmedicin (WCMM).

KEY PUBLICATIONS

Patrik Nasr, Mikael Forsaren, Wile Balkhed, Cecilia Jönsson, Nils Dahlström, Christian Simonsson, Shan Cai, Anna Cederborg, Martin Henriksson, Henrik Stjernman, Martin Rejler, Daniel Sjögren, Gunnar Cedersund, Wolf Bartholomä, Ingvar Rydén, Peter Lundberg, Stergios Kechagias, Olof Dahlqvist Leinhard & Mattias Ekstedt. A rapid, non-invasive, clinical surveillance for CachExia, sarcopenia, portal hypertension, and hepatocellular carcinoma in end-stage liver disease: the ACCESS-ESLD study protocol. BMC Gastroenterology (2023) 23:454. https://doi.org/10.1186/s12876-023-03093-8.



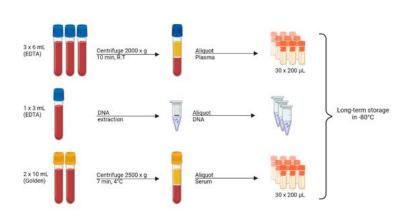


Figure 2. Overview of blood sample acquisition and biorepository. Created with BioRender.com.

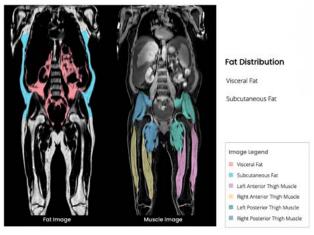


Figure 3. An example of clinical report for body composition profiling (AMRA® Profiler 4 MASS Scan), including whole-body water-fat separated imaging examples (bottom left), the muscle assessment score (MASS; blue region of the report) which are the biomarkers used in the primary aim to assess sarcopenia, as well as measurements of abdominal adiposity (bottom right).

Al-Based Medical Record Screening for Patient-Safe MRI Examination

The project "AI-based Medical Record Screening for Patient-Safe MRI Examination" focuses on developing an innovative AI-based method to significantly enhance patient safety prior to magnetic resonance imaging (MRI) scans. This method leverages automatic identification of "implant terms" through contextual processing of patient records.

Currently, when a patient has, or is suspected of having, an implant, the process of identifying such devices is entirely manual. This procedure is time-consuming, labor-intensive, and involves multiple experts with specialized knowledge. There is a pressing need to accelerate this process while simultaneously improving its accuracy and reliability.

It is particularly challenging to determine whether a patient has an implant, as patients themselves often do not know the exact model or may even be unaware of the implant's presence. Additionally, even when implants have been removed, residual leads or components may be unintentionally left behind. In Region Östergötland alone, approximately 30,000 MRI examinations are performed annually, with an increasing proportion of patients having implants. From a technical perspective, the primary challenge is to automatically and accurately identify a small number of highly specialized implant-related terms scattered within millions of words in unstructured and often "noisy" text documents. Developing a model capable of reliably detecting the presence of implants or other hazardous objects before an MRI scan is a complex task.

Implant-related terms may include words indicating devices such as

"pacemaker," "shunt," "stent," "prosthesis," "nail," "metal clips," "electrode," and similar items. However, medical records are linguistically complex, written by healthcare professionals who frequently use a wide range of medical shorthand. This includes not only standard medical jargon but also numerous unpredictable abbreviations, spelling variations (in-

cluding typographical errors), numbers, model references, and other inconsistent notations.

To address this challenge, we utilize state-of-the-art AI methods based on deep learning to automatically detect implant-related terminology and improve patient safety in MRI examinations.

MRI Cardiovascular Neurology Oncology Musculoskeletal Gastrointestinal

Project information

PROJECT NAME

aiMPLANT

PROJECT LEADER

Peter Lundberg, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Oscar Jerdhaf, Emma Eneling, Erik Ylipää, Arne Jönsson, David Abramian, Aditya Tejaswi, Håkan Gustafsson, Tomas Bjerner, Anders Tisell, Yosef Al-Abasse, Johan Kihlberg.

GRANTS

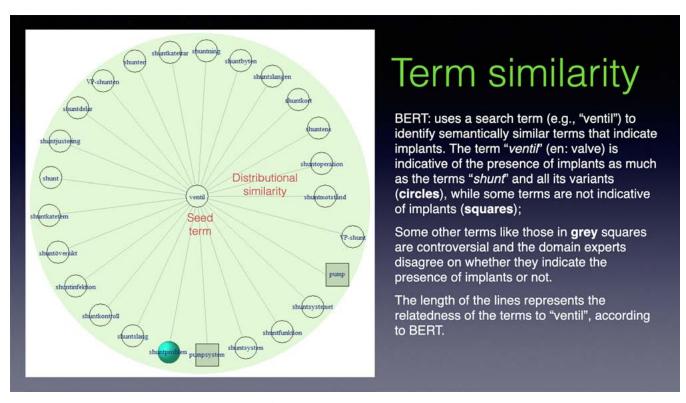
MedTech4Health Vinnova Socialstyrelsen Nordic Innovation

KEY PUBLICATIONS

Chomutare T, Babic A, Peltonen LM, Elunurm S, Lundberg P, Jönsson A, Eneling E, Gerstenberger CV, Siggaard T, Kolde R, Jerdhaf, Hansson M, Makhlysheva A, Muzny M, Ylipää E, Brunak S, Dalianis H (2024) Implementing a Nordio-Baltic Federated Health Data Network: a case report arXiv:2409.17865v1 https://doi.org/10.48550/arXiv.2409.17865.

Jerdhaf O, Santini M, Lundberg P, Bjerner T, Al-Abasse Y, Jönsson A (2022)
Evaluating Pre-Trained Language Models for Focused Terminology Extraction from Swedish Medical Records, LREC 2022
Workshop Language Resources and Evaluation Conference, 20-25 June, Marseille, 2022.

Danielsson B, Santini M, Lundberg P,
Al-Abasse Y, Jönsson A, Eneling E,
Stridsman M (2022) Classifying ImplantBearing Patients via their Medical
Histories: A Pre-Study on Swedish EMRs
with Semi-Supervised GAN-BERT, LREC
2022 Workshop Language Resources
and Evaluation Conference, 20-25 June,
Marseille, 2022.



The aiMPLANT project is focused on the use of multilingual federated training of large language models. And the purpose is to determine suitable conditions for patient safety during medical imaging procedures. The end result involves the ability to rapidly highlight certain important contexts in individual patient journals, based on term similarity, illustrated here with the term 'ventil' as a seed term.

Health Effects of Resistance Training in Postmenopausal Women

After menopause, most women experience hot flushes and sweating, which can be highly distressing and may persist for more than 5-7 years (median) or even lifelong. These hot flushes have been suggested as an independent risk factor for cardiovascular disease. Furthermore, the hormonal changes associated with menopause accelerate bone loss, negatively affect lipoprotein metabolism, and impact neuronal tissue, increasing the risk of neurodegeneration. Although hormone therapy with estrogen combined with a progestogen is effective, it is not suitable for all women due to contraindications or side effects

Based on the mechanisms underlying hot flushes, which stem from the thermoregulatory center in the brain (hypothalamus), we investigated whether resistance training could alleviate these symptoms. In a randomized controlled trial, approximately 60 women were included and randomly assigned to either 60 minutes of supervised resistance training, three days per week for 15 weeks, or to a control group instructed to maintain low physical activity. Participants completed questionnaires, provided blood samples, and underwent MRI at baseline, after the 15-week intervention, and again after 24 months.

To date, our findings show that hot flushes decreased by approximately 50% following the 15-week intervention. Quality of life improved significantly, muscle strength and muscle volume increased, lipoprotein metabolism shifted towards a more favorable profile, and markers of inflammation decreased. Additionally, both intra-abdominal and subcutaneous fat decreased significantly. A two-year follow-up of some of the data has recently been published.

Ongoing analyses include measurements of telomere length and the conversion of white to brown fat. Three PhD students have graduated with projects based on this study, and two additional PhD students are currently working on related projects.



Project information

PROJECT NAME

Health Effects of Resistance Training in Postmenopausal Women.

PROJECT LEADER

Mats Hammar, Department of Biomedical and Clinical Sciences, Children's and Women's Health.

MAIN PROJECT PARTICIPANTS

Anna-Clara Spetz Holm, Hanna Lindblom, Lotta Lindh-Åstrand, Magnus Borga, Janne West, Emilia Berin, Sofia Thorell, Sigrid Nilsson Moa Henriksson.

GRANTS

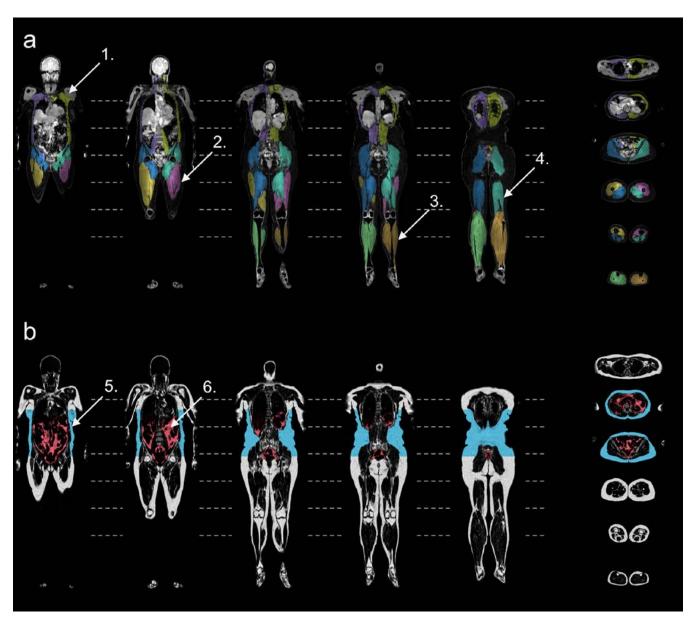
Vetenskapsrådet (ended 2022-12-31) ALF grants (Anna-Clara Spetz Holm)

KEY PUBLICATIONS

Berin E, Spetz Holm AC, Hammar M, Lindh-Åstrand L, Berterö C. Postmenopausal women's experiences of a resistance training intervention against vasomotor symptoms: a qualitative study. BMC Womens Health. 2022 Jul 30;22(1):320. doi: 10.1186/s12905-022-01900-0. PMID: 35907840; PMCID: PMC9338607.

Nilsson S, Henriksson M, Berin E, Engblom D, Holm AS, Hammar M. Resistance training reduced luteinising hormone levels in postmenopausal women in a substudy of a randomised controlled clinical trial: A clue to how resistance training reduced vasomotor symptoms. PLoS One. 2022 May 26;17(5):e0267613. doi: 10.1371/journal. pone.0267613. PMID: 35617333; PMCID: PMC9135255.

Sigrid Nilsson, Mats Hammar, Janne West, Magnus Borga, Sofia Thorell, Anna-Clara Spetz Holm. Resistance training decreased abdominal adiposity in postmenopausal women. Maturitas, 2023; 176:1-7.



Whole-body magnetic resonance images showing a middle-aged woman. The top row shows segmentation of muscles, and the lower row shows segmentation of fat deposits. The difference between subcutaneous fat and visceral fat is visualized as red and blue (West J. et al. https://doi.org/10.1371/journal.pone.0192495.g001 CC BY 4.0).

Detect and Monitor Domain Shift

Ensuring that AI models in healthcare consistently deliver reliable results over time is of utmost importance. Numerous studies have highlighted potential generalization and reliability issues faced by AI diagnostic systems due to longitudinal domain shift – changes in data distribution that occur over time – often leading to a decline in model performance. However, there is currently a lack of comprehensive studies on how to effectively approach and resolve this issue within the field of AI for digital pathology.

We hypothesize that multiple factors in the histopathology data preparation pipeline may interact to influence the performance and resilience of AI models over extended periods. These factors include the introduction of new scanner equipment, variations in staining protocols, adjustments to scanner parameters, evolving diagnostic capabilities, shifts in patient cohorts, and software updates. Our project focuses on unsupervised AI approaches to detect potential performance degradation over time.

The primary objective of this project is to study longitudinal domain shift within the context of tumor classification, using an extensive retrospectively collected histopathological skin dataset. A skin pathologist will provide slide-level annotations to classify lesions into three malignant diagnoses: malignant melanoma, basal cell carcinoma, and squamous cell carcinoma. An AI model will be trained to differentiate between these diagnoses. The model's performance will then be evaluated on datasets collected in subsequent years to identify when domain shift effects begin to emerge. Finally, we aim to develop an unsupervised method for detecting performance changes.

This project will provide valuable insights into the importance of monitoring AI model robustness in digital pathology. Ensuring patient safety requires the continuous surveillance of AI model performance over extended periods in clinical settings. In the long term, such methods could alert key stakeholders – including quality assurance experts and pathologists – when model performance begins to drift beyond a predefined threshold, enabling proactive interventions to maintain model efficacy.

Digital Microscopy Oncology
Al/Data analytics

Project information

PROJECT NAME

Detect and monitor longitudinal domain shift for deep learning in digital pathology.

PROJECT LEADER

Caroline Bivik Stadler, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Milda Pocevičiūtė, Erik Ylipää, Maria Madentzoglou, Anna Bodén, Joel Pettersson, Claes Lundström.

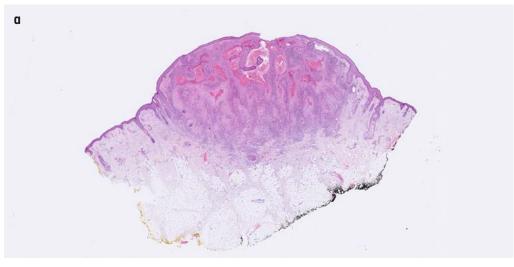
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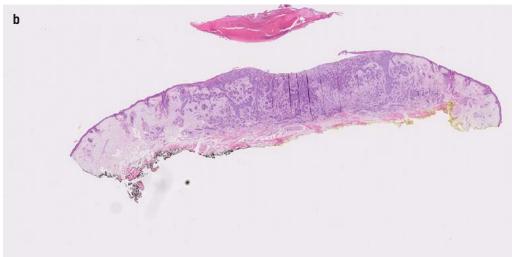
VINNOVA Medtech4Health Analytic imaging diagnostic arena (AIDA) innovation grant (2023–2025)

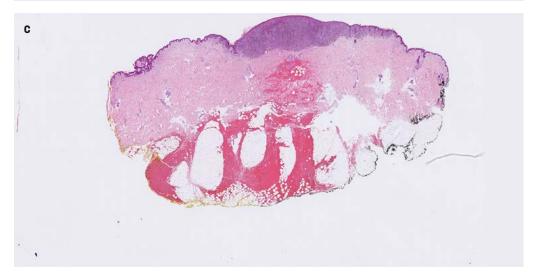
KEY PUBLICATIONS

Pocevičiūtė M, Eilertsen G, Garvin S, Lundström C. Detecting Domain Shift in Multiple Instance Learning for Digital Pathology Using Fréchet Domain Distance. In: MICCAI 2023: 26th International Conference, Vancouver, BC, Canada, October 8-12, 2023, Proceedings, Part V. Springer, Berlin, Heidelberg, p 157-167.

Stacke K, Eilertsen G, Unger J, Lundstrom C. Measuring Domain Shift for Deep Learning in Histopathology. IEEE J Biomed Health Informatics. 2021;25(2):325–336.







Whole slide images of hematoxylin ϑ eosin (H&E)-stained skin specimens acquired using a digital pathology scanner as a part of clinical routine. The images illustrate three types of skin malignancies (a) squamous cell carcinoma, (b) basal cell carcinoma, and (c) malignant melanoma.

Precision Panorama

Primary liver cancers are malignant tumors originating in the liver, with hepatocellular carcinoma (HCC) being the most prevalent type. Although the prognosis for these cancers remains poor, accurate and early diagnosis can expand treatment options and improve patient outcomes. For patients at high risk of developing HCC, as those with cirrhosis or chronic hepatitis, the LI-RADS categorization system is utilized for regular surveillance. The diagnostic challenge arises from the continuum of lesion progression ranging from benign to malignant states.

This project aims to systematically collect liver malignancy data into a comprehensive diagnostic panorama using advanced imaging technologies, with a strong emphasis on seamless clinical integration. A key objective is to establish an efficient process for creating a structured platform to house both the data and its associated metadata. This integrated precision panorama will encompass data from in-vivo and ex-vivo radiology, pathology, electronic patient records and genomics, with high-resolution photon counting CT being a particularly important resource.

In this proof-of-concept phase, the computational research focus is on upstream enrichment AI aimed at improving radiology precision through insights gained from downstream data sources. This involves establishing spatial correlation and precise linkages across the diagnostic pipeline, connecting radiology to downstream pathology microscopic features and molecular examinations of smaller lesions.

Our long term primary medical research direction is focused on refining future liver malignancy diagnostics to improve treatment for HCC patients and enhance surveillance for those at risk of developing HCC. Leveraging a comprehensive integration of multi-scale, multi-modal data allowing for a more holistic understanding of liver malignancies. During this initial pilot project, we will make contributions serving as milestones on this path.



Project information

PROJECT NAME

PrecisionPanorama: A comprehensive datadriven approach to liver cancer diagnosis.

PROJECT LEADER

Caroline Bivik Stadler, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

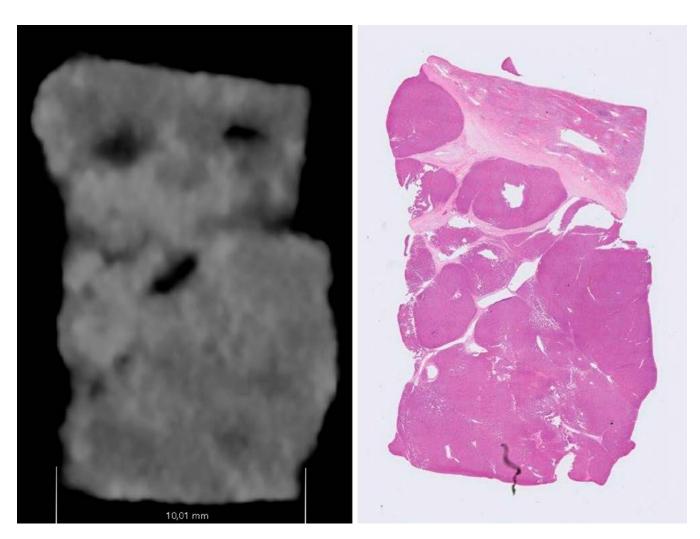
Tomas Bjerner, Bergthor Björnsson, Simone Ignatova, Claes Lundström, Per Sandström, Darren Treanor.

GRANTS

LiU Cancer

KEY PUBLICATIONS

Stadler, C.B, Lindvall, M, Lundström, C et al.
Proactive Construction of an Annotated
Imaging Database for Artificial Intelligence
Training. J Digit Imaging 34, 105–115 (2021).
Lundström CF, Gilmore HL, Ros PR. Integrated
diagnostics: the computational revolution
catalyzing cross-disciplinary practices
in radiology, pathology, and genomics.
Radiology, 2017 Oct;285(1):12–5.



Two images of the same liver malignancy resection sample captured using different imaging techniques: a CT image obtained with a photon-counting computed tomography (PCCT) (A) and a hematoxylin and eosin (H&E)-stained whole slide image acquired using a digital pathology scanner (B).

Bigpicture

To advance AI development in pathology, a European consortium composed of leading research centers, hospitals, and major pharmaceutical companies is creating the world's largest repository for sharing pathology data. This 6-year, €70 million initiative, called Bigpicture, marks a transformative moment in the field of pathology.

The Center for Medical Image Science and Visualization (CMIV) at Linköping University is playing a key role in the Bigpicture project, overseeing the technical infrastructure in collaboration with the Swedish ELIXIR node at SciLifeLab Bioinformatics platform NBIS and the Finnish ELIXIR node at CSC. The project draws on the expertise developed through the AIDA Data Hub, hosted by CMIV, and involves close cooperation with Bigpicture partners Region Östergötland and Sectra.

Bigpicture aims to accelerate AI development in pathology by creating the first European ethical and GDPR-compliant platform for large-scale data sharing and AI algorithm integration. This quality-controlled platform will be developed sustainably and inclusively, connecting pathologists, researchers, AI developers, patients, and industry stakeholders.

The project focuses on four key areas for large-scale data collection. First, the creation of an infrastructure - both hardware and software - to store, share, and process millions of images, each potentially gigabytes in size. Second, ensuring compliance with legal and ethical standards to protect patient privacy and data confidentiality. Third, the collection and storage of an initial set of 3 million digital slides from human and animal samples, providing essential data for developing AI tools in pathology. Lastly, developing functionalities that support the database's use for diagnostics, research, and image processing.

Project information

PROJECT NAME

Bigpicture.

PROJECT LEADER

Joel Hedlund, Department of Science and Technology, Media and Information Technology.

MAIN PROJECT PARTICIPANTS

Claes Lundstrom, Jeroen van der Laak, Caroline Bivik Stadler, Darren Treanor, Anna Boden, Pontus Freyhult, Betul Eren, Varshith Konda, Emre Balsever, Minh Ha Le, Jesper Molin, Catrin Nejdeby.

GRANTS

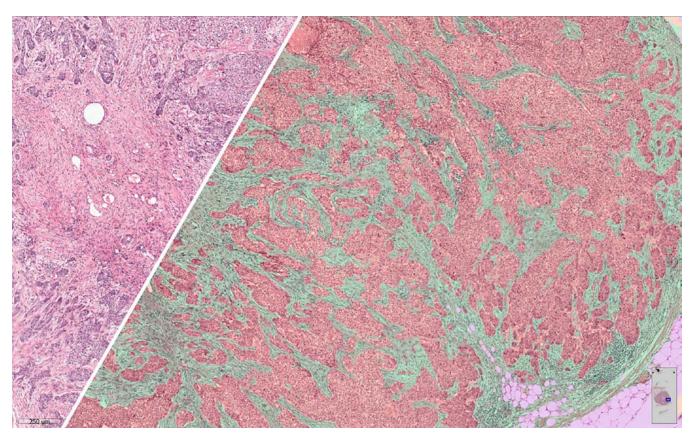
Innovative Medicines Initiative (Horizon2020, EFPIA)











Close-up view of a breast cancer histopathology slide using standard hematoxylin and eosin staining, shown here before vs. after (top-left vs. bottom-right) an AI algorithm that can recognize breast cancer was used to color the cancerous cells red and the healthy cells green. The image shows only a small portion of the full microscopy slide, as indicated by the blue rectangle in the thumbnail image at the bottom-right. The scale indicator on the bottom left indicates the length of 250µm at this level of magnification.

Spectral Photon-Counting CT Radiotherapy

DIRA typically classifies image pixels into bone and soft tissue. Bone pixels provide information on compact bone and red/yellow bone marrow proportions, while soft tissue pixels indicate the relative percentages of water, protein, and lipid. This framework also allows for organ-specific classifications.

Estimating material composition with DIRA can enhance medical diagnosis and treatment. For example, it enables precise measurement of the prostate gland's calcium content, a critical factor in brachytherapy planning with low-energy photons. High calcium content can alter the spatial distribution of absorbed dose due to the high atomic number of calcium. Similarly, DIRA's material composition analysis can benefit proton radiation therapy, as the dose maximum location is sensitive to tissue composition.

DIRA serves as a proof-of-concept tool for testing various data processing approaches. For instance, we have developed a bone segmentation method using a deep learning algorithm (González Sánchez et al., 2020) (Figure 2) and a neural network-based method for estimating the elemental composition of segmented tissues. We continue to evaluate DIRA's potential to improve radiation therapy planning accuracy and are developing techniques to integrate raw data from clinical CT scanners.

Additionally, we have created and tested methods for calculating absorbed dose distributions in proton therapy using the general-purpose Monte Carlo code TOPAS (Figure 3). These methods allow

us to quantify the improvements in dose distribution accuracy achieved by DIRA.

Our current research focuses on adapting DIRA for use in spectral CT.

Computed Tomography Oncology Musculoskeletal Modeling AI/Data analytics
Simulation

Project information

PROJECT NAME

Spectral photon-counting CT for more accurate radiotherapy.

PROJECT LEADER

Åsa Carlsson Tedgren, Department of Medicine, Health and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Alexandr Malusek, Maria Magnusson, Michael Sandborg.

GRANTS

VR-NT (2017-2020) Cancerfonden (2013-2015, 2016-2018, 2019-2021) Patientsäkerhetsforskning, Region Östergötland (2018-2019)

KEY PUBLICATIONS

Magnusson M, Alm Carlsson G, Sandborg M, Carlsson Tedgren Å and Malusek A 2023. "On the Choice of Base Materials Alvarez- Macovski and DIRA Dualenergy Reconstruction Algorithms in CT." In: Photon Counting Computed Tomography. Clinical Applications, Image Reconstruction and Material Discrimination. Edited by Hsieh, S and Iniewski K, Springer Nature Switzerland AG. ISBN 978-3-031-26061-2.

Magnusson M, Sandborg M, Alm Carlsson G, Henriksson L, Carlsson Tedgren Å and Malusek A 2021 Accuracy of CT Numbers Obtained by Dira and Monoenergetic Plus Algorithms in Dual-Energy Computed Tomography Radiat Prot Dosimetry, Vol. 195, No. 3-4, pp. 212-217.

Gonzalez Sanchez J C, Magnusson M, Sandborg M, Carlsson Tedgren Å and Malusek A 2020 Segmentation of bones in medical dual-energy computed tomography volumes using the 3D U-Net Phys Med 69 241–7.

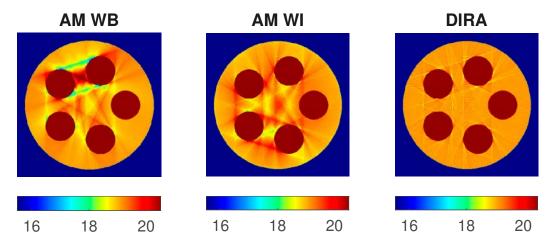


Figure 1. Reconstructed images of a cylindrical protein phantom containing water, bone, and iodine solution at 50 keV. Reconstructions were performed using the Alvarez-Macovski method with (a) the (water, bone) doublet and (b) the (water, iodine) doublet. (c) Image reconstructed by DIRA, applying the (water, bone) doublet in bone and soft tissue regions and the (iodine, water) doublet in iodine solution regions. Adapted from Magnusson et al. http://doi.org/10.1093/rpd/ncab097 under CC BY.

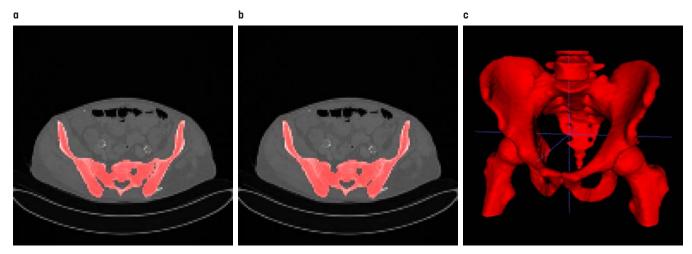


Figure 2. Segmentation of pelvic bones using the 3D U-Net architecture. (a) Ground truth segmentation. (b) Algorithm-predicted segmentation. (c) 3D visualization of the predicted segmentation. Adapted from González Sánchez et al. (2020) under CC BY.

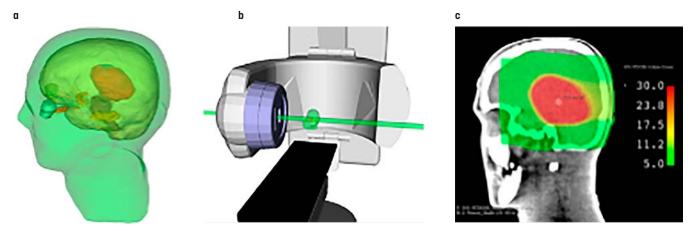


Figure 3. (a) Radiation therapy (RT) structures displaying essential organs and the tumor in a phantom head model. (b) A single proton field from a radiation treatment plan. (c) Spatial distribution of absorbed dose from protons within the head tumor.

Medical Digital Twin

A medical digital twin is a computer model that contains information and parameters that describe a person's anatomy and physiology and form a personalized digital copy. Access to digital, functional models of organs in the body offers invaluable opportunities for research and for development of products related to visualization of medical data.

Medical Digital Twin, MeDigiT, is a platform project financed by Visual Sweden aiming to facilitate the use of individualized digital models in healthcare for better diagnostics, more individualized treatment of illness, and simplified and improved education for healthcare professionals. The platform also aims to create and promote a network for research and exchange of knowledge and experience between Linköping University (LiU), Region Östergötland (RÖ) and companies active within medical visualization.

The platform was formed in 2019 and has since then connected several partners. Currently, six demonstrator projects are active:

A collaboration project between CMIV, Sectra, RÖ and LiU, investigates how we in a controlled way can synthesize disease progression in histopathology images using generative AI for the purpose of education of pathologists. CMIV's cutting edge research on imaging of the cardiovascular system is used in a project involving LiU, RÖ, and Cordicity AB. Simulations of heart flow based on CT images are used to individualize digital twins for diagnosis and treatment evaluation in heart disease. The research aims to improve valve surgery and risk assessment of blood clot formation for

atrial fibrillation patients. LiU researchers in collaboration with AstraZeneca and SUND develop models of physiological processes, e.g., cardiovascular characteristics and metabolism, with the goal of personalizing a whole-body digital twin. The models can be used in eHealth applications to prevent diseases and individualize advice to promote a healthy lifestyle. In collaboration with AMRA, a usability study is conducted to investigate how information from digital

twins can be presented to physicians and patients. Another project, led by Mentice, investigates, develops and improves methods to convert clinical imaging data into 3D models of patient-specific cardiovascular anatomy with the goal of creating a planning tool for endovascular surgery. Finally, the HEALTH2 study acquire clinical whole-body data that can provide invaluable information and imaging data on common diseases linked to type 2 diabetes.

 Computed Tomography
 MRI
 Cardiovascular
 Musculoskeletal
 Metabolism
 Acquisition

 Modeling
 Al/Data analytics
 Visualization
 Simulation
 Imaging Biomarkers

${\it Project information}$

PROJECT NAME

Medical Digital Twin.

PROJECT LEADER

Jonas Lantz, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Maria Ewerlöf, Tilda Herrgårdh, Mikael Forsgren, Henrik Storm, Gunnar Cedersund, Peter Gennemark, Gabriel Eilertsen, Theresa Lindholm, Mattias Ekstedt.

GRANTS

Visual Sweden (2022-2025) In-kind contributions from several companies

KEY PUBLICATIONS

Simonsson C., Nyman E., Gennemark P., Gustafsson P., Hotz I., Ekstedt M., Lundberg P., Cedersund G., "A unified framework for prediction of liver steatosis dynamics in response to different diet and drug interventions.", Clin Nutr. 2024, 43(6):1532–1543. https://doi.org/10.1016/j. clnu.2024.05.017.

Ohlsson, L., Sandstedt, M., Papageorgiou, J.-M., Svensson, A., Bolger, A. F., Tamás, É., Granfeldt, H., Ebbers, T., Lantz, J. (2024). Haemodynamic significance of extrinsic outflow graft stenoses during HeartMate 3™ therapy. European Heart Journal. Imaging Methods and Practice, 2(3). https://doi.org/10.1093/ehjimp/qyae082

Linge, J., Birkenfeld, A. L., & Neeland, I. J. (2024). [Review of Muscle Mass and Glucagon-Like Peptide-1 Receptor Agonists: Adaptive or Maladaptive Response to Weight Loss?]. Circulation, 150(16), 1288–1298. https://doi.org/10.1161/CIRCULATIONAHA.124.067676.



 ${\tt Jonas\,Lantz\,presenting\,the\,Medical\,Digital\,Twins\,concept\,at\,Museum\,of\,Technology,\,Stockholm.\,Copyright/photographer:\,Maja\,Meurling.}$

BrAInScap: Substudy Brain in Scapis 2

Acute myocardial infarction has decreased during the last decades, with stroke now being the most common acute cardio-vascular disease in Sweden today. There is also a rise in the prevalence of dementia in the general population, which is a diagnosis likewise connected to the presence of cardiovascular risk factors and cardiovascular disease. Normal pressure hydrocephalus is another condition where there is a related co-morbidity with cardiovascular disease, but the underlying mechanisms are not clearly understood.

The overall purpose of this study is to elucidate underlying disease mechanisms, to identify risk factors, and to contribute to improved prevention, diagnostics, and treatment of vascular disease of the brain such as stroke, hydrocephalus, and dementia.

In addition to this research, focused on identifying factors with a predictive value for brain disease and the investigation of the correlation between early brain changes and future disease development, this study will enable the exploration of incidental findings in an asymptomatic population. The substantial number of scans will also provide a solid foundation for AI analysis and method developments regarding volumetric analyses and automatic screening of incidental findings.

The data in this study, the SCAPIS 2 (Swedish CArdio Pulmonary bioImage Study) sub-study Brain, consists of 4 500 study participants, who will be included for an examination of the brain with the new technology of the photon counting detector computed tomography (PCCT) in addition to the core protocol of SCAPIS 2.

This is a multicenter study, with collaboration between Linköping, Uppsala and Stockholm in which participants will be enrolled and examined at the three different sites. In addition to the brain-CT protocol performed for the whole group, the different sites also have local study protocols; in Uppsala a subgroup will go through a CT of the temporal bone, in Stockholm a subgroup will be examined with brain magnetic resonance imaging (MRI), and in Linköping a subgroup will be examined with CT angiography of the carotid arteries, a collaboration with another CMIV project: CarFUP (Dyverfeldt and Good).

Primary data collection is well underway with expected completion in early 2026, with ensuing data analysis.

Computed Tomography Cardiovascular

Neurology Al/Data analytics

Imaging Biomarkers

Project information

PROJECT NAME

Neuroradiology, new technology, and Al in conjunction to explore cardiovascular effects on the brain from a population perspective.

PROJECT LEADER

Ida Blystad, Radiology Department, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Kristina Söderberg, Erik Tesselaar, Elin Good, Petter Dyverfeldt, David Fällmar, Tobias Granberg.

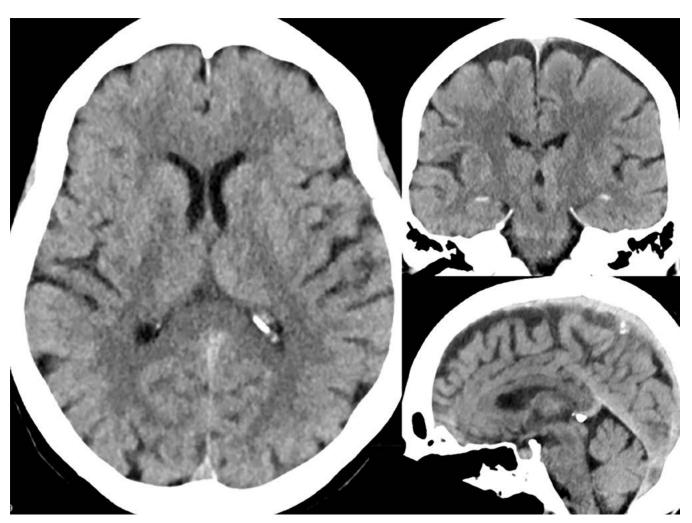
GRANTS

Clinical research grant Region Östergötland Student till docent Region Östergötland Clinical fellowship with Wallenberg Center for Molecular Medicine

KEY PUBLICATIONS

Fällmar D and Andersson O, Kilander L, Löwenmark M, Nyholm D, Virhammar J. Imaging features associated with idiopathic normal pressure hydrocephalus have high specificity even when comparing with vascular dementia and atypical parkinsonism. Fluids Barriers CNS. 2021 Jul 29;18(1):35. doi: 10.1186/ s12987-021-00270-3. PMID: 34325703.

Bos D, Poels MM, Adams HH, Akoudad S, Cremers LG, Zonnenveld, et al. Prevalence, Clinical Management, and Natural Course of Incidental Findings on Brain MR Images: The Populationbased Rotterdam Scan Study. Radiology. 2016;281(2):507-15.



Photon counting detector computed tomography of the brain.

Post-COVID, Chronic Fatigue, and Exhaustion

Persistent, debilitating fatigue is increasingly recognized as a major societal challenge, with many individuals reporting lower quality of life than those with cancer or stroke. Fatigue is a key symptom of Myalgic Encephalomyelitis/Chronic Fatigue Syndrome (ME/CFS), Exhaustion Disorder (ED), and is commonly reported after COVID-19 infection.

Our study seeks to better understand the shared and distinct mechanisms behind these conditions to develop more effective diagnostic tools and treatments. We are investigating immunological, nutritional, psychological, and brain network measures in 200 patients with post-COVID fatigue, ME/CFS, ED, alongside healthy controls and recovered individuals.

We hypothesize that common biopsychosocial vulnerability factors contribute to the development and persistence of fatigue, regardless of the diagnosis. Additionally, we suspect that subgroups within these conditions exhibit distinct profiles of these factors, where having multiple factors may lead to poorer prognosis. We will also explore the relationships between biomarkers, brain network connectivity, and symptoms like pain, stress sensitivity, and post-exertional malaise across these groups.

Central sensitization, which amplifies sensory signals in the central nervous system, is thought to play a key role in long-term fatigue conditions. However, there is limited research on fatigue as the primary symptom. Some studies have identified abnormal functional connectivity in ME/CFS, ED, and post-COVID conditions, but it's unclear whether these persist after recovery. More research is needed to understand the role of these

brain connectivity changes in both illness and recovery.

Preliminary findings from collaborators in Stockholm show that patients with ME/CFS exhibit symptom patterns similar to acute inflammation. Our research has also examined how fatigue develops in response to inflammation and how this affects the success of psychological treatments. Recent findings suggest that chronic pain and fibromyalgia patients show changes in immune-related proteins and reduced brain connectivity between motivation and cognition areas. This pattern is also seen in individuals with high fatigue, including those with irritable bowel syndrome (IBS) and multiple sclerosis.

Collaborators have also found that psychological therapies, like Acceptance and Commitment Therapy (ACT), hold promise for ME/CFS, while behavioral interventions are beneficial for ED. Understanding the shared mechanisms of central sensitization could guide the development of more targeted treatments for fatigue-related conditions.

This research will enhance our understanding of post-COVID syndrome and fatigue's transdiagnostic mechanisms, leading to more precise diagnosis and treatment strategies. Our goal is to improve healthcare outcomes through interventions that target the underlying biological and psychosocial mechanisms of fatigue, ultimately improving quality of life for affected individuals.

MRI Neurology Metabolism
No Method Development

Project information

PROJECT NAME

Post-COVID, Chronic Fatigue, and Exhaustion.

PROJECT LEADER

Rozalyn Simon, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Anna-Karin Norlin, Bijar Ghafouri, Elena Dragioti, Maria Engström, Hanna Linnros, Elin Lindsäter, Anna Andreasson, Karin Jensen.

GRANTS

ALF Från Student till docent VR Forte Sinnecentrum

KEY PUBLICATIONS

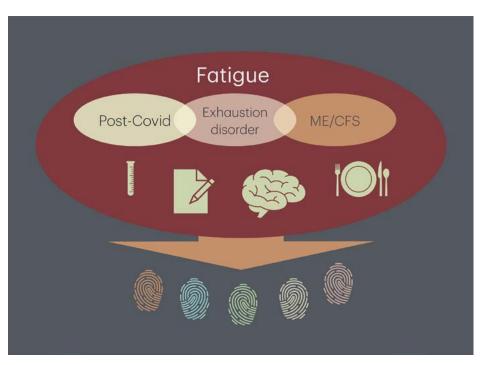
Jonsjö MA, Olsson GL, Wicksell RK, Alving K, Holmström L, Andreasson A. The role of low-grade inflammation in ME/CFS (Myalgic Encephalomyelitis/Chronic Fatigue Syndrome)-associations with symptoms. Psychoneuroendocrinology. 2020 Mar 1;113:104578.

Lindsäter E, Axelsson E, Salomonsson S, Santoft F, Ejeby K, Ljótsson B, Åkerstedt T, Lekander M, Hedman-Lagerlöf E. Internetbased cognitive behavioral therapy for chronic stress: a randomized controlled trial. Psychotherapy and psychosomatics. 2018 Jul 24;87(5):296-305.

Norlin AK, Walter S, Icenhour A, Keita ÅV, Elsenbruch S, Bednarska O, Jones MP, Simon R, Engström M. Fatigue in irritable bowel syndrome is associated with plasma levels of TNF-α and mesocorticolimbic connectivity. Brain, behavior, and immunity. 2021 Feb 1;92:211-20.



A woman struggling with fatigue.



Overlapping symptoms in diagnoses and subgroup profiles for specialized treatment.

Automatic Ventricle Segmentation Using 3D Quantitative MRI

Normal Pressure Hydrocephalus (NPH) has an estimated prevalence of 11 in 100.000 people but is probably substantially underdiagnosed. It occurs mainly in elderly people and is characterized by disturbed gait, incontinency issues and confusion. Due to unknown factors the ventricles in the brain swell causing these symptoms. In many cases the symptoms are confused with dementia, while a relatively standard procedure of placing a drain to remove surplus cerebrospinal fluid (CSF) from the ventricles can alleviate the symptoms instantly.

One challenge in diagnosing and monitoring NPH is the lack of automated methods to measure the volume of the ventricles. Visual inspection of MR images to estimate its size is very imprecise and typically requires at least a change of 20 ml (>10%) to be radiologically visible.

Quantitative Magnetic Resonance Imaging offers the ability to measure physical characteristics of the patient's brain. Using absolute measures allows for robust segmentation of specific tissue types, such as the brain and CSF. For NPH patients a specific ventricle segmentation was developed to separate all detected CSF into ventricular CSF and extra-axial CSF. Manual segmentation requires 15–30 minutes and is clinically not possible. The segmentation, however, builds on a 6-minute MR acquisition and requires only seconds of post-processing.

The algorithm was trained on 45 manually segmented ventricles by a neurologist and a neuro-surgeon and tested on 93 cases including both pre- and postshunt operation datasets. Segmentation is challenging due to thin membranes in the CSF between the ventricles and other cisterns, patient-specific anatomical variations, and image artifacts caused by shunt placement. The Dice overlap scoring between manual segmentation and the current automatic segmentation is 98%. The average difference is 0.5 ml. In the figure a correlation plot is shown of automatic segmentation as a function of manual segmentation. In the brain images red shows manual segmentation, green shows automatic segmentation.

SyntheticMR AB, a spin-off company from CMIV, was founded in 2007 to commercialize MR quantification. Their product, SyMRI, is sold worldwide on all MR vendors and today they have sales offices in the USA, India and Japan. So far MR quantification was performed based on a multi-slice TSE sequence with high in-plane resolution but relatively few slices. Recently, a full 3D quantification was released. The automatic ventricle segmentation is a further development on this approach, which may become an important tool for monitoring hydrocephalus patients in the future.



Project information

PROJECT NAME

Automatic Ventricle Segmentation Using 3D Quantitative MRI.

PROJECT LEADER

Marcel Warntjes, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

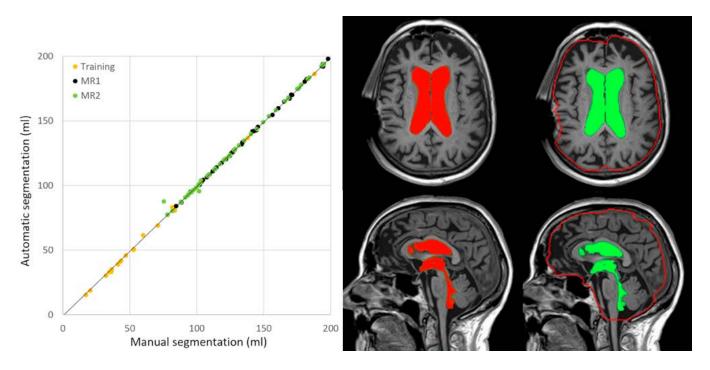
Rafael Holmgren, Charalampos Georgiopoulos, Anders Tisell.

KEY PUBLICATIONS

Kvernby S, Warntjes M, Haraldsson H et al. Simultaneous three-dimensional myocardial T1 and T2 mapping in one breath hold with 3D-QALAS. Cardiovasc Magn Reason 2014;16:102. DOI: 10.1186/ s12968-014-0102-0.

Fujita S, Hagiwara A, Hori M et al. Threedimensional high-resolution simultaneous quantitative mapping of the whole brain with 3D-QALAS: An accuracy and repeatability study. Magn Reson Imaging 2019;63:235-243. DOI: 10.1016/j. mri.2019.08.031.

Fujita S, Yokoyama K, Hagiwara A et al. 3D Quantitative Synthetic MRI in the Evaluation of Multiple Sclerosis Lesions. AJNR Am J Neuroradiol 2021;42:471-478. DOI: 10.3174/ajnr.A6930.



Correlation plot of automatic segmentation as a function of manual segmentation of 45 training datasets and 93 NPH cases, both pre- and post shunt operation. In the brain images, red shows manual segmentation, green shows the corresponding automatic segmentation.

Localization of Seizure Onset Zone in Focal Epilepsy

EEG-fMRI is a method that combines EEG (electroencephalogram) and fMRI (functional magnetic resonance imaging) to localize the epileptogenic zone in patients with medically refractory focal epilepsy who are candidates for epilepsy surgery. The method is in use in some epilepsy centers around the world but not in clinical practice in Sweden. The aim of this study is to implement the method in epilepsy surgery evaluation and to compare the results with other investigations.

Epilepsy is a disorder with uncontrolled electric activity in the cortex of the brain. In most people with epilepsy, the seizures are controlled by medication. About 30 % of patients continues to have seizures despite medication with one or more antiepileptic drugs. The disease is then defined as medically refractory and some of these patients are evaluated for epilepsy surgery. Epilepsy surgery is a treatment option that can cure patients with epilepsy. In most cases, a small part of the brain is resected. Before this operation, it is very important to define the area where the seizures starts, called the seizure onset zone. There are many different methods such as MRI (structural lesion), EEG (electrical activity), PET (metabolism) and SPECT (blood flow) used to localize this zone. Sometimes invasive methods like intracranial EEG must be used. Combined EEG-fMRI allow mapping of BOLD (blood oxygen level dependent) signal changes correlated to epileptiform discharges in the EEG. The electrical discharges in the cortex that is typical for epilepsy correlates to localized changes in oxygen consumption and blood flow, which alters the BOLD-signal (the hemodynamic response function). The EEG defines the time for epileptiform discharges and fMRI is recorded continuously. Studies in other centers have concluded that this method can accurately localize the seizure onset zone. It is difficult to record EEG of good quality in the MR scanner because of artifacts induced by the magnetic and electromagnetic fields. Special equipment is necessary to be successful in recording a good quality EEG in the MR scanner. CMIV and The Department of Clinical Neurophysiology at the University Hospital in Linköping has the equipment for recording of EEG in the MR scanner.

Method: With an MR safe EEG cap, EEG is recorded with 64 electrodes during fMRI scanning (3T) for 30 minutes. Offline analysis of EEG to identify epileptiform discharges and timing of these events. Analysis of fMRI data with different hemodynamic response functions in relation to the events in EEG. This gives maps with the strongest BOLD changes.

Material: Twenty adult patients with medically refractory focal epilepsy who are evaluated for epilepsy surgery were included in the study. The collection of data started in September 2019 and has now been concluded.

Results: The EEGs have been examined and in seven patients there were sufficient amount epileptiform activity during scanning to analyze the correlation between epileptiform activity and BOLD-changes. Preliminary results from two patients are shown in figure 1 and 2. The data will be further analyzed.



Project information

PROJECT NAME

Localization of Seizure Onset Zone in Focal Epilepsy.

PROJECT LEADER

Hans Lindehammar, Department of Clinical Neurophysiology, University Hospital Linköping.

MAIN PROJECT PARTICIPANTS

Helena Gauffin, Mats Svantesson, Paul Hamilton, Katarina Henell Eklund.

GRANTS

Sinnescentrum, Region Östergötland Föreningen Margarethahemmet

KEY PUBLICATIONS

Contribution of EEG/fMRI to the definition of the epileptic focus. Pittau F, Dubeau F, Gotman J. Neurology 2012;78:1479-1487.

The hemodynamic response to interictal epileptic discharges localizes the seizure-onset zone. Khoo HM, Hao Y, von Ellenrieder N et al. Epilepsia 2017;58(5):811–823.

Clinical benefit of presurgical EEG-fMRI in difficult-to -localize focal epilepsy: A single-institution retrospective review. Kowalczyk MA, Omidvarnia A, Abbott DF et al. Epilepsia 2020;61:49-60.



Figure 1. The most significant BOLD-changes correlated to epileptiform activity in a patient with epilepsy that was earlier operated for focal cortical dysplasia in the left frontal lobe.

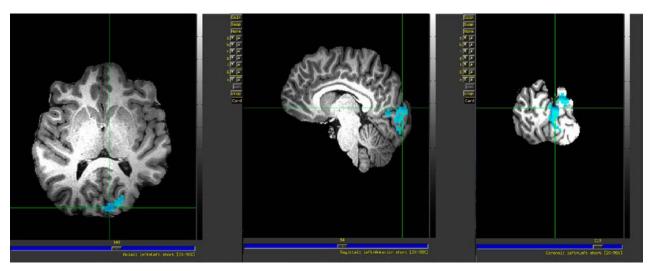


Figure 2. The most significant BOLD-changes correlated to epileptiform activity in a patient with epilepsy that was earlier operated for focal cortical dysplasia in the right occipital lobe.



Figure 3. Patient and nurses by the MR scanner.

Detection and Neurological Effects of Manganese

Manganese (Mn) is a metal that occurs naturally in the environment. It is an essential substance that is part of several important enzyme systems; for example, it participates in the body's energy conversion and helps protect against free radicals. Among the general population, food is the main source of manganese exposure.

In occupational settings, exposure to manganese-containing dust and fumes occurs primarily during welding but also within the steel and smelting industries. Through inhalation of dust and fumes, manganese can be deposited in the respiratory tract, where some is absorbed and transported further into the body.

Manganese can cross the protective barriers of the brain and accumulate in specific areas, such as the basal ganglia. MRI studies on welders have previously shown manganese accumulation in the brain. Once exposure ceases, manganese is only gradually excreted, and its concentration in the body returns to a natural equilibrium.

Workers exposed to high levels of airborne manganese (>1 mg/m³) over extended periods are at risk of developing manganism, a serious condition with symptoms similar to Parkinson's disease. Several studies have demonstrated potentially harmful effects on the central nervous system, including impaired motor and cognitive functions, increased tremors, and a higher prevalence of neuropsychiatric symptoms among workers exposed to significantly lower levels than 1 mg/m³.

Many welding methods result in air exposure levels where negative effects on the central nervous system have been observed, with indications that these effects may persist even after exposure has ended. Compared to smelters, welders exhibit significantly higher manganese accumulation in the basal ganglia and thalamus, along with greater alterations in neurotransmitter function. This is despite the fact that traditional exposure measures, such as airborne manganese concentration, were found to be ten times lower for welders. The form of manganese exposure (including particle size and chemical composition) therefore appears to play a crucial role in determining which areas of the brain are affected.

This project aims to investigate the effects of manganese accumulation, particularly in the subcortical tissues, and its cognitive impact on the brains of welders with specific types of occupational exposure. The study protocol includes quantitative MRI techniques such as spectral editing for neurotransmitter detection, diffusion measurements, and resting-state fMRI. Additionally, the project encompasses a wide range of occupational assessments, including blood analyses.

MRI Neurology Acquisition
Imaging Biomarkers

Project information

PROJECT NAME

Detection and Neurological Effects of Manganese (Mn) in the Brain of Welders and Other Subjects (MANGAN).

PROJECT LEADER

Peter Lundberg, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

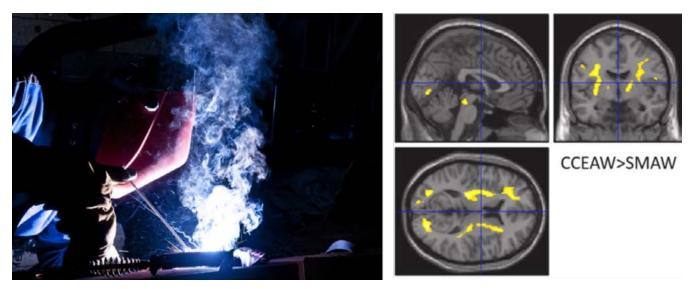
Per Thunberg, Karin Åberg, Göran Lidén, Gunilla Wastensson, Bernt Bergström, Louise Fornander, Mary Adjeiwaah, Jens Tellman, Anders Tisell, Ida Blystad.

GRANTS

FORTE

KEY PUBLICATIONS

Thunberg P, Wastensson G, Lidén G,
Adjeiwaah M, Tellman J, Bergström
B, Fornander L, Lundberg P (2024)
Welding techniques and manganese
concentrations in blood and brain:
Results from the WELDFUMES study,
NeuroToxicology, Volume 105, December
2024, Pages 121-130 (Open access/
Creative commons).



Via inhalation of dust and smoke, manganese can be deposited in the respiratory tract where some is taken up and transported further into the body. Subsequent manganese accumulation in the brain is different for different welding methods (larger for Continuous Consumable Electrode Arc Welding – CCEAW compared with Shielded Metal Arc Welding – SMAW). (Thunberg P, et al, NeuroToxicology, Volume 105, December 2024, Pages 121-130 (Open access/Creative commons).

Improved Diagnosis of Pediatric Brain Tumours Using Al-Based Digital Pathology

Clinical pathology is a cornerstone of healthcare in medical diagnostics. Diagnostics is primarily performed at the cellular level, where tissue is classified and assessed according to various criteria. A biopsy analysis involves multiple sub-analyses that contribute to the development of various treatments.

Rapid medical advancements, particularly in cancer care, are moving towards individually tailored treatments (known as "precision medicine"), placing increasingly high demands on efficiency and quality in clinical pathology. Cancer diagnostics are already highly resource-intensive, and their number and scope are expected to increase significantly in the future. This is due to both the growing proportion of elderly individuals and a healthier aging population, as well as advancements in technology.

This places significant demands on diagnostic tools in clinical pathology, which are evolving at the same rapid pace as the rest of cancer care. This trend is not unique to cancer care; similar developments are observed across many disease areas.

The development of advanced decision support systems in pathology will therefore be essential to streamline processes and further enhance diagnostic safety. The digitalization of clinical pathology has enabled the use of rapid advancements in artificial intelligence (AI) and machine learning to develop AI-based support systems, such as image analysis for clinical decision support.

However, a particular challenge in developing these tools is the limited availability of training data, which is often inaccessible to research groups and companies with expertise in the field.

In this project, we have digitalized a national pediatric brain tumor cohort from Barntumörbanken (BTB). Moreover, we aim to develop and implement AI algorithms and similar methods as a diagnostic supplement for tumors of the central nervous system in children. The vision is that, after validation, the AI-based tools can serve as clinical decision support, enhancing safety and precision in clinical pathology and greatly benefiting future patients.

Digital Microscopy Neurology Oncology AI/Data analytics Imaging Biomarkers

Project information

PROJECT NAME

Improved Diagnosis of Central Nervous System Tumours in Both Children and Adolescents Using Al-Based Digital Pathology.

PROJECT LEADER

Peter Lundberg, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine Neda Haj Hosseini, Department of Biomedical Engineering, Division of Biomedical Engineering.

MAIN PROJECT PARTICIPANTS

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GRANTS

Barncancerfonden LiU-Cancer Joanna Cocozzas stiftelse för barnmedicinsk forskning Forsknings-ALF Region Östergötland

KEY PUBLICATIONS

Tampu IE, Nyman P, Spyretos C, Blystad I, Shamikh A, Prochazka G, Sandgren J, Lundberg P, Haj-Hosseini N, Pediatric brain tumor classification using digital histopathology and deep learning: evaluation of SOTA methods on a multicenter Swedish cohort (2024), arXiv.

Tampu IE, Bianchessi T, Blystad I, Lundberg P, Nyman P, Eklund A, Haj-Hosseini N, Pediatric brain tumor classification using deep learning on MR images from the Children's brain tumor network (2024), medRxiv.

Spyretos C, Tampu IE, Khalili N, Pardo Ladino JM, Nyman P, Blystad I, Eklund A., Haj-Hosseini N, Early Fusion of H&E and IHC Histology Images for Pediatric Brain Tumor Classification (2024) accepted in MICCAI Workshop on Computational Pathology with Multimodal Data (COMPAYL); Proceedings in Machine Learning Research.



 $\label{thm:continuous} The image shows the histology slides from {\tt Barntum\"orbanken}\ that\ are\ digitalized\ in\ the\ {\tt SmallPicture}.$

Ketamine Reduces Neural Self-Other-Distinction of Affective Touch

A coherent sense of self is crucial for social functioning and mental health. Ketamine induces short-term dissociative experiences and has therefore been used to model an altered state of self-perception. This study investigated the mechanisms behind ketamine's effects on the bodily sense of self in the context of affective touch, by comparing the effects of ketamine and placebo. Thirty healthy participants received either ketamine or placebo while touching their own arm and while being touched by someone else during an MRI scan.

During and after ketamine administration, participants reported more dissociative experiences compared to placebo. Moreover, the difference in neural activity in the right temporoparietal cortex between self- and other-touch was smaller during ketamine than during placebo. This reduction was related to ketamine-induced reductions in interoceptive awareness - the perception of internal bodily processes. Ketamine also increased the crosstalk between brain regions: Connectivity between the temporoparietal cortex, somatosensory cortex, and insula was stronger during other- compared to self-touch. Stronger connectivity was associated with greater dissociative symptoms in participants.

The results of this study show that ketamine-induced disruption of selfexperience affects neural activity related to the way we experience self- and other-touch. This happens in the temporoparietal cortex, a region involved in touch perception and social cognition. This process may result from ketamine's effect on neural signals that reflect our beliefs and expectations about sensory information from the outside world and one's own body. These signals may become blurred, making it more difficult to distinguish between sensations caused by oneself and those caused by somebody else. It also shows that in cases of dissociative experiences, the processing of tactile sensory information is likely altered.

This study is also important for understanding how neural processing may differ in patients with a distorted sense of self, such as those with schizophrenia. MRI Neurology Imaging Biomarkers

Project information

PROJECT NAME

Ketamine reduces the neural distinction between self- and other-produced affective touch: a randomized double-blind placebocontrolled study.

PROJECT LEADER

Rebecca Böhme, Department of Biomedical and Clinical Sciences, Center for Social and Affective Neuroscience.

MAIN PROJECT PARTICIPANTS

Reinoud Kaldewaij, Paula Salamone, Adam Enmalm, Andrea Johansson Capusan, Lisbet Severin, Markus Heilig, Håkan Olausson.

GRANTS

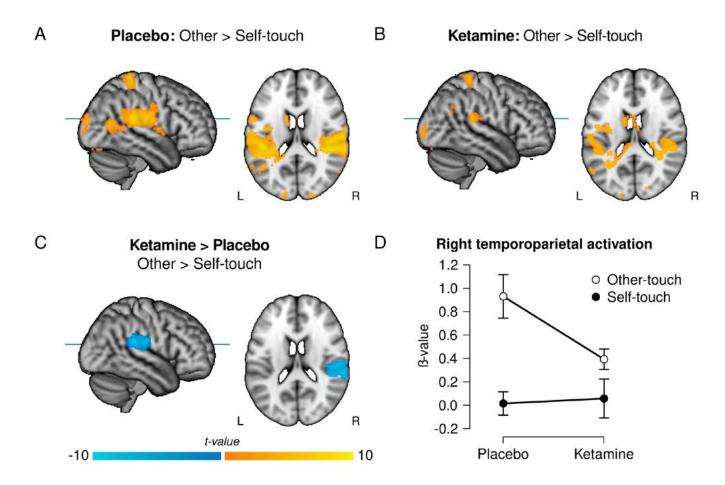
Vetenskapsrådet startbidrag Åke Wiberg stiftelse FORSS ALF RÖ

KEY PUBLICATIONS

Kaldewaij, R., Salamone, P. C., Enmalm, A., Östman, L., Pietrzak, M., Karlsson, H., ... & Boehme, R. (2024). Ketamine reduces the neural distinction between self-and other-produced affective touch: a randomized doubleblind placebo-controlled study. Neuropsychopharmacology, 1-8.

Boehme, R., Karlsson, M. F., Heilig, M., Olausson, H., & Capusan, A. J. (2020). Sharpened self-other distinction in attention deficit hyperactivity disorder. Neurolmage: Clinical, 102317.

Boehme R, Hauser S, Gerling G, Heilig M, Olausson H. Distinction of self-produced touch and social touch at cortical and spinal cord levels. Proceedings of the National Academy of Sciences (PNAS), Jan 22, 2019.



A, B Activation differences for other- vs. self-touch under placebo A and ketamine B. C Ketamine reduces self-other-differentiation in the right temporoparietal cortex. Negative values indicate a ketamine-related reduction. D Mean beta-values for the different treatment and touch conditions, extracted from the cluster of voxels for display purpose, showing the significant interaction depicted in C. Data originally published in Neuropsychopharmacology (Kaldewaij, R., Salamone, P.C., Enmalm, A. et al. Ketamine reduces the neural distinction between self- and other-produced affective touch: a randomized double-blind placebo-controlled study. Neuropsychopharmacol. 49, 1767–1774 (2024). https://doi.org/10.1038/s41386-024-01906-2.

Schizophrenia's Altered Sense of Self

Schizophrenia is a psychiatric condition associated with an altered sense of self, characterized by heightened self-referential thinking and difficulties in distinguishing between self-generated and externally generated sensations. This study investigated the tactile self-other distinction through an ecologically valid touch task during brain imaging, comparing individuals with schizophrenia to healthy controls. During fMRI recordings, participants were instructed to either touch their own arm (self-touch condition) or be touched on the arm by an experimenter (other-touch condition). Schizophrenia patients exhibited heightened brain activity across various sensory processing regions in response to touch, regardless of the condition.

Notably, patients showed increased activation in brain regions associated with social and bodily self-awareness, such as the superior temporal gyrus during the self-touch condition, and in areas crucial for self-other distinction, such as the temporoparietal junction, during the other-touch condition. These findings suggest that individuals with schizophrenia may experience altered perceptions of self- and other-generated touch. Understanding these alterations in touch processing could shed light on self-related disturbances in schizophrenia and related disorders.

MRI Neurology Imaging Biomarkers

Project information

PROJECT NAME

Schizophrenia's altered sense of self: a multimethod study of self-other differentiation and interoception in patients and controls.

PROJECT LEADER

Rebecca Böhme, Department of Biomedical and Clinical Sciences, Center for Social and Affective Neuroscience.

MAIN PROJECT PARTICIPANTS

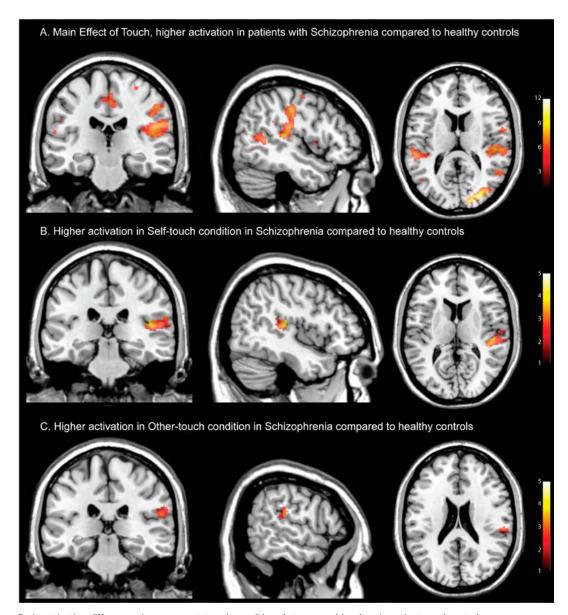
Paula Salamone, Adam Enmalm, Andrea Johansson-Capusan.

GRANTS

Fredrik och Ingrid Thurings stiftelse ALF FORSS the Swedish Research Council (2019-2023)

KEY PUBLICATIONS

Salamone, P.C., Enmalm, A., Kaldewaij, R., Åman, M., Medley, C., Johansson-Capusan, A., Olausson, H., & Böhme, R. Schizophrenia's altered sense of self: a multimethod study of selfother differentiation and interoception in patients and controls. (In prep), preregistration: https://osf.io/kzscj.



Brain activation differences in response to touch conditions between schizophrenia patients and controls. (A) Schizophrenia patients showed increased activation across several brain areas in response to touch, independent of the specific condition, including sensory regions (e.g., postcentral and precentral gyri) and associative regions (e.g., fusiform gyrus, supramarginal gyrus). (B) During self-touch, schizophrenia patients revealed higher activation in the right superior temporal gyrus (STG) compared to controls. (C) In the other-touch condition, patients also showed increased activation in a temporoparietal area.

Spinal Cord Activity during Touch from Self and Other

Touch is crucial for identifying the physical boundary between our own body and the outside world. It therefore plays an important role in our sense of self and social interactions. The distinct experiences of 'being touched' and 'touching oneself' are reflected in primary sensory brain areas, but also regions that are important for social cognition and interoception. Previous studies provide some clues that self and other-touch are already processed differently at the level of the spinal cord, but the exact mechanisms are not yet understood.

During MRI of the brain and spinal cord, participants either touched their own left forearm (i), touched an object (ii), or were touched on their left forearm by an experimenter (iii). The touch consisted of slow and gentle stroking movements, which mimic real-life social touch. Two slightly different parts of the spinal cord were investigated, in the region of the neck.

Brain activation patterns for self-touch other-touch and object-touch were similar to previous findings. In one part of the spinal cord, two areas of activation were found that were stronger for selftouch. This activation was probably related to the touch sensation on the touching hand and the movement of the touching hand. In another part of the spinal cord, a third area of activation showed to stronger activation for other-touch compared to self-touch. This last finding shows that the way we process self-touch is already distinct at the level of the spinal cord. This third area in the spinal cord showed a similar activation pattern to brain regions that are important for movement initiation. This shows that the brain is communicating with, and perhaphs also influencing, activity in the spinal cord.

This study is important for our understanding of how we distinguish touch from ourselves versus to touch from others. We often assume that this process is entirely carried out by the brain, but now we have reasons to believe that the spinal cord is also involved. This also means that if we want to understand why some people have trouble distinguishing self-touch from touch by somebody else, we may need to look not only at the brain, but also at the spinal cord.

MRI Neurology Imaging Biomarkers

Project information

PROJECT NAME

The backbone of the self? Differential spinal cord activity during self-other-object touch.

PROJECT LEADERS

Rebecca Böhme and Håkan Olausson, Department of Biomedical and Clinical Sciences, Center for Social and Affective Neuroscience.

MAIN PROJECT PARTICIPANTS

Reinoud Kaldewaij, Adam Enmalm, Robin Kämpe, Paula Salamone, Juergen Finsterbusch, Alexandra Tinnermann.

GRANTS

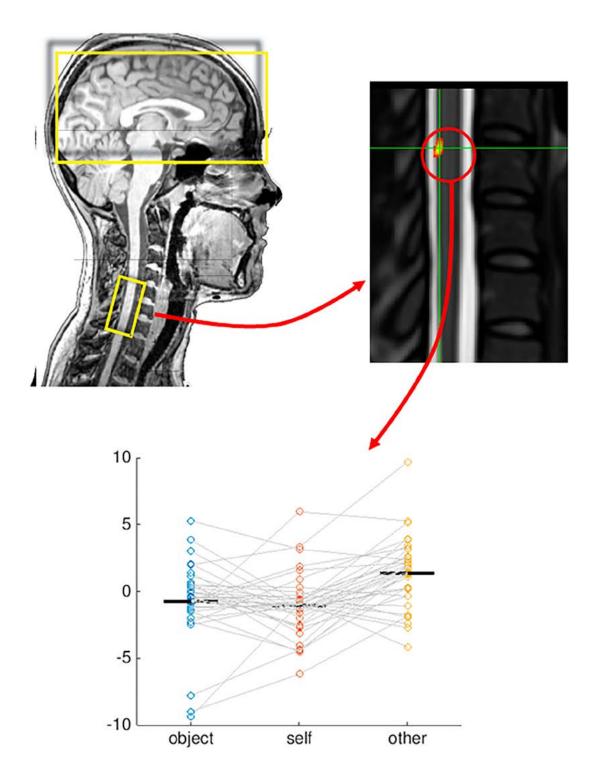
Vetenskapsrådet startbidrag Åke Wiberg stiftelse FORSS ALF RÖ

KEY PUBLICATIONS

Kaldewaij, R., Salamone, P. C., Enmalm, A., Östman, L., Pietrzak, M., Karlsson, H., ... & Boehme, R. (2024). Ketamine reduces the neural distinction between self-and other-produced affective touch: a randomized doubleblind placebo-controlled study. Neuropsychopharmacology, 1-8.

Boehme, R., Karlsson, M. F., Heilig, M., Olausson, H., & Capusan, A. J. (2020). Sharpened self-other distinction in attention deficit hyperactivity disorder. Neurolmage: Clinical, 102317.

Boehme R, Hauser S, Gerling G, Heilig M, Olausson H. Distinction of self-produced touch and social touch at cortical and spinal cord levels. Proceedings of the National Academy of Sciences (PNAS), Jan 22, 2019.



 $\label{prop:condition} \mbox{Activation in the spinal cord was stronger for other-touch compared to self-touch.}$

PoCo-19: a Multidisciplinary Study on Fatigue in Patients with Post-Covid Condition

In the aftermath of the COVID-19 pandemic, it has become clear that the infection caused by the coronavirus can result in long-term sequelae for some patients. The underlying causes of these lingering problems are not clear, and the symptoms are diverse, often suggesting brain involvement. Patients can, for example, experience cognitive impairment, fatigue, depression, and anxiety.

In this multidisciplinary project, researchers from rehabilitation medicine, neuropsychology, neuroradiology, biomedical engineering, pre-clinical sciences, qualitative research in medical humanities, and the phenomenology of medicine have come together to explore patients' experiences of fatigue in post-COVID syndrome and its underlying characteristic disease mechanisms. Patients who have post-COVID syndrome and who suffer from fatigue are investigated with brain MRI, as well as clinical examinations, neuropsychological tests, cytokine profile analysis, and qualitative phenomenological philosophy analysis.

Previous studies have shown the MRI images of post-COVID patients to be unspecific in their pattern. To enhance our understanding of the structure and function of the brain in this patient group, we are now using advanced quantitative MRI sequences to measure changes that are not visible in ordinary MRI images. With these quantitative techniques, we can detect microstruc-

tural changes in the brain tissue, as well as investigate functional aspects, such as connectivity – i.e., how the different parts of the brain communicate with each other. Using an advanced diffusion MRI technique, we have previously demonstrated microstructural changes in the white matter of the brain in patients who were hospitalized for COVID-19 and had persisting symptoms at follow-up.

In this ongoing study, we are now in the final phase of analyzing data on patients with post-COVID syndrome and fatigue, as well as healthy controls for comparison. Since this is a multidisciplinary project, the different analytic steps in this multidisciplinary project are undergoing cross-reading and triangulation to create an understanding of the research questions on different levels and from different angles.

MRI Neurology Imaging Biomarkers

Project information

PROJECT NAME

Biomedicine, Clinical Knowledge, and the Humanities in Collaboration: A Novel Epistemology for Radically Interdisciplinary Health Research and Policy-Work on Post-Covid-19 Syndrome.

PROJECT LEADER

Ida Blystad, Radiology Department, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

Kristin Zeiler, Department of Thematic Studies, Technology and Social Change.

MAIN PROJECT PARTICIPANTS

Anders Eklund, Anders Tisell, Richard Levi, Anestis Divanoglou, Ulrika Birnberg Thornberg, David Engblom, Sofia Jämterud Morberg, Felipe León.

GRANTS

Vetenskapsrådet (dnr 2021-01245).

KEY PUBLICATIONS

MRI with generalized diffusion encoding reveals damaged white matter in patients previously hospitalized for COVID-19 and with persisting symptoms at follow-up. Boito D, Eklund A, Tisell A, Levi R, Özarslan E, Blystad I. Brain Communications, 2023, DOI: 10.1093/braincomms/fcad284.

Brain MRI and neuropsychological findings at long-term follow-up after COVID-19 hospitalisation: an observational cohort study. Hellgren L, Birberg Thornberg U, Samuelsson K, Levi R, Divanoglou A, Blystad I. BMJ Open. 2021 Oct 27;11(10):e055164. doi: 10.1136/bmjopen-2021-055164. PMID: 34706965; PMCID: PMC8551746.

Reimagining illness through post-COVID-19 condition: the need for radically interdisciplinary health research. Macnaughton, J, Zeiler K. The Lancet, 2024. Volume 404, Issue 10455, 840 – 841. doi: 10.1016/S0140-6736(24)01760-4. PMID: 39216962.

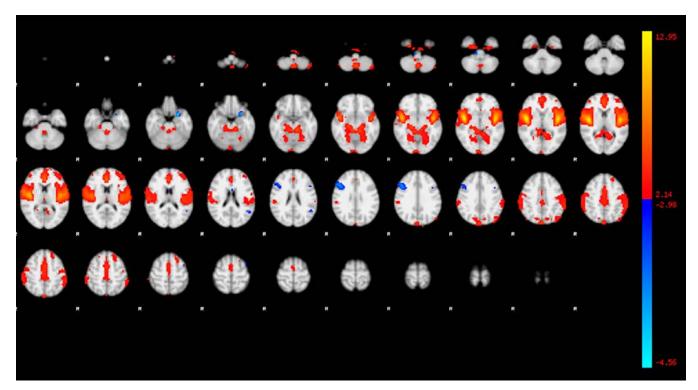


Figure 1: The salience network works as a switch between the default mode network and the central executive network and is relevant for the experience of fatigue.



Figure 2: The research group uses MRI to collect information on brain tissue properties and function. $\label{eq:properties}$

Evaluation of Reconstruction Methods in CT

In all diagnostic X-ray examinations using ionizing radiation, it is imperative to produce images of good diagnostic quality while simultaneously keeping the radiation dose to human organs as low as reasonably achievable (the ALARA principle) to minimize harmful radiation effects. Abdominal and thoracic computed tomography (CT) are common examinations that lead to the irradiation of radiosensitive tissues in humans.

In CT imaging, image quality is directly related to radiation exposure. A reduced exposure can lead to increased image noise and may reduce the visibility of anatomical structures and pathological findings. Therefore, any reduction in patient exposure must be carefully evaluated to ensure diagnostic accuracy is not compromised. Recent technological advancements offer a wide range of noise and dose reduction strategies, the latest being iterative image reconstruction (IR). The aim of this project is to evaluate the performance and dose reduction potential of advanced modeled iterative reconstruction (ADMIRE), a model-based reconstruction algorithm.

In prospective visual grading experiments, radiologists evaluated clinical image quality by comparing images of the same patient to determine potential dose reductions while maintaining image quality. Established European guidelines on image quality criteria were used, and the responses were statistically analyzed using ordinal logistic regression models. This approach allows for the computation of potential patient dose reductions from the regression coefficients of the statistical model.

A review of current published literature was also conducted to assess the performance of ADMIRE in abdominal CT (Kataria et al. 2021). The review highlighted that a variety of methodologies can be used to assess image quality and estimate potential dose reductions. Objective quantitative measurements in anthropomorphic phantoms partially support our results from the qualitative subjective assessments by radiologists. However, subtle changes in noise texture due to the IR algorithm indicate that phantom measurements alone are insufficient and need to be complemented with evaluations in human subjects.

Our experimental design proved successful, and the novel statistical analysis can be used to optimize clinical protocols. Visual grading studies on human subjects should be prioritized, as in vivo assessments are more complex than lesion assessments in phantoms.

The important conclusion is that the model-based reconstruction algorithm ADMIRE improved image quality in thoracic and abdominal CT, allowing for significant dose reductions (30%) in abdominal CT that have been implemented clinically. Higher strengths of the ADMIRE algorithm, combined with thin-slice imaging, also allows for dose reductions or improved anatomical visualization and may be beneficial in thinslice imaging protocols in abdominal CT. Potential dose reductions can be estimated using ordinal regression models, as they allow for the simultaneous analysis of several independent parameters.



Project information

PROJECT NAME

Visual grading evaluation of reconstruction methods in Computed Tomography for improved patient safety.

PROJECT LEADER

Bharti Kataria, Radiology Department, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Michael Sandborg, Anders Persson, Örjan Smedby and Jonas Nilsson Althen, Mischa Woisetschläger.

GRANTS

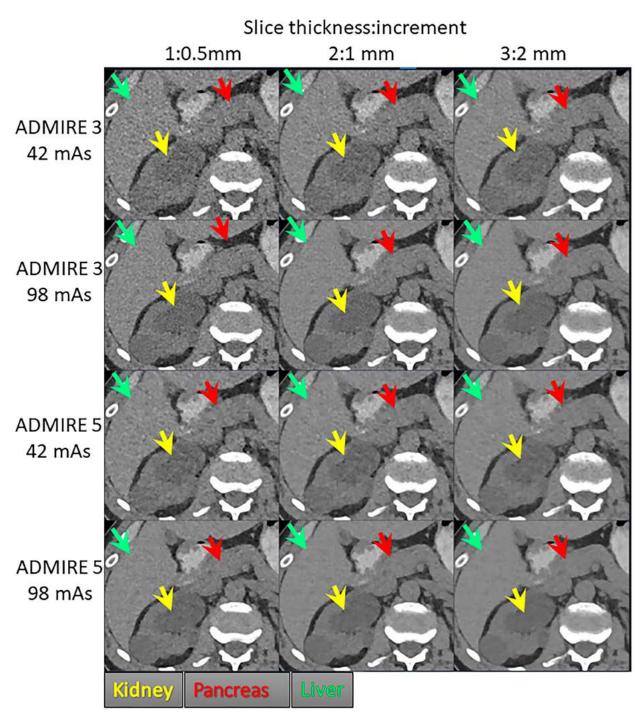
ALF (2017, 2018, 2021) FoU (2017-2024) Patientsäkerhetsforskning (2018-2019) RFoU (2017-2023)

KEY PUBLICATIONS

Kataria B, Nilsson Althén J, Smedby Ö,
Persson A, Sökjer H and Sandborg
M Assessment of image quality
in abdominal CT: potential dose
reduction with model-based iterative
reconstruction. European Radiology 2018;
28: 2464-2473. https://doi.org/10.1007/
s00330-017-5113-4.

Kataria B, Nilsson Althén J, Smedby Ö, Persson A, Sökjer H and Sandborg M. Image Quality and Potential Dose Reduction Using Advanced Modeled Iterative Reconstruction (Admire) in Abdominal Ct - a Review, Radiat Prot Dosimetry 195 (3-4) (2021) 177-187, https://doi.org/10.1093/rpd/ncab020.

Kataria B, Woisetschläger M, Nilsson Althén J, Sandborg M and Smedby Ö. Image quality assessments in abdominal CT: Relative importance of dose, iterative reconstruction strength and slice thickness. Radiography 2024; 30(6): 1563-1571.



Images of the same patient using full dose (Qref 98 mAs) or reduced dose (Qref 42 mAs) reconstructed with ADMIRE-strength 3 and 5 and slice thickness 1, 2 and 3 mm with 0.5, 1 and 2 mm overlap.

Elastography of the Liver

Fatty liver is the most common chronic liver disease in the world, with a global prevalence of approximately 38%. Individuals with fatty liver disease can develop fibrosis, i.e., excessive accumulation of extracellular matrix. Liver fibrosis can progress to cirrhosis. Individuals with metabolically caused fatty liver disease have an increased risk of developing and dying from hepatocellular carcinoma (HCC), and fatty liver is now the main reason why HCC is increasing rapidly.

For the evaluation of fatty liver, the subjective method B-mode ultrasound is still the most common approach in radiology departments in Sweden, even though its diagnostic accuracy is low for detecting mild fatty liver and it generally shows low reproducibility. A new quantitative program integrated into the ultrasound device has been launched, providing a facility to measure and grade the level of fat in the liver. However, this new method is not yet standardized and is not commonly used across all radiology departments, as more research is needed on how to perform measurements with high diagnostic accuracy.

The project has so far demonstrated that increased ultrasound probe force during measurements increases accuracy in diagnosing fatty liver, as shown in Figures 1 and 2. The results also indicate that measurements can be performed with the body in a slightly left decubitus position, which is sometimes needed to improve visibility of the liver.

For the evaluation of liver fibrosis and cirrhosis, the quantitative shear wave elastography (2D-SWE) program integrated into the ultrasound device can be used to detect and stage different fibrosis stages and is commonly employed in several radiology departments in Sweden. However, in challenging cases such as overweight and obesity, measurements tend to fail, requiring patients to undergo invasive liver biopsy for accurate diagnosis. Going forward, the project intends to investigate the potential to enhance feasibility and improve diagnostic accuracy in these challenging cases, which has not been previously assessed.

In the project, ultrasound measurements are compared to magnetic resonance imaging (MRI) to determine which ultrasound approach is most accurate. The findings contribute new and clinically valuable knowledge that improves diagnostic accuracy. This project is expected to significantly impact quality development and patient safety in radiography, radiology, and medicine in general.



Project information

PROJECT NAME

Elastography of the liver.

PROJECT LEADERS

Marie Byenfeldt and Johan Kihlberg, Department of Health, Medicine and Caring Sciences. Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Marie Byenfeldt, Johan Kihlberg, Peter Lundberg, Patrik Nasr, Shan Cai, Wolf Bartholomä, Jens Tellman, Mattias Ekstedt.

GRANTS

County of Jämtland Cancer and Nursing Foundation Sweden, Lion's Cancer Research Foundation Umeå University Sweden (LP 20-2221) and Unit of Research, Education and Development County council Jämtland Härjedalen Sweden (to MB).

Swedish Research Council and County council Östergötland Sweden (to PL).

ALF Grants, County council Östergötland, Medical Research Council of Southeast Sweden (grant no. 752871) (to ME and PN).

Wallenberg Centre for Molecular Medicine, Linköping University, Linköping, Sweden (PN).

KEY PUBLICATIONS

2024 Byenfeldt M, et al. Altered probe pressure and body position increase diagnostic accuracy for men and women in detecting hepatic steatosis using quantitative ultrasound. Eur Radiol. PMID: 38459346.

2024 Byenfeldt M. Reply to Letter to Editor:

"Altered probe pressure and body position increase diagnostic accuracy for men and women in detecting hepatic steatosis using quantitative ultrasound". Eur Radiol. PMID: 39112751.



Figure 1. Image from the ultrasound guided attenuation parameter (UGAP) program integrated in the ultrasound device GE E10, which is a quantitative method for evaluation of fatty liver. Here, measurement is performed with normal ultrasound probe force.



Figure 2. The same participant as in figure 1, but now measured during increased ultrasound probe force. The diagnostic accuracy improved according to magnetic resonance imaging proton density fat fraction (MRI-PDFF).



Figure 3. Image from the 2D shear wave elastography (2D-SWE) program integrated in the ultrasound device GE E10 shows the presence of liver fibrosis. This quantitative method is used for evaluation of liver fibrosis and cirrhosis.

Assessment of Hepatic Function in Health and Disease

The long-term purpose of this project is to achieve the procedural means for a thorough understanding of the complex both short time-scale and long-timescale events involved in liver disease, especially early stages, and to devise a both comprehensive and non-invasive method for their quantification. Major aims of the project are to allow the early detection of liver inflammation and fibrosis as proxies for chronic liver disease, and also to be able to understand the underpinnings of the consequences of fibrosis and fat storage on up-stream events including portal hypertension. Portal hypertension is clinically highly significant and early signs are therefore of importance. Quantitative measurement of hepatic blood flow would be useful to the understanding of disease progression in the cirrhotic liver, particularly the early development of fibrosis and inflammation, since the development of liver fibrosis and lipid accumulation constrict the blood flow to the liver.

The project is divided into two separate phases, the first being a developmental phase involving different protocols and healthy research subjects, and the second clinical patients. The research will in the early phase mainly focus on the challenges of developing, implementing and validating the technologies for measurements of dynamic characteristics

of disease including restrictions of flow. Four-dimensional flow (4D-Flow) MRI is an emerging method for quantitative evaluation of hemodynamics of in the liver and abdomen, however, it is limited to be used in clinical setting due to the long acquisition time. Compressed sensing (CS) is a method for image acquisition acceleration that is gaining in popularity in abdominal imaging.

MRI Gastrointestinal Acquisition Modeling Visualization Imaging Biomarkers

Project information

PROJECT NAME

Comprehensive Assessment of Hepatic Function in Health and Disease, Techniques for early disease detection and tissue characterization.

PROJECT LEADER

Peter Lundberg, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Stergios Kechagias, Mattias Ekstedt, Nils Dahlström, Markus Karlsson, Jens Tellman, Shan Cai, Christian Simonsson, Frederik Testud, Ralph Sinkus, Marcel Warntjes, Magnus Borga, Karin Markenroth Bloch.

GRANTS

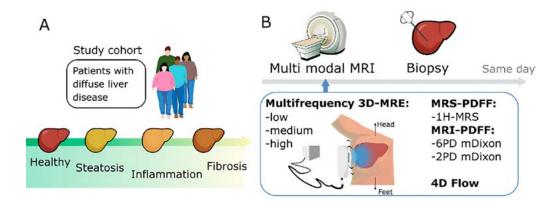
Swedish Research Council (VR/NT) (2021-2024/2025 etc) ALF (2019-2022)

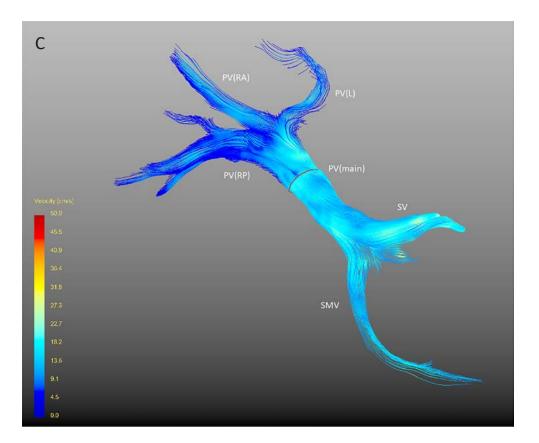
KEY PUBLICATIONS

Cai S, Simonsson C, Tellman J, Dahlström N, Ignatova S, Kechagias S, Nasr P, Ekstedt M, Sinkus R, Lundberg P (2024) Hepatic inflammation grading in diffuse liver disease using three-dimensional multifrequency MR elastography, ISMRM, Singapore.

Simonsson C, Cai S, Tellman J, Karlsson M, Cedersund G, Ignativa S, Ekstedt M, Kechagias S, Dahlström N, Lundberg P (2024) Evaluation of MRS- and MRI-PDFF and Liver Biopsy Measure of Hepatic Fat Fraction In a Clinically relevant Cohort. ISMRM, Singapore.

Forsgren MF, Nasr P, Karlsson M, Dahlström N, Noren B, Ignatova S, Sinkus R, Cedersund G, Dahlqvist Leinhard O, Ekstedt M, Kechagias S, Lundberg P (2020) Biomarkers of liver fibrosis: prospective comparison of multimodal magnetic resonance, serum algorithms and transient elastography. Scan J Gastroenterology, https://doi.org/10.1080/00365521.2020.1786599.





MR-measurements of liver at 3 T. Patients with suspected diffuse liver disease were recruited to undergo a multi-modal MRI exami-nation. A) The patients ranged from being moderately healthy, steatosis, hepatic inflammation, and pres-ence of fibrosis.

B) The MRI examination included 3D MRE with three vibration frequencies (range: 16-54 Hz), and fat fraction measurements using three sequences, 'H MRS, 6-point Dixon, and T1-weighted 2-point Dixon. Liver biopsies were performed under ultrasound guidance on the same day after the MRI examination.

(C) 4D Flow: The Portal Vein transports blood from the gastrointestinal tract, the spleen and the pancreas and consists of the Main Portal Vein, here denoted PV(main), which inside the liver di-vides into the following major branches: PV(RA): Right Anterior branch, PV(RP): Right Posterior branch and PV(L): Left branch. The two major tributaries to the Main Portal Vein are the Superior Mesenteric Vein (SMV) and the Splenic Vein (SV), seen in the lower right corner. Colour signifies the local blood velocity, here showing a lowering of the velocity as the blood travels from the SMV and SV into the liver.

Artificial Intelligence in Mammography Screening

Medical applications of artificial intelligence (AI) in medicine are increasing rapidly. However, the field of validation of AI in medicine is still in its infancy. The use of AI in a real clinical setting needs to be accompanied by clinical studies that not only explore sensitivity and specificity but also possible biases, lack of robustness, and performance of the AI tool over time. In this project, AI is used to improve diagnostic quality and efficiency in mammography screening in Östergötland. The project has progressed from a retrospective evaluation of the performance of an AI tool (ClinicalTrials. gov ID NCT05048095) to the current ongoing prospective clinical study (ClinicalTrials.gov ID NCT06187350), where AI is used in clinical work, replacing one of two radiologists for examinations where the risk of cancer is low (according to the AI tool). This reduces radiologists' workload by approximately 33%. More importantly, the use of the AI tool improves diagnostic quality, reducing the number of interval cancers in Östergötland as well, as has been shown elsewhere. The results from this work have been crucial for the clinical implementation of AI in mammography screening in Östergötland.

This project is collaborating with the project "VAI-B: A multi-center platform for the external validation of artificial intelligence algorithms in breast imaging," which is an ambitious international project where Region Östergötland is an important part.

An important aspect of implementing AI in healthcare is to study whether its use leads to benefits such as an increase in quality-adjusted life years (QALYs) and reduced costs across diagnostic disciplines and the healthcare system as a whole. Therefore, this project also conducts research within the field of health economics related to the implementation of AI in mammography screening in Östergötland.

In the coming year, this project will enter its next phase with a large clinical study called Screetrust3 in collaboration with Karolinska Institutet. This project will further explore how AI can improve diagnostic quality and reduce the radiologist workload in mammography screening.

Other Oncology Al/Data analytics

Project information

PROJECT NAME

Artificial Intelligence in Mammography Screening.

PROJECT LEADER

Håkan Gustafsson, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Pantelis Gialias, Maria Kristoffersen Wiberg, Tomas Bjerner, Fredrik Strand, Lars-Åke Levin, Lars Bernfort, Johan Lyth, Magnus Husberg.

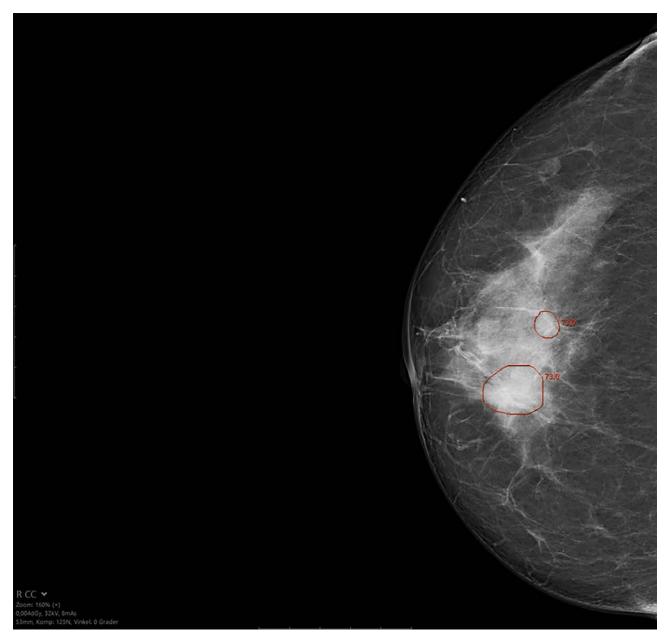
GRANTS

Bröstcancerförbundet Vinnova RCC

KEY PUBLICATIONS

VAI-B: A multi-center platform for the external validation of artificial intelligence algorithms in breast imaging. Fernando Cossío, Haiko Schurz, Mathias Engström, Carl Barck-Holst, Apostolia Tsirikoglou, Claes Lundström, Håkan Gustafsson, Kevin Smith, Sophia Zackrisson, Fredrik Strand. Journal of Medical Imaging 10 (2023) 061404 https://doi.org/10.1117/1. JMI.10.6.061404.

Så kan AI valideras för klinisk implementering. Fredrik Strand, Sophia Zackrisson, Håkan Gustafsson. Läkartidningen 120 (2023) 23065.



 $\label{thm:correctly} The AI system correctly identified the malign process in the breast, but it was missed by the radiologists. \\$

MR-Mammography 3.0

Breast cancer is the most common form of cancer in women, with a lifetime risk of over 12%. A major risk factor for breast cancer is breast density. Women with dense breasts have been shown to have a four- to six-fold increased risk of developing breast cancer.

Dense breast tissue contains higher amounts of stroma, including collagen, and less fat tissue. Conflicting results regarding the amount of epithelial cells have been reported, although it varies only between 1–6%, and the proliferation of these cells is also very low. Hence, the underlying biological mechanism(s) behind the higher breast cancer risk associated with dense breast tissue remains unexplored.

In addition to dense breast tissue, exposure to sex steroids such as estradiol is an established risk factor for breast cancer. An inflammatory microenvironment has also been associated with increased cancer risk, and a reduced risk of breast cancer has been reported in women who regularly use anti-inflammatory drugs.

Despite the widespread use of mammography as a general screening tool for breast cancer, this method has a painfully high false-negative rate (about 10–25%).

Today, there is growing interest in using Magnetic Resonance (MR) for breast cancer screening, particularly in younger populations, as the higher density of younger breast tissue can obscure underlying lesions in mammography. The absence of ionizing radiation also makes MR a particularly interesting tool for clinical research on breast cancer risk factors.

To perform studies involving MR and MR-based risk assessment and diagno-

sis, a clinically useful MR protocol has recently been developed. The protocol was developed, implemented at CMIV, and used in a pilot study on 40 female subjects. Furthermore, methods for quantifying clinically relevant parameters from the MR data have been explored.

The aims of BREASA are to further validate a comprehensive MR protocol and to investigate the clinical relevance

of the derived MR-based parameters in a cohort of subjects treated with an anti-inflammatory agent. Will the treatment affect the levels of inflammatory biomarkers, and will it impact the quantitative assessment of stroma, associated imaging biomarkers, and tissue characteristics? The ultimate long-term endpoint is to determine whether the treatment will reduce the risk of breast cancer.

MRI Oncology Acquisition Modeling Imaging Biomarkers

Project information

PROJECT NAME

MR-Mammography 3.0 (BREASA): Pharmacological Prevention of Breast Cancer Monitored Using a Novel Comprehensive Magnetic Resonance-Based Protocol.

PROJECT LEADER

Peter Lundberg, Department of Health, Medicine and Caring Sciences, Division of Diagnostics and Specialist Medicine.

MAIN PROJECT PARTICIPANTS

Charlotta Dabrosin, Anette Karlsson, leva Tomkeviciene, Mikael Forsgren, Jens Tellman, Johan Kihlberg, Maria Kristoffersen Wiberg, Magnus Borga, Marcel Warntjes, Anna Rzepecka.

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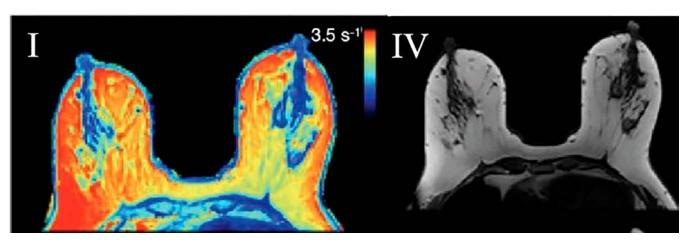
LiU-Cancer Cancerfonden

KEY PUBLICATIONS

Lundberg P, Abrahamsson A, Kihlberg J, Tellman J, Tomkeviciene I, Karlsson A, Kristoffersen Wiberg M, Warntjes M, Dabrosin C. (2024) Low-dose acetylsalicylic acid reduces local inflammation and tissue perfusion in dense breast tissue in postmenopausal women. Breast Cancer Res. 2024 Feb 5;26(1):22. doi: 10.1186/s13058-024-01780-2.PMID: 38317255. Clinical Trial.

Lundberg P, Forsgren M, Tellman J, Kihlberg J, Rzepecka A, Dabrosin C (2022) Breast density is strongly associated with multiparametric magnetic resonance imaging biomarkers and pro-tumorigenic proteins in situ, Br J Cancer. 2022 Sep 22. doi: 10.1038/s41416-022-01976-3.

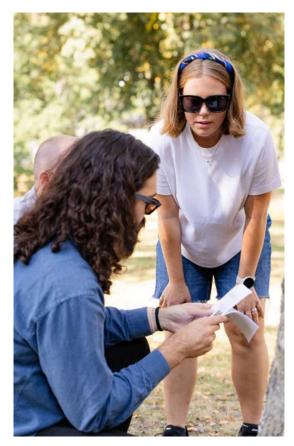
Ekstrand J, Zemmler M, Abrahamsson A, Lundberg P, Forsgren M, Dabrosin C. (2022) Breast Density and Estradiol Are Major Determinants for Soluble TNF-TNF-R Proteins in vivo in Human Breast Tissue, Front Immunol. 2022 Mar 30;13:850240. doi: 10.3389/ fimmu.2022.850240. eCollection 2022, PMID: 35432372.



Multimodal MRI and qMRI maps. C (I) R1 relaxation rate map; (IV) synthetic T1w (from Lundberg P et al, Breast Cancer Research (2024) 26:22; Open Access/Creative commons).







André Da Luz Moreira and Julia Andersson.



Gustav Magnusson.



Dennis Carlsson and Gerry Lindell.



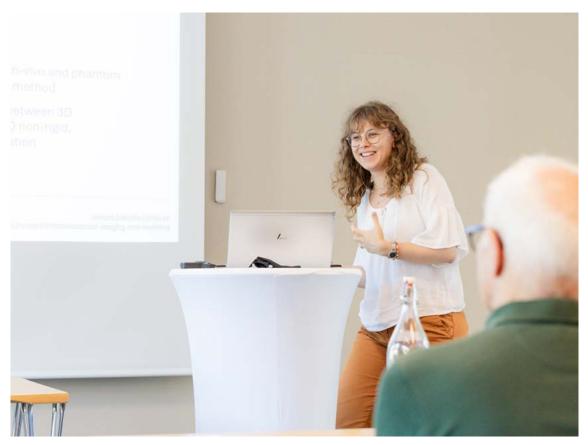
Julia Andersson, Christoforos Spyretos, Gustav Magnusson and Ann-Sofi Björkman.



Mårten Sandstedt.



Petter Quick.



Tamara Bianchessi.



Pre-run warm-up.



Tomas Bjerner and Frida Dohlmar are warming up.



Tino Ebbers and Dennis Carlsson.



Linnéa Adolfsson, Dennis Carlsson and Gerry Lindell.



Ann-Sofi Björkman, Shan Cai, Martin Stridsberg, Tamara Bianchessi and Sohaib Ayaz Qazi.



Anders Persson.



Linus Ohlsson, Anders Persson, Twan Bakker, Anders Tisell, Frida Dohlmar, Erik Tesselaar, and Gustav Magnusson at the top of Ramundberget in Söderköping.





Contrast Agents for Biomedical Imaging in 3D

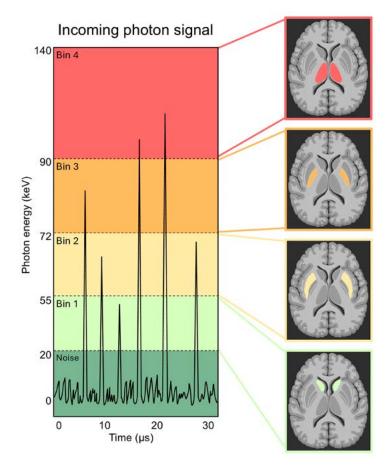
In CT images of the human body, there is a high contrast between bones and soft tissue, where bones appear white and soft tissue appears almost black, making it easy to differentiate bones from soft tissue. However, when two tissues generate similar signals in the CT image, as is the case with a cancerous tumor embedded within healthy tissue, it becomes more challenging to differentiate between them. Is it possible to distinguish between tissues with the same or similar CT signals but with different elemental compositions?

Currently, CT images are reconstructed based on the total intensity of

incoming photons, without considering their respective energies. This limitation can result in two different tissue types appearing similar in the reconstructed image. Photon-counting CT (PCCT) addresses this issue by differentiating signals from incoming photons based on their energy levels. In PCCT, photon signals are sorted into energy bins according to the registered energy of each photon. Images can subsequently be reconstructed with signals from each bin separately. The unique combination of signals in each bin enables distinct identification of different tissues.

We aim to explore the potential for element- and tissue-specific imaging using PCCT. This can be achieved by integrating newly developed photon-counting detectors, designing innovative nanomaterials, and utilizing energy binning and K-edge imaging techniques. In our initial experiments, we investigated contrast enhancement with dilution series of Gd, I, Ce, Bi, and Ca using two energy bins. With the recent availability of four bins, we are now conducting experiments with this expanded setup. We are interested in answering the following questions:

- Can we accurately determine concentrations?
- How effective is K-edge imaging?
- Is it possible to differentiate between elements?
- · What are the detection levels?
- What is the lowest detectable concentration?
- How should nanomaterials be designed, and how do we choose elemental combinations based on bin thresholds? My background is in materials science and bioengineering, and this project aims to combine my knowledge with the medical field to improve visualization in medical images. To summarize, our goal is to advance PCCT to deliver 3D images with element-specific information.



With PCCT, the incoming photon signals can be divided into energy bins based on their respective energies. The unique combination of signals within each bin can then be used to differentiate between tissues. Separate reconstructions can be generated from the energy bins, highlighting areas with different compositions.

PROJECT INFORMATION

Project

Contrast Agents for Biomedical Imaging in 3D

Supervisors

Kajsa Uvdal, Anders Persson, Caroline Brommesson.

Short CV

PhD Student at Linköping University,
December 2023-Present.
Research Assistant at Linköping University,
June 2023-December 2023.
Master of Science in Engineering Biology
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Bachelor of Science in Biotechnology from
Linköping University, June 2021.

Assessment of Blood Flow in an Artificial Heart

Patients with severe heart failure may depend on transplantation. With the current shortage in donor hearts, mechanical total artificial hearts can be used as a bridge-to-transplant solution. While existing total artificial hearts save lives, they still pose risks of complications such as infection, stroke, and blood cell damage. Improving total artificial hearts involves better assessment of flow dynamics during the design process, which could help minimize these risks.

At CMIV, we used 4D flow MRI (Magnetic Resonance Imaging) to measure and evaluate the flow in a prototype artificial heart by Scandinavian Realheart AB. To make this possible, we constructed an MR-safe test rig and modified the artificial heart by using 3D printing. This setup allowed us to essentially have a look inside the prototype. With this method we can measure flow patterns and turbulent kinetic energy which have been linked to blood cell damage.

The technique reveals the complexity of the flow within the artificial heart prototype, as indicated in the figure. The measured turbulent kinetic energy in the artificial heart was found to be slightly higher than observed in a healthy heart but remains much lower than levels found in diseased hearts. This suggests that the device is more comparable to the healthy heart when it comes to turbulent kinetic energy.

We found that combining 4D flow MRI with 3D printing provides valuable insights for the design process and facilitates rapid prototyping. In the future we plan to expand this work by comparing our insights from the MRI to other techniques. This includes simulations using computational fluid dynamics that can provide an even finer resolution in time and space. We also aim to compare the beforementioned techniques to blood lab experiments that have been conducted on the artificial heart.

Together, these approaches will give us a more complete understanding of the flow dynamics within the total artificial heart. Our goal is to help reduce the risk of blood damage for patients who depend on these life-saving devices.

PROJECT INFORMATION

Proiect

Assessment of Blood Flow in an Artificial Heart.

Supervisors

Jonas Lantz, Tino Ebbers, Ina Laura Perkins

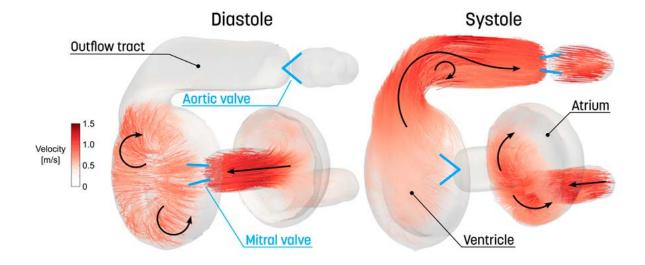
Short CV

PhD student Linköping University, since September 2023.

Chairman of the CMIV Research School, 2024-present.

Research Engineer at CMIV, 2022-2023 MSc. Mechanical Engineering, Linköping University, 2022.

BSc. Aeronautical Engineering, Inholland University of Applied Sciences, 2017. Design Engineer at Airbus Defence and Space, 2017–2020.



Applications of MR Contrast in Liver Diagnostics

Posthepatectomy liver failure (PHLF), a serious complication of liver surgery, remains a significant risk for patients undergoing liver resection. PHLF arises when the remaining liver tissue after surgery fails to perform essential functions such as detoxification, synthesis, and metabolism. The risk of PHLF depends on factors such as the extent of liver resection and overall liver health, with pre-existing liver disease further increasing the risk.

Studies indicate that PHLF occurs in 0–6% of cases when the Future Liver Remnant (FLR) volume exceeds a critical threshold, but this rate rises dramatically to 20–90% when the FLR volume falls below it. This presents a major challenge for hepatobiliary surgeons, as no direct treatment for liver failure exists – supportive care is the only option until liver function hopefully recovers. If recovery fails, liver transplantation is the only cure. Therefore, precise preoperative assessment and careful patient selection are crucial to preventing PHLF and improving outcomes.

A key factor contributing to PHLF is an inadequately sized or poorly functioning FLR. In current clinical practice, the minimum safe FLR volume is determined by a standardized fraction of the total liver volume, typically 20–40%, depending on whether the patient has pre-existing diffuse liver disease such

as steatosis or fibrosis. However, this approach does not account for individual patient variability.

MRI with liver-specific contrast offers a significant improvement by combining liver volumetry with functional information on the FLR, thereby enhancing preoperative risk stratification and surgical planning.

Our study evaluates the Hepatic Uptake Index (HUI) derived from Gadoxetic acid-enhanced MRI to predict severe post-hepatectomy liver failure (PHLF) in 292 patients from Nordic hospitals. Among these patients, 8.6% developed severe PHLF Results show that patients with severe PHLF had significantly lower HUI values, demonstrating HUI's strong predictive ability (AUC = 0.758), outperforming traditional volumetric measures such as standardized future liver remnant (sFLR, AUC = 0.628).

By combining HUI with the MELD 3 score, predictive accuracy improved (AUC = 0.803). A key finding is that patients with an HUI above 697 were at low risk for severe PHLF, providing 100% sensitivity and classifying 35.6% of the cohort as low risk. In contrast, sFLR thresholds proved less clinically useful.

Our findings highlight that integrating functional imaging data (such as HUI) with laboratory scores enhances risk assessment for PHLF and may improve surgical outcomes. However, limitations include variability in MRI protocols across centers and the relatively small number of severe cases. Incorporating MRI-derived HUI into multivariable models alongside routine clinical indicators could significantly improve patient risk stratification.

The study results have been presented in poster form at the ESMRMB conference in Barcelona and are in the final stages of preparation for publication.

PROJECT INFORMATION

Project

Applications of MR Contrast in Liver Diagnostics.

Supervisors

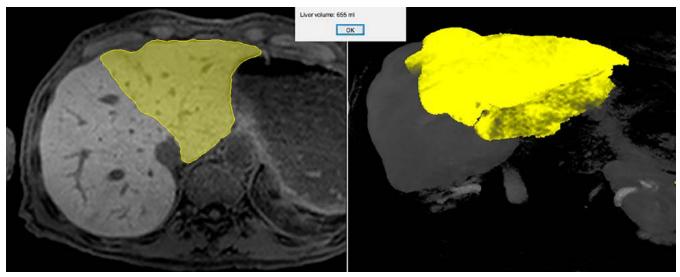
Peter Lundberg, Nils Dahlström, Per Sandström, Mischa Woisetschläger.

Short CV

Medical degree, Medical School, Justus-Liebig University, Gießen, Germany, 2002.

Radiologist, Department of Radiology, University Hospital, Linköping, Sweden, 2010

Consultant Radiologist, Department of Radiology, University Hospital, Linköping, Sweden, 2014 - present. European Diploma in Radiology, 2016 - . ESGAR Certificate of Excellence in Abdominal Radiology, Level II, 2021 - .



FLR (Future Liver Remnant) calculation.

Turbulent Kinetic Energy from 4D Flow MRI Can Identify Mild Valve Diseases

 In healthy individuals, cardiovascular flow is predominantly laminar; however, its values are close to the turbulence threshold. These conditions change with age-related or pathological processes affecting the valves, vessels, or cardiac chambers, leading to regions of turbulent flow during the cardiac cycle. Valvular heart diseases (VHDs) are significant contributors to cardiovascular disease, with prevalence varying between high-income and low-income countries. VHDs cause turbulent blood flow, and turbulent kinetic energy (TKE) is a commonly used measure of flow turbulence intensity, representing the energy dissipated in turbulent flows. TKE can be quantified using 4D Flow MRI, making it a potential marker for VHDs.

In this project, we investigated TKE and its relationship with velocity, heart geometry, and Reynolds number, as well as the differences between individuals with VHD and healthy controls across the whole heart. The VHDs analyzed in this study included mild aortic stenosis, aortic regurgitation, mitral regurgitation,

pulmonary stenosis, pulmonary regurgitation, and tricuspid regurgitation.

Time-resolved 3D deep learning segmentations of the four cardiac chambers, ascending aorta, and pulmonary artery were used to evaluate TKE and velocity.

Our results showed a strong correlation between velocity and TKE in all regions. Heart geometry exhibited weaker correlations, while Reynolds number, influenced by both velocity and geometric factors, demonstrated stronger correlations than velocity alone. In all regions except the left ventricle, TKE was significantly higher in individuals with VHD compared to controls. In contrast, velocity differences were only significant in the pulmonary artery and right ventricle.

The strong correlation between TKE and velocity, along with the observed differences between individuals with VHD and controls, further supports the relevance of TKE in evaluating turbulent flow. These findings suggest that TKE is a more effective hemodynamic marker than velocity for identifying mild VHDs.

PROJECT INFORMATION

Project

Turbulent kinetic energy from 4D flow MRI identifies valvular heart diseases better than velocity.

Supervisors

Petter Dyverfeldt, Carl-Johan Carlhäll, Elin Good.

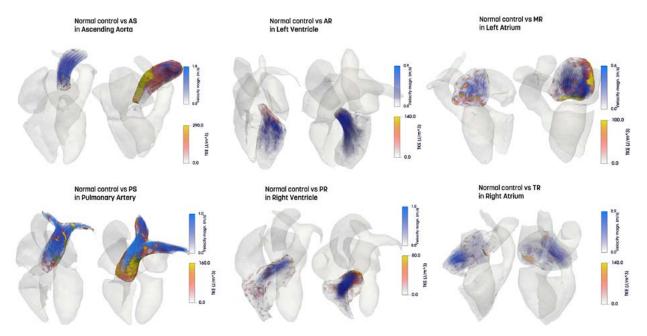
Short CV

PhD Candidate at the Unit of
Cardiovascular Science at Linköping
University Hospital, July 2023-Present.
Research engineer at the Unit of
Cardiovascular Science at Linköping
University Hospital, January 2023June 2023

Research preparatory course, Department of Health, Medicine and Caring Sciences at Linköping University Hospital, June 2022-December 2022.

Master of Science, Biomedical Engineering, Linköping University, Sweden, August 2020-June 2022. Bachelor of Science, Biomedical

Engineering, Politecnico di Milano, Italy, October 2016-March 2020.



Visualization representing the velocity (blue to white color scale) and turbulent kinetic energy (red to yellow color scale) in each of the segmented regions analyzed for one control against different type of VHDs. For the ascending aorta, pulmonary artery, and the atria the visualizations are at peak systole, for the ventricles at peak early filling. AS: aortic stenosis, AR: aortic regurgitation, MR: mitral regurgitation, PS: pulmonary stenosis, PR: pulmonary regurgitation, TR: tricuspid regurgitation.

Spectral CT for the Musculoskeletal System

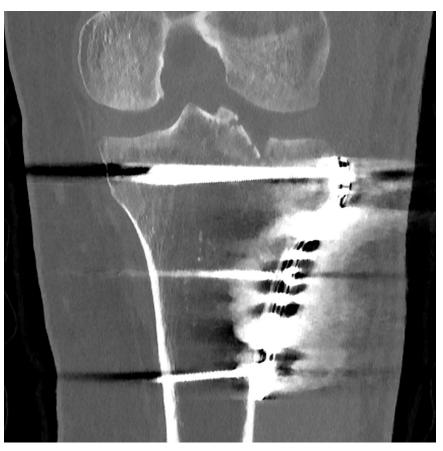
■ Musculoskeletal disorders affecting bones, joints, and soft tissues can be diagnosed using various imaging techniques, each with its own advantages and disadvantages. Computed tomography (CT) is highly effective for detecting fractures, offering fast imaging and suitability for almost all patients. However, when visualizing soft tissues, magnetic resonance imaging (MRI) is superior to CT. If new techniques could enable CT to replace MRI in certain cases, it would be highly beneficial.

Another common challenge in imaging is metal artifacts, which arise from metallic implants commonly inserted during orthopedic surgery. These artifacts appear as distortions and/or streaks in the images, making interpretation difficult or even impossible.

Recent technical advancements, including dual-energy CT (DECT) and photon-counting detector CT (PCD-CT), offer potential improvements in image quality and expanded applications for CT imaging. The key feature of these tech-

nologies is their ability to utilize energy separation of X-ray photons, a principle known as Spectral CT. The overall aim of this PhD project is to leverage Spectral CT to enhance musculoskeletal imaging, with a particular focus on the knee.

The ongoing FORT study investigates patients with knee fractures requiring surgical fixation with metal plates and screws. These patients undergo PCD-CT imaging in addition to the conventional post-surgical CT examination. It is well established that PCD-CT detectors improve spatial resolution and reduce image noise, but they may also mitigate the issue of metal artifacts. The primary objective of the FORT study is to determine the optimal PCD-CT settings for minimizing metal artifacts and enhancing image quality, as well as to compare PCD-CT with conventional CT. An image quality assessment based on these patient images has been conducted, and the results are currently being analyzed.



An example of metal artifacts in a CT image. This patient has a knee fracture that has been repaired with a metal plate and screws. In the CT image, both distortions as well as white and black streaks, caused by the metal, are present. Metal artifacts can obscure important structures and make image interpretation difficult or even impossible.

PROJECT INFORMATION

Project

Spectral CT for the Musculoskeletal System.

Supervisors

Anders Persson, Seppo K Koskinen, Håkan Gauffin, Alexandr Malusek.

Short CV

Doctor of Medicine (MD), Linköping University, 2010. Resident in Radiology, Radiology Department at Linköping University Hospital 2012–2020. Radiologist, Radiology Department at Linköping University Hospital 2020-. PhD student 2020-.

Enhancing Digital Pathology for Visual Precision

Pathology, a discipline centered on the microscopic examination of tissues, frequently employs various staining techniques. Each staining method in histopathology serves a distinct purpose, enhancing the visualization of tissue components and facilitating accurate disease diagnosis. Understanding the principles and applications of these stains, along with different review strategies – such as slide navigation patterns – forms the foundation of this study.

Typically, the review of a stain is contextualized within a case; however, manually screening slides involves both navigation and search activities. Depending on the stain, cells and tissues exhibit different observable features and patterns at varying magnification levels. Digital pathology enhances pathologists' overview and orientation at the slide level, encouraging the adoption of novel review strategies. This study aims to explore these strategies in relation to different stains and their effect on a new visualization method, Feature Enhancing Zoom (FEZ). The FEZ method consists of three steps: color deconvolution, extraction of a predefined reference color, and blending the extracted information with the original image.

In a prior prototype study, Scale Stain: Multiresolution Feature Enhancement in Pathology Visualization, two common clinical tasks - detection of Helicobacter pylori and estimation of KI67 expression - were examined. The findings revealed that applying the FEZ method reduced the time pathologists spent navigating and searching (panning and zooming), leading to a 15% increase in efficiency. The FEZ tool has now been further developed and integrated into the clinical environment, aiming to assess its impact on the review process related to diagnostic features across different areas, based on real-case scenarios.

Key questions to be explored include the tool's usability, its effectiveness in presenting various stains, pathologists' adaptability to this innovative strategy, and the level of trust and interpretability of FEZ results. The significance of this research lies in its potential to revolutionize pathology review from a bottom-up perspective, enhancing both efficiency and accuracy in pathological diagnoses. Ultimately, this could improve patient outcomes by enabling faster and more precise disease identification.

PROJECT INFORMATION

Project

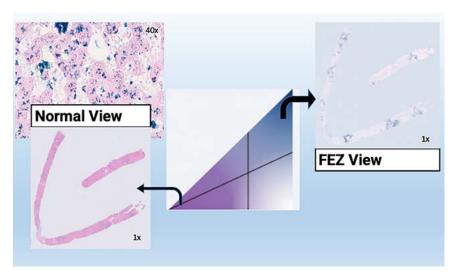
Feature-Enhancing Zoom –a visualization tool to support pathologist review.

Supervisors

Darren Treanor, Claes Lundström, Martin Hallbeck.

Short CV

Clinical work experience:
Consultant pathologist in clinical
pathology, subspecialized in breast
pathology, Linköping University
hospital, 2010-present.
Medical degree, KI, 2000.
Research education:
Half time seminar, 2021.
PhD student at Department of Biomedical
and Clinical Sciences (MVIKE223),
2015.
Current other Research projects/
collaboration platforms:
Bigpicture, 2021.



Images from a two-piece liver biopsy stained with Prussian Blue, a stain used to detect iron deposits in tissues, such as those found in hemochromatosis or hemosiderosis. The stain reacts with ferric iron, producing a blue color that highlights areas of iron accumulation. In the FEZ View (right), the stain's maximum blue enhancement visualizes iron deposits even at low resolution, allowing detection without the need to zoom in at 40x magnification. The normal view is shown at low resolution (1x) in the lower left, alongside a high-resolution (40x) image of the same sample. At the center, the navigator triangle represents the two-dimensional parameter space, where the sensitivity dimension extends from top to bottom, and the blending factor ranges from left to right.

Multimodal Magnetic Resonance Measurements of Diffuse Liver Disease

Diffuse liver disease, caused by infections, inherited conditions, immune or autoimmune disorders, and vascular injuries, is a growing public health concern worldwide. Metabolic dysfunction-associated steatotic liver disease (MASLD) is the most common form, affecting up to 25% of the global population. Diffuse liver disease can lead to inflammation, fibrosis, and, ultimately, cirrhosis and liver failure. However, its early symptoms are nonspecific, and diagnosis often occurs at advanced, irreversible stages.

Currently, diagnosing liver disease often requires a liver biopsy – an invasive procedure associated with potential complications such as bleeding and pain and limited by sampling errors. Therefore, we aim to explore the potential of non-invasive Magnetic Resonance Imaging (MRI) techniques to detect liver disease progression at an early stage.

Our specific objectives include quantifying inflammation, fibrosis, fat deposition, portal hypertension, and liver function. Multiple MRI modalities, such as MR elastography (MRE), proton density fat fraction (¹H-MRS PDFF), 4D blood flow measurement, and gadoxetate (EOB)-enhanced MRI, combined with mathematical modeling, will be utilized for these purposes.

In our current study, we are investigating the role of three-dimensional (3D) MRE in assessing diffuse liver disease progression by correlating MRE-derived biomechanical parameters with histopathological analyses of inflammation and fibrosis (figure). MRE is a powerful tool for evaluating liver stiffness by measuring shear wave propagation through liver tissue. The application of 3D MRE enables the measurement of full 3D vector motion within the liver, allowing the separation of the complex shear modulus into its real component, the storage modulus (elasticity), and its imaginary component, the loss modulus (viscosity). We believe these viscoelastic parameters could provide valuable insights into the mechanisms of tissue inflammation and fibrosis and serve as potential biomarkers for the early detection and improved staging of diffuse liver disease progression.

PROJECT INFORMATION

Project

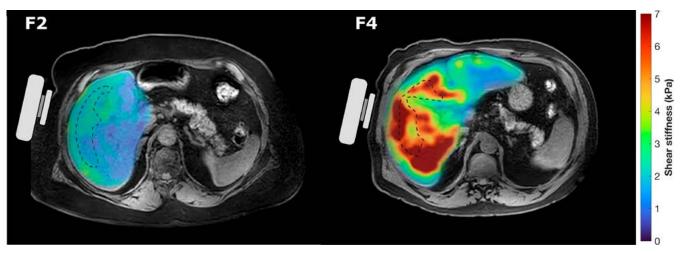
Multimodal Magnetic Resonance Measurements of Diffuse Liver Disease - Technological Developments and Novel Imaging Biomarkers.

Supervisors

Peter Lundberg, Karin Markenroth Bloch, Magnus Borga, Nils Dahlström, Stergios Kechagias.

Short CV

Master of Science (MSc), Biomedical Engineering, Linköping University, 2020–2022.



Examples of 3D MRE for a moderate fibrotic (left, F2) and a cirrhotic (right, F4) patient measured using an electromagnetic active transducer at 50 Hz. The elastograms with the regions of interest (ROIs) marked by a black dashed outline are superimposed on the conventional THRIVE images acquired prior the MRE. Increased stiffness values and more heterogeneity are shown in the elastograms as the fibrosis stage advances.

Automated Treatment Planning for Brachytherapy

■ Brachytherapy is a type of radiation therapy where a small iridium-192 radioactive source is used to irradiate tumors from within. This is done by inserting catheters, needles, or applicators – designed to fit the anatomy of different disease sites – into or close to the tumor. The source stops at predefined positions inside the instruments for a specific duration to deliver the prescribed absorbed dose. Brachytherapy is commonly used for prostate and cervical cancer in combination with external beam radiation therapy.

In the curative treatment of advanced cervical cancer, brachytherapy plays a crucial role in delivering a high absorbed dose to the tumor while minimizing radiation exposure to surrounding healthy tissue. A treatment planner determines how long the radiation source should remain at each predefined position. The standard method for treatment planning is manual, where decisions are made in a trial-and-error manner. Alternatively, optimization tools can be used to determine the source dwell times; however, these automated plans often lack essential

characteristics, such as a pear-shaped dose distribution, high central doses, and short dwell times near the target volume's borders.

To address these issues, we have developed a method using pseudo-structures to control the dwell time pattern and achieve a pear-shaped dose distribution. This method was compared to both manual treatment plans and inverse treatment plans without pseudo-structures (referred to as the straightforward method). Our results demonstrate that treatment plans generated using pseudo-structures closely resemble manually created plans.

In diagnostic radiology, observer studies are commonly used to compare new imaging techniques, employing statistical tests to assess differences in image quality. This approach is now gaining traction in radiation therapy to compare different treatment planning methods. Our aim is to adapt the well-established methodologies from radiology to radiation therapy, enabling the design of a robust observer study to evaluate our method for cervical brachytherapy.

PROJECT INFORMATION

Project

Dosimetric evaluation and development of new methods for automated brachytherapy treatment planning.

Supervisors

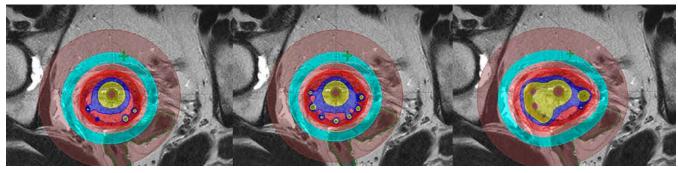
Åsa Carlsson Tedgren, Torbjörn Larsson, Michael Sandborg, Björn Morén.

Short CV

Master of Science in Medical Physics, 2009.

Medical Physicist, Blekingesjukhuset, Karlskrona, 2009–2010.

Medical Physicist, Region Östergötland, 2010-present.



Axial T2 MR image showing a patient case with the three different methods, manual (left), inverse with pseudo-structures (middle) and, inverse straightforward (right). The colored lines showing the contoured target volume (red), tumor (blue) and organs at risk (pink - bladder and green - sigmoid). Colored fields showing the volumes receiving up to 1.75 Gy (brown), 3.5 Gy (turquoise), 5.25 Gy (pink), 7 Gy (red), 10.5 Gy (blue) and 14 Gy (yellow).

PCD-CT for Better Visualization of the Wrist

Diagnostic imaging plays a crucial role in clinical practice, aiding in the identification of fractures, pathological conditions such as degenerative and inflammatory changes, postoperative complications in the hand and wrist, and assessing bone healing.

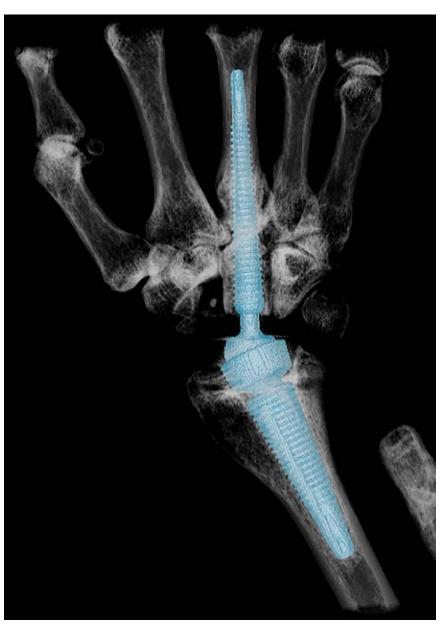
Radiographic imaging is commonly used in clinical routines; however, its sensitivity for fracture detection is relatively low, around 70%, and its ability to assess bone healing is even lower. CT is increasingly utilized in clinical practice due to its capability to visualize structures in

multiplanar reconstructions. The latest CT technology, photon-counting detector CT (PCD-CT), offers several advantages, including improved spatial resolution, elimination of electronic noise, reduced radiation dose, additional spectral information, and potentially fewer artifacts from high-density materials such as metal implants.

The aim of this thesis is to evaluate image quality in hand and wrist imaging using PCD-CT and compare it with energy-integrating detector CT (EID-CT).

The results from our first two studies demonstrated improved image quality in bone imaging, particularly in spatial resolution, enabling visualization of bone microstructures. Additionally, PCD-CT provided superior image quality compared to EID-CT, even at half the radiation dose. In the third study, we observed better visualization of scaphoid fractures and increased diagnostic confidence using PCD-CT.

In our ongoing study, we are evaluating metal artifacts caused by implants using different imaging techniques.



Wrist with metal prosthesis.

PROJECT INFORMATION

Project

Visualisation and assessment of diseases and healing processes in hand and wrist using photon-counting detector computed tomography.

Supervisors

Erik Tesselaar, Simon Farnebo, Anders Persson, Mårten Sandstedt.

Short CV

Senior consultant, Radiology Department at Motala Hospital and Linköping University Hospital, 2012-.

Medical director, Radiology Department at Motala Hospital, 2015–2024.

Head of Section, Radiology Department at Motala Hospital, 2019–2021.

Head of Department, Radiology Department at Motala Hospital, 2021–2024.

PhD student 2021-

Quantitative MR for Diagnosis and Treatment Follow-Up of Brain Tumors

Each year, approximately 100 children in Sweden are diagnosed with tumors in the brain or central nervous system. Moreover, there are over 100 different types of brain tumors, each with varying symptoms and treatment approaches. Advanced treatments - often involving surgery, chemotherapy, or radiotherapy - have led to a survival rate of around 80%. Although this is relatively high, no significant improvements have been made in recent decades, and survivors frequently experience long-term side effects. These may include neurocognitive impairments such as memory dysfunction, reduced logical reasoning, and slower processing speed.

The primary imaging tool for diagnosing, evaluating, and planning treatment of pediatric brain tumors is magnetic resonance imaging (MRI), which provides visualization of both brain structure and neurological function. In our research, we have investigated a central brain structure called the corpus callosum, which connects the two hemispheres, using a range of novel and advanced MRI techniques. This study focuses on 18-year-old individuals who were treated for brain tumors during childhood. Additionally, a group of self-reported healthy 18-year-olds undergoes MR imaging for comparison, allowing us to assess differences in the size and structure of the corpus callosum between the two groups.

Although results are still preliminary, we have observed a size reduction of the corpus callosum in patients, particularly in those who received radiotherapy. However, no significant differences were found in parameters such as relaxation rate, proton density, or myelin concentration.

We will also further investigate the potential link between therapy and permanent neurocognitive dysfunction.

PROJECT INFORMATION

Project

Quantitative MR for Diagnosis and Treatment Follow-Up of Brain Tumors.

Supervisors

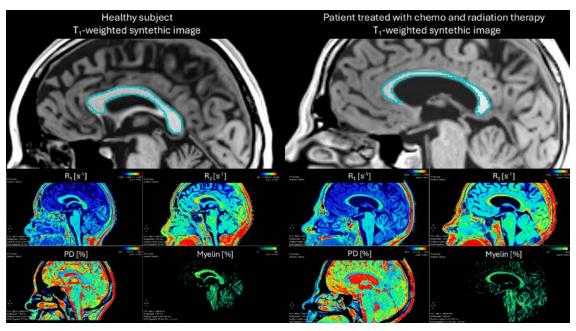
Emelie Adolfsson, Ida Blystad, Peter Lundberg, Anders Tisell.

Short CV

Vice chairman and chairman of CMIV research school, Sep 2023 - Sep 2024.

Medical physicist, radiation therapy,
Linköping University hospital,
2015-present.

Master of science in medical physics, 2013 Lund University.



Images for two different youths, one healthy subject and one patient treated for medulloblastoma. Top row shows corpus callosum, where there is a difference in size, segmented in T_1 -weighted MRI images. Below are images visualizing properties that are structure dependent such as relaxation rate, proton density and myelin concentration, where no difference were found.

Cerebrovascular Reactivity studies

Patients who suffer from subarachnoid hemorrhage (SAH) are at risk of developing secondary complications, such as delayed cerebral ischemia (DCI). DCI occurs in approximately 30% of patients who survive the initial hemorrhage, with peak incidence around one week after the initial bleed. It is associated with increased morbidity and mortality. To detect early signs of DCI and, if possible, limit its consequences, these patients are monitored in a neurosurgical intensive

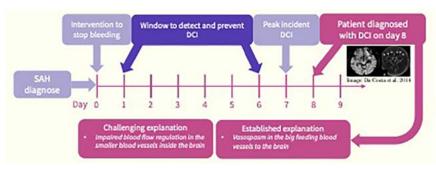


Figure 1: Timeline of Subarachnoid Hemorrhage (SAH) care. After initial treatment, patients are monitored in the neuro ICU for up to two weeks due to risks like delayed cerebral ischemia (DCI). Traditionally linked to large-vessel vasospasm, recent evidence points to dysregulation in smaller vessels as a key contributor.

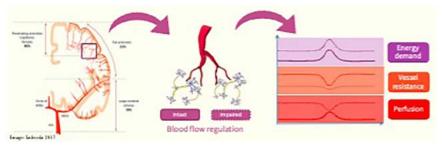


Figure 2: "Spiral Up, Spiral Down" hypothesis for DCI. The figure shows two neural populations: one with normal blood flow regulation and one impaired. In healthy tissue, neurovascular coupling maintains perfusion. In impaired regions, poor vascular response causes steal effects, diverting blood from healthy areas. Over time, regulation may recover ("spiral up") or deteriorate, worsening steal and risking DCI ("spiral down").

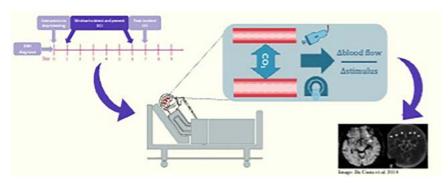


Figure 3: Planned CVR measurements in SAH patients. We aim to track cerebrovascular reactivity (CVR) over time to assess its potential in predicting delayed cerebral ischemia (DCI). Using a custom CO_2 delivery method to create a blood flow stimulus, we will monitor responses via transcranial Doppler or MRI. CVR will be calculated as the ratio of change in blood flow to change in stimulus (Δ blood flow/ Δ stimulus).

care unit (ICU) with advanced surveillance for up to two weeks after the hemorrhage.

The exact cause of DCI remains unclear, and none of today's established monitoring techniques have sufficient sensitivity or specificity to reliably identify which patients are at risk of developing DCI in time.

A potential technique that may improve both understanding and early detection of DCI is the measurement of cerebrovascular reactivity (CVR). CVR provides information about the brain's ability to regulate its blood flow, which has been identified as a critical factor in DCI. During a CVR examination, blood flow is monitored while a physiological stimulus is applied to induce changes in cerebral circulation. By comparing the resulting blood flow alterations with the applied stimulus, a measure of vascular reactivity can be obtained, reflecting the vasoregulatory reserve - the vessels' ability to further dilate. Initial studies on CVR measurements in SAH patients have shown promising results, suggesting that the method could help indicate DCI risk.

In this project, we aim to evaluate the feasibility of implementing CVR measurement as a routine clinical procedure for patients with SAH.

PROJECT INFORMATION

Project

Magnetic Resonance Imaging Studies on Cerebrovascular Reactivity.

Supervisors

Anders Tisell, Maria Engström, Charalampos Georgiopoulos, Gunnar Cedersund, Lovisa Tobiesson.

Short CV

Bachelor and master's degree in engineering physics from Chalmers University.

Research assistant at Gothenburg University.

Research engineer at Linköping University Former chair of CMIV Research School 22/23

Chair of DOMFIL 24/25.

Brain Tumors in Children: Clinical Applications of Novel MR Biomarkers

Central nervous system (CNS) tumors are the second most common type of cancer in chil-dren, requiring treatments such as neurosurgery, chemotherapy, and radiotherapy. Diagno-sis and evaluation primarily rely on MRI scans to assess the tumor's location, extent, and characteristics. Tumor growth in critical areas severely limits treatment options. For chil-dren with brain or spinal cord tumors, accurately distinguishing tumor tissue from healthy tissue is essential for effective treatment planning. However, diffuse tumor spread is partic-ularly difficult to detect using conventional MRI.

Furthermore, current treatments can unintentionally damage healthy brain tissue, and such changes are also challenging to classify with existing imaging techniques. This highlights the need for improved detection methods in pediatric oncology to differentiate between residu-al tumors, recurrences, and treatment-induced changes.

This study evaluates quantitative imaging biomarkers (APT-CEST, qMRI, and QTI) through the introduction of a novel MRI protocol for pediatric brain tumors, aiming to enhance both diagnostic precision and visualization. These advanced techniques will be integrated in-traoperatively as well as during follow-ups, including assessments up to two years after di-agnosis.

Additional examinations will be conducted at age 18, incorporating qMRI and QTI alongside complementary functional MRI and resting-state fMRI (rs-fMRI), with comparisons made against matched control subjects. This project fosters interdisciplinary collaboration be-tween medicine, physics, and engineering while also strengthening clinical partnerships among the Children's Cancer Center, neurosurgeons, and CMIV at LiU.

PROJECT INFORMATION

Project

Brain Tumours in Children: Clinical Applications of Novel Magnetic Resonance Biomarkers (BAQA and BAQA-18).

Supervisors

Peter Lundberg, Ida Blystad, Jan Hillman.

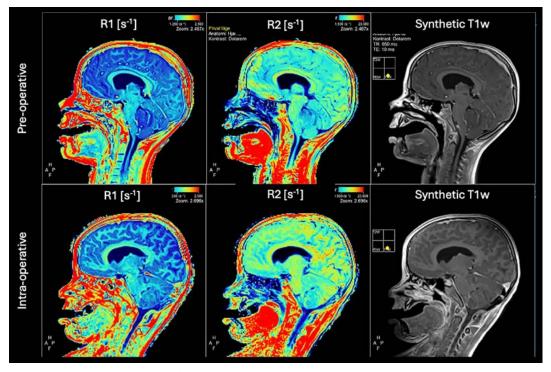
Short CV

PhD Student Medical Radiophysics, Linköping University and Center for Medical Image Science and Visualization (CMIV), 2021.

Specialist in Pediatric Oncology and Hematology, Linköping University Hospital, 2019.

Specialist in Pediatrics, Linköping University Hospital, 2015.

Doctor of Medicine, Linköping University Hospital /Motala Hospital, 2009. Bachelor of medicine and surgery, Lund University, Sweden, 2007.



Pre- and intraoperative qMRI images of a pediatric patient. R1- and R2-maps, and synthetic T1w images. Tumour in cerebellum (pre-operative) was removed surgically (intra-operative).

The Heart During Left Ventricular Assist

Heart failure is one of our most severe common diseases, where progression to advanced failure leads to poor prognosis and few treatment options. Recent advancements in the use of a left ventricular assist device system, HeartMate 3 (HM3), have shown significant benefits in long-term mechanical assist. The transition is particularly significant as HM3 is likely not only to serve as a bridge to transplantation but is increasingly being discussed as an effective destination alternative.

Despite these advancements, the need for meticulous hemodynamic monitoring remains during all types of mechanical circulatory support. While ultrasound remains the primary hemodynamic imaging method, its effectiveness is limited. The introduction of photon-counting detector computed tomography (PCD-CT) now offers time-resolved cardiac imaging with decreased metal artifacts. This, combined with computational modelling, potentially presents a novel approach to understand cardiac

function and hemodynamics during this therapy. The aim of my research is accordingly to investigate and describe both intracardiac geometry and hemodynamics in patients with ongoing therapy and correlate potential findings with device settings.

During 2024, we have published one systematic review on the challenges with ultrasound and the remaining knowledge gaps. We have also published an optimization-study for a PCD-CT protocol for HM3-imaging, including an in-depth assessment of metal artifacts. This protocol is now used in a cross-sectional study imaging HM3-patients with PCD-CT. During this inclusion, an interesting incidental finding of cases with extrinsic outflow graft stenoses (eOGO) led to one further publication regarding the hemodynamic significance of these stenoses. This by using a numerical approach as visualized in the image below. This study was also accepted for presentation at RSNA 2024 in Chicago.

PROJECT INFORMATION

Project

Cardiac function and hemodynamics during left ventricular assist device therapy.

Supervisors

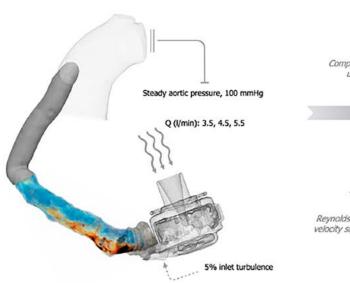
Tino Ebbers, Hans Granfeldt, Jonas Lantz, Éva Tamás.

Short CV

Visiting Scientist, Dept. of Radiology, Mayo Clinic, 2025.

Research intern Physician (Forskar-AT), Linköping University Hospital, 2024–. Junior Physician, Dept. of Cardiothoracic Surgery, Region Östergötland, 2024. Medical degree (MD), Linköping University, 2018–2024

Chairman, CMIV Research School,
Linköping University, 2023–2024.
Junior Physician, Dept of Clinical
Physiology, Region Östergötland, 2023.
PhD-student, Dept. of Cardiothoracic
Surgery, Region Östergötland, 2022.
Research Assistant, CMIV, Linköping
University, 2022.



Computational fluid dynamics (CFD) using ANSYS CFX 2022 R2 (Canonsburg, PA, USA). $u' = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (u_i - \overline{u})^2}$ $\mathsf{TKE} = \frac{1}{2} \rho (u'^2 + v'^2 + w'^2)$

Reynolds decomposition to decompose the velocity signal into a mean and a fluctuating component.

- Turbulent Kinetic Energy (mJ)
- Blood flow speed (m/s)
- Pressure (mmHg)

Numerical modelling of extrinsic outflow graft stenoses during left ventricular assist.

Close-to-Bedside MRI in Neurosurgical Critical Care

■ In the realm of neurosurgery, patients in the neurosurgical critical care unit (NCCU) often require repeated diagnostic imaging. However, the conventional practice of intrahospital transport for imaging poses significant risks, as even minor fluctuations in patients' physiological parameters can lead to secondary brain injury.

To address this critical concern, among other, an MRI scanner was installed in our NCCU for intraoperative use. With this, we've developed a preparation and transportation approach that we believe minimizes the impact on patients' vital signs when imaging with MRI is necessary. Unlike traditional intrahospital transfers to the Radiology department, our new method, that we refer as "close-to-bedside MRI", allows us to conduct all necessary preparations within the patient's own care room.

This approach is carried out by a highly skilled core staff, utilizing com-

prehensive checklists and specialized transportation techniques to ensure the safety of both the patient and the MRI procedure. Most notably, the MRI scanner is situated within the ward itself, reducing transportation time to a mere couple of minutes.

Our first project is dedicated to evaluating the effectiveness of the close-to-bedside MRI approach in preserving critical physiological parameters, as compared to the traditional practice of transporting patients outside the NCCU to the Radiology department. This will help us understand if this new approach is as safe and effective as we believe it to be.

Furthermore, we aim to investigate the impact of different professional constellations on patient and MRI safety. In contrast to standard practice, where radiographers collaborate closely with external anesthesia teams, our approach involves NCCU's intensive care nurses working alongside radiographers to ensure safety during MR scans.

If our approach proves successful in maintaining patient and MRI safety, we can foresee integrating MRI as a repeatable imaging tool for NCCU patients. This would open up new avenues for studying patient groups that often lack access to MRI scans due to their instability.

One of the exciting possibilities is the daily measurement of cerebral blood flow, which could be invaluable in detecting vasospasm – an all-too-common complication following subarachnoid hemorrhage. Early detection and treatment of vasospasm can make a life-saving difference for patients, and we believe our close-to-bedside MRI approach can play a pivotal role in achieving this.

We believe that this approach in the NCCU promises to improve patient care by making MRI scans safer, more accessible, and offering invaluable insights into the well-being of patients in critical care.



Bringing the MRI Table into the patient's own care room enables safe and efficient imaging within the Neurosurgical Critical Care Unit.

PROJECT INFORMATION

Project

Magnetic Resonance Imaging as a Monitoring and Diagnostic Method in Neurosurgical Care.

Supervisors

Peter Zsigmond, Anders Tisell, Johan Kihlberg, Charalampos Georgiopoulos.

Short CV

MRI Radiographer, Linköping's University Hospital, 2016-present. Modality Leader MRI 6, CMIV, 2020-2023. Master of Science (1 year) in Medical Sciences (Radiography), Karolinska Institute, Sweden, 2018-2021.

General Radiographer, Nyköping's Regional Hospital, 2014–2016.

Bachelor of Science, Radiography, Coimbra Health School, Portugal, 2009–2013.

Comparison of EID-CT and PCD-CT in Assessment of Coronary Arteries

Cardiovascular disease (CVD) remains the leading cause of mortality worldwide.

Computed tomography (CT) plays a crucial role in risk evaluation, with coronary artery calcium scoring (CACS) serving as a key method for detecting coronary artery calcifications (CAC). Since the 1990s, CACS has been used to assess risk in asymptomatic patients.

While CACS provides a quantitative measure of calcified burden in the coronary arteries, coronary CT angiography (CCTA) enables direct visualization of coronary artery plaques in relation to vessel lumens, allowing for stenosis evaluation. Conventional energy-integrated detector CT (EID-CT) demonstrates high sensitivity in detecting coronary artery stenosis and has excellent negative predictive value. However, this method often overestimates coronary artery disease (CAD), leading to moderate specificity and positive predictive value.

A recent advancement in CT technology is photon-counting detector CT (PCCT), which offers several technical benefits. Of particular relevance to this project are its potential applications in coronary artery diagnostics, including how improved spatial resolution and reduced blooming artifacts could enhance diagnostic accuracy. Additionally, the ability to capture multiple energy levels enables more detailed plaque characterization.

When introducing a new clinical imaging technique, it is essential to determine whether established scoring methods, such as the Agatston Score (AS), remain reliable for early CAD detection and risk stratification. Furthermore, a comprehensive evaluation of PCCT's applications in coronary artery diagnostics is crucial for a deeper understanding of its clinical impact.

The primary interest and potential advantage of this project lie in the possibility that if PCCT demonstrates a high positive predictive value, it could refine the diagnostic process and improve patient selection for invasive coronary angiography (ICA). This, in turn, may reduce complications associated with invasive procedures and lower healthcare costs.

The aim of my thesis is to evaluate the new CT technology (PCCT) in comparison to well-established techniques, EID-CT and ICA.

PROJECT INFORMATION

Droiect

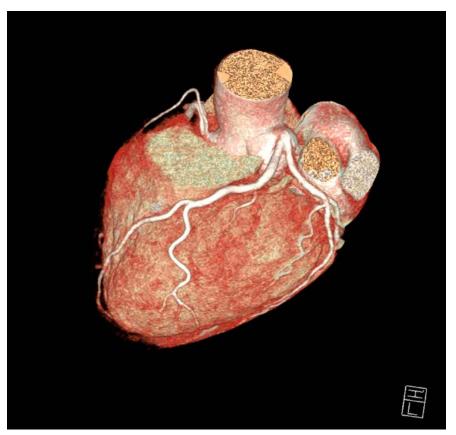
Comparison of EID-CT and PCD-CT in Assessment of Coronary Arteries.

Supervisors

Erik Tesselaar, Håkan Gustafsson, Anders Persson, Mårten Sandstedt.

Short CV

Consulting thoracic radiologist PhD student since 2021.



3D image of a heart from a CT examination.

Multimodal Pediatric Brain Tumor Diagnosis Using Deep Learning

■ Whole slide images (WSIs) with various stains, such as hematoxylin and eosin (H&E) and immunohistochemistry (IHC), assist pathologists in diagnosing brain tumors by providing a costeffective means for visualization, sharing, and archiving pathology information. The introduction of WSIs has led to an extensive volume of available data, facilitating the application of deep learning to support pathologists in making faster and more consistent decisions.

In my PhD project, the classification of pediatric brain tumors is investigated using H&E-stained slides. Additionally, the potential benefits of early fusion of unregistered H&E, Ki-67, and glial fibrillary acidic protein (GFAP)-stained images for improving diagnostic predictions are explored, compared to using H&E slides alone. Ki-67 is particularly useful for diagnosing medulloblastomas and astrocytomas, as well as distinguishing between different astrocytoma grades. GFAP is a reliable marker for differentiating between glial and non-glial tumors and for grading astrocytomas.

Experiments were conducted on glioma grading and the classification of

major tumor families/types, including low-grade astrocytoma gliomas (grades 1 and 2), high-grade astrocytoma gliomas (grades 3 and 4), ependymomas, meduloblastomas, and gangliogliomas. Endto-end classification of WSIs using deep learning is particularly challenging due to their immense size. To address this, a weakly supervised learning method called clustering-constrained attention multiple instance learning (CLAM) was employed to perform classification tasks by aggregating patch-level features into slide-level representations.

The experiments yielded promising results in classifying pediatric brain tumor families/types using only H&E slides. The early fusion of unregistered Ki-67 and GFAP with H&E slides significantly improved the differentiation between low-grade and high-grade astrocytoma gliomas (p < 0.05), supporting the diagnostic potential of Ki-67 and GFAP stains, which aligns with their established clinical applications. However, across multiple tumor classes, fusing H&E with IHC did not enhance classification performance beyond what was achieved using H&E images alone.

To maximize the potential of multi-stain fusion for this application, future research should explore alternative fusion strategies beyond early fusion, such as late and intermediate fusion techniques. The results of this study have been published as a conference paper in the MICCAI Workshop on Computational Pathology with Multimodal Data (COMPAYL).

PROJECT INFORMATION

Project

Fusion of H&E and IHC Histology Images for Pediatric Brain Tumor Classification.

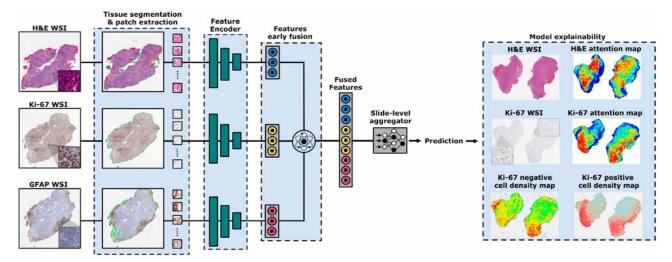
Supervisors

Neda Haj-Hosseini, Anders Eklund, Ida Blystad.

Short CV

University of Patras, BSc in Mathematics, 2014–2019.

University of Linköping, MSc in Machine Learning and Statistics, 2021-2023. University of Linköping, Department of Biomedical Engineering, Research Assistant, July 2023- August 2023. University of Linköping, PhD candidate, September 2023- present.



Concept of data preprocessing and fusion of WSIs, model training and explainability analysis.

Photon Counting CT for Characterization of Arterial Plaque

Atherosclerosis is a cardiovascular disease characterized by the accumulation of lipids and calcium, forming plaques in the coronary arteries. The disease can be diagnosed and monitored using CT imaging, where plaque visualization is possible due to the X-ray attenuative properties of calcium. Plaques may be classified as high- or low-risk for causing cardiovascular events based on their degree of calcification and size.

However, studies have shown that arterial plaque can sometimes be incorrectly labeled as high-risk due to size overestimation. This misclassification can lead to unnecessary medical interventions, which not only increase healthcare costs but also pose potential risks to patients. The overestimation of object sizes in CT imaging is primarily caused by blooming artifacts, a visual distortion that occurs at the interface between hard and soft materials. At these interfaces, adjacent detector elements in the X-ray detector register a large difference in

signal intensity. This discrepancy leads to signal spill-over between pixels in the reconstructed image, as the reconstruction algorithm struggles to compensate for the abrupt signal variation. The occurrence of this artifact is unpredictable, as it depends on the composition of the scanned object, image reconstruction settings, and detector hardware.

Photon-counting CT (PCCT) represents a major advancement in medical imaging. The latest generation of CT scanners utilizing photon-counting X-ray detectors inherently offer higher spatial resolution compared to their predecessors. This results in a more anatomically accurate visualization of the human body and more precise plaque size assessments due to reduced blooming artifacts. Additionally, smaller plaques can be detected thanks to the improved level of detail. The new capability of spectral imaging will further enable advanced imaging techniques, allowing for more detailed

characterization of plaque composition based on its constituent elements.

This project aims to quantify the blooming artifact and investigate how it is influenced by the image reconstruction process. The extent of blooming artifacts will be examined across a wide range of materials with varying dimensions, densities, and complexities. Additionally, complementary material characterization tools such as X-ray photoelectron spectroscopy (XPS) will be utilized to enhance the understanding of CT's capabilities and limitations as a material analysis tool. The long-term goal of this research is to advance CT imaging for improved arterial plaque characterization and high-precision diagnostics.



Supervisors Kajsa Uvdal, Caroline Brommesson, Anders

PROJECT INFORMATION

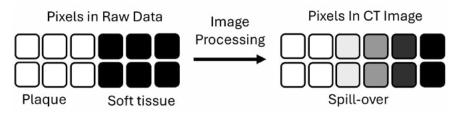
Persson.

Short CV

MSc Biotechnical Engineering, Linköping University, 2018 - 2023. Research Assistant, IFM, Linköpina

University, June 2023 - December

PhD Student, IFM, Linköping University, December 2023 - Present



Schematic view of the blooming artefact. Signal spill-over distorts the visualization of material interface, hindering accurate size measurements in the micrometer to millimeter range.

Imaging Biomarkers in Liver Cirrhosis

Chronic liver disease is a major global health concern. Driven by the obesity epidemic and alcohol consumption, the incidence of liver cirrhosis – the end stage of chronic liver disease – is increasing. The prognosis for liver cirrhosis is poor, with fewer than half of patients surviving five years after diagnosis. Liver disease-related mortality is also rising, with an estimated two million deaths annually

worldwide. While some patients die from liver cancer – prompting the implementation of a screening program for early tumor detection – the majority succumb to other liver-related complications, and predicting the course of the disease remains a challenge. It is still unclear why some patients remain asymptomatic for decades, while others experience rapid deterioration.

Figure 1. Subtle changes of liver cirrhosis.

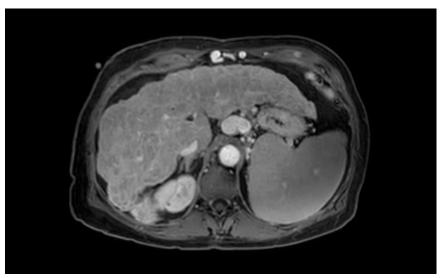


Figure 2. Severe changes of liver cirrhosis.

Liver cirrhosis has characteristic imaging features that correlate with pathological findings; however, in some cases, the cirrhotic liver may appear completely normal on imaging. This project aims to describe the morphological changes associated with liver cirrhosis on magnetic resonance imaging (MRI) and evaluate whether these changes correlate with disease severity.

As part of an ongoing prospective multicenter cohort study (ACCESS-ESLD), 150 patients with cirrhosis undergoing liver cancer screening are being followed biannually with clinical examinations, questionnaires, blood tests, liver stiffness measurements, and MRI. Preliminary analysis of baseline MRI examinations suggests that morphological changes in liver cirrhosis vary depending on the etiology of the disease and correlate with laboratory findings and clinical symptoms.

The next step is to assess the progression of cirrhotic changes on imaging as this cohort undergoes follow-up MRI scans over the next two years. This imaging data will be correlated with clinical findings in the hope of improving disease monitoring and predicting outcomes in liver cirrhosis.

PROJECT INFORMATION

Project

Imaging Biomarkers in Liver Cirrhosis.

Supervisors

Mattias Ekstedt, Peter Lundberg, Nils Dahlström, Charlotte Söderman.

Short CV

Medical degree, Karolinska Institute, 2006 Radiologist, Department of Radiology, Capio St Göran Hospital, Stockholm

European Diploma in Radiology, 2018 Consultant radiologist, Department of Radiology, Capio St Göran Hospital, Stockholm, 2024-present.

Pediatric Brain Tumor Image Analysis

■ Summary of Results: Results from magnetic resonance imaging (MRI) demonstrated that deep learning (DL)-based classification among three tumor types is feasible, with the highest performance observed when using ADC or T2-weighted data. For histopathology images, hierarchical classification across up to 13 tumor types was successfully performed by models focusing on pathology-relevant regions within the images. While the pretraining strategy did not improve classification performance for MRI data, histopathology-pretrained foundation models significantly outperformed ImageNet-pretrained models across multiple classification tasks when using histopathology images as input.

Background: Although rare, brain tumors are the most common type of solid neoplasm in children and young adults. Timely treatment is critical for improving outcomes in this population, and MRI can provide an initial diagnosis to guide therapy. The final diagnosis is established through histological exami-

nation of tissue samples, often integrated with molecular profiling. This process is time-consuming and requires specialized expertise, which is frequently limited.

This project explores the potential of DL-based predictive models for diagnosing pediatric brain tumors using preoperative MRI data and postoperative histology images. While numerous studies have applied DL to brain tumor classification in adults, relatively few have focused on the pediatric population.

Multi-sequence preoperative MRI from 178 subjects, along with age information, was used to classify the three main types of pediatric tumors. For the histology image analysis, a multi-center Swedish cohort was curated in collaboration with the Barntumörbanken at Karolinska Institute. For tumor diagnosis prediction based on MRI data, ResNet50 and ViT models were trained and evaluated on transverse images displaying tumors, experimenting with different pretraining strategies and input modalities. In the experiments utilizing

histopathology images, a multipleinstance learning approach was implemented for patient-wise classification, using patch-level features extracted from recently released histopathology-pretrained foundation models.

PROJECT INFORMATION

Proiect

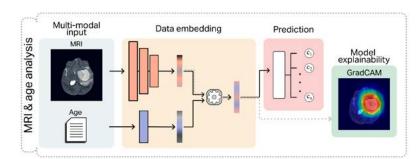
Pediatric brain tumor classification using deep learning on MRI and histopathology images.

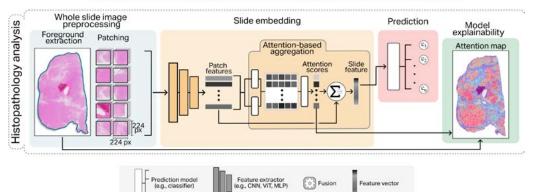
Supervisors

Neda Haj-Hosseini, Anders Eklund, Ida Blystad, Oliver Gimm.

Short CV

University of Padova, BSc in Biomedical Engineering, 2013–2016. Linköping University, MSc in Biomedical Engineering, 2017–2019. Linköping University, Department of Biomedical Engineering, Research Engineer, June 2019– January 2020. Linköping University, PhD candidate, February 2020–now.





From data preprocessing to model training and explainability analysis: a study on pediatric brain tumor classification using deep learning on MRI and histopathology images.

Nonsize Factors in Aortic Dilation

Aneurysmal dilation of the aorta is an asymptomatic condition that often remains undetected until a fatal dissection or rupture occurs. Current clinical guidelines traditionally rely on measuring aortic size to determine the need for surgical intervention. However, size alone is an insufficient predictor of complications. For instance, most patients with ascending aortic dissection have small aneurysms and therefore do not meet the current surgical criteria. This highlights a critical gap in our scientific understanding and clinical management of individuals with aortic dilation.

The primary objective of this project is to investigate whether aortic dilation

is associated with alterations in aortic wall properties or blood flow. We aim to achieve this using advanced cardiovascular magnetic resonance (CMR) imaging. By enhancing our understanding of aortic dilation and identifying novel measures to distinguish between cases and controls, this project may pave the way for improved risk stratification in individuals with aortic dilation.

Recently, we explored the associations between blood flow markers measured with 4D Flow CMR and circulating biomarkers in the plasma of patients with healthy aortic valves but mild-to-moderate ascending aortic dilation. The study population was a sub-

cohort of the Swedish CArdioPulmonary bioImage Study (SCAPIS) in Linköping. Ascending aortic diameters were measured using chest computed tomography (CT) images, identifying 74 individuals with previously undiagnosed ascending aortic dilation, corresponding to a prevalence of 1.5%. These individuals were invited for a CMR scan and venous blood sampling to identify plasma biomarkers. A total of 47 subjects participated, and they were compared with age- and sexmatched controls (Figure 1).

The study's key finding was an inverse correlation between the oscillatory shear index (OSI) and type I collagen a1 chain (COL1a1) in patients with aortic dilation (Figure 2). OSI is a blood flow CMR marker that quantifies the oscillation of shear forces on the aortic wall. Elevated OSI is indicative of reverse flow or abnormal vortices. COL1a1 is a protein essential for the tensile strength of the aortic wall. A loss of collagen or deposition of disorganized collagen weakens the aortic wall, making it more susceptible to dilation. An increase in circulating collagen suggests potential leakage from the aortic wall into the bloodstream. This study, therefore, identified a possible link between pathological hemodynamic patterns in the ascending aorta and the underlying biological mechanisms contributing to aortic dilation.

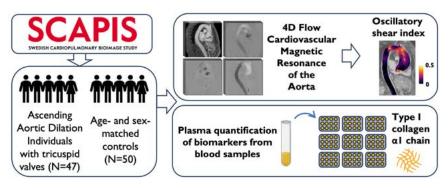


Figure 1. Overview of the study: patients with normal tricuspid aortic valves and ascending aortic dilation and sex- and age-matched controls were recruited from the SCAPIS study. These subjects underwent a 4D Flow CMR examination to quantify oscillatory shear index. Plasma biomarkers were quantified in venous blood samples.

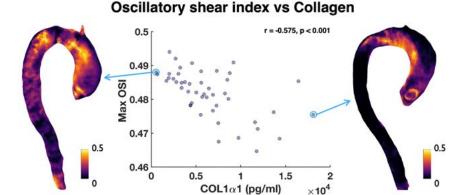


Figure 2. Scatter plots showing the distribution of oscillatory shear index vs Type I collagen α 1 chain (COL1 α 1). The colormaps show distribution of oscillatory shear index in the ascending a rta for the subjects with min/max COL1 α 1. r = Spearman correlation coefficient.

PROJECT INFORMATION

Project

Novel Assessment of Aortic Function in Health and Disease.

Supervisors

Petter Dyverfeldt, Tino Ebbers, Marcus Lindenberger, Lena Jonasson.

Short CV

Master's degree in biomedical engineering
- Biomechanics and Biomaterials,
Politecnico di Milano University, Milan,
Italy

Bachelor's degree in biomedical engineering, Politecnico di Milano University, Milan, Italy.

Cardiovascular Digital Twins for Blood Pressure Regulation

 Hypertension, or high blood pressure, is a major risk factor for cardiovascular diseases such as stroke, coronary artery disease, and heart failure. Current treatments for hypertension include lifestyle modifications and a variety of blood pressure-lowering medications. However, treatment selection is often based on general guidelines rather than patient-specific factors, relying on a trial-and-error approach where different medications are tested until an optimal effect is achieved. To improve treatment outcomes, a more comprehensive, patient-specific understanding of blood pressure regulation is needed.

This project focuses on developing mathematical models to better understand the individual mechanisms underlying short- and long-term blood pressure regulation in health, disease, and during treatment. Using 4D flow magnetic resonance imaging (MRI) and blood pressure data, we create patient-specific mathematical models

- so-called digital twins. These models range from detailed lumped parameter models, which simulate blood flow and pressure dynamics during a single heartbeat, to models that assess exercise effects over minutes or hours, as well as long-term blood pressure changes over several years.

Our lumped parameter models have demonstrated the ability to comprehensively analyze and estimate hemodynamic variables, revealing differences between patient groups that cannot otherwise be derived non-invasively. Together, these models form a multi-timescale digital twin that replicates each patient's hemodynamics, allowing for the description, explanation, and prediction of patient-specific changes in blood pressure and blood flow – both in the short term and over extended periods.

To advance the development of multi-timescale cardiovascular digital twins and further explore patient-specific responses to antihypertensive treatment, we are collecting detailed data on cardiac and vascular function before, during, and after the initiation of antihypertensive therapy. These measurements are conducted at rest and during exercise. By integrating new data with our models, we aim to gain deeper insights into the complex mechanisms of cardiovascular function, ultimately contributing to more personalized approaches for the prevention, diagnosis, and treatment of hypertension.

PROJECT INFORMATION

Project

Cardiovascular mechanistic twins for blood pressure regulation.

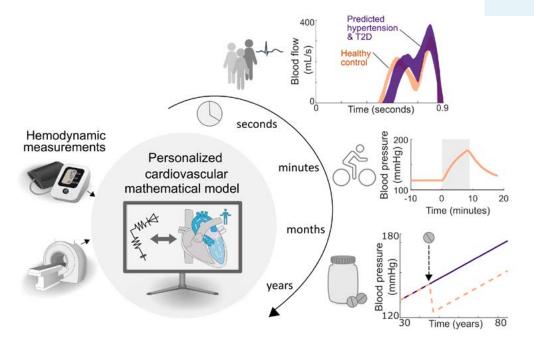
Supervisors

Gunnar Cedersund, Tino Ebbers, Carl-Johan Carlhäll.

Short CV

PhD student Linköping University, since February 2020.

M.Sc. in Engineering Biology, Linköping University, 2021.



Using detailed measurements from 4D flow MRI and blood pressure, personalized cardiovascular models can be created. These models can describe and predict the blood pressure and blood flow on several timescales: from one heartbeat to exercise during several minutes, to drug treatments during months or years.

Background Offset Correction for 4D Flow MRI with Deep Learning

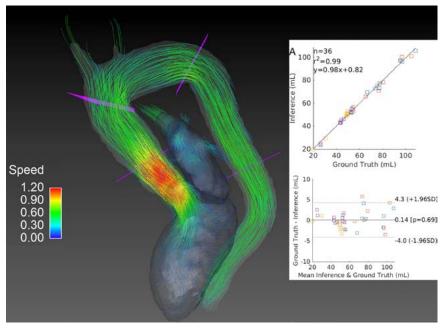
The quality of 4D flow MRI data is influenced by various factors, including the type of MRI sequence used, scan duration, and temporal/spatial resolution. Additionally, phase errors, particularly background phase offset errors, can further degrade data quality. Several methods have been proposed to correct background phase offsets in 4D flow MRI, but none have proven fully effective in eliminating these errors. The most accurate approach involves measuring the offset field in a static phantom after in vivo acquisition and applying this measurement to correct the in vivo data. However, this phantom-based method significantly increases scan time. As a more practical alternative, a commonly used approach involves fitting a polynomial function to the measured velocities

in static tissue, which is identified using magnitude image thresholding.

The use of deep learning, particularly convolutional neural networks (CNNs), in medical imaging is becoming increasingly widespread. Recent studies have demonstrated the effectiveness of CNNs in correcting background phase offsets in abdominal and cerebral 4D flow MRI. These networks were trained using the polynomial fit approach as ground truth, leveraging the abundance of static tissue in abdominopelvic and cerebral regions. However, in thoracic imaging, static tissue is scarce, making the accuracy of the polynomial fit method more uncertain.

In this study, we aimed to develop an automated deep learning-based background offset correction method for cardiovascular 4D flow MRI, using static phantom measurements as ground truth. Phantom data were acquired within a few days of the in vivo scans and used as reference data during CNN training. The input to the CNN consisted of 4D flow MRI velocity images, while the output was the predicted correction field.

Our results showed that the CNN could generate offset fields comparable to those obtained from phantom measurements, while requiring only a few seconds - compared to the 8-10 minutes needed for a phantom measurement. To validate this, we compared flow measurements in phantom-corrected and deep learning-corrected data at four locations along the aorta (Figure). Additionally, we assessed the internal consistency of the polynomial fit and deep learning correction methods by comparing flow differences across multiple planes in the ascending aorta, demonstrating the superiority of the deep learning approach.



Regression plot and Bland-Altman plot for the volumetric flow computed at four locations along the aorta in the phantom-corrected and deep learning-corrected data.

PROJECT INFORMATION

Project

Automatic background offset correction of cardiovascular 4D flow MRI data using Deep Learning.

Supervisors

Tino Ebbers, Petter Dyverfeldt, Carl-Johan Carlhäll, Farkas Vanky.

Short CV

Research Engineer at the Unit of Cardiovascular Science at the Linköping University Hospital, November 2014–Current.

MSc in Biomedical Engineering, Linköping University of Technology, Linköping, Sweden, Sept 2012 - Sept 2014.

BSc in Electronic Engineering with highest honors; 110/110 cum laude, Università degli studi di Palermo, Palermo, Italy, October 2002- July2007.

Automatic and Semi-Automatic CMR Segmentation of the Left Ventricle

 In addition to echocardiography, cardiovascular magnetic resonance (CMR) has become a key modality in cardiac imaging. However, CMR requires good patient cooperation to ensure high image quality and is a relatively lengthy procedure. Limited access to cardiac MRI is one of the reasons why its clinical use remains restricted. Despite these challenges, CMR offers high accuracy and reproducibility in the evaluation of cardiac chamber volumes, mass, and function. These quantitative clinical parameters rely on precise segmentation of the left ventricle, which involves delineating the epi- and endocardium in a well-defined plane. Since segmentation is an essential part of a CMR examination, improving its efficiency could facilitate earlier diagnosis and treatment.

Manual segmentation methods, though accurate, are time-consuming. To streamline the process and reduce human error, several semi-automated and fully automated segmentation techniques have been developed. Various commercial software solutions for segmentation are available, and rapid advancements in artificial intelligence (AI) have led to its increasing use as a clinical support tool.

In our study, we aim to compare fully automatic and semi-automatic segmentation methods for left ventricular CMR images. We analyzed data from two patient groups examined using two different MRI scanner brands, applying three commercially available software solutions currently used in Sweden. In all software programs, expert imaging specialists carefully segmented the epi- and endocardium in the short-axis view at both end-diastole and end-systole, with manual confirmation of these phases in all programs. Papillary muscles were excluded from the segmentation. One of the programs included an automatic determination of the mitral valve plane, which could be manually adjusted, whereas the mitral valve was not labeled in the other programs.

With segmentation now complete, we have entered the analysis phase. A key question remains: Can AI-assisted automatic left ventricular segmentation be recommended for routine clinical use? A positive outcome would support a shift in patient workflow and improve accessibility to CMR, ultimately enhancing patient care.

PROJECT INFORMATION

Proiect

Usability of cardiac magnetic resonance for patients with acute coronary syndrome and well-preserved myocardial function: user perspective, patient experience and prognostic value.

Supervisors

Johan Kihlberg, Patric Karlström, Lene Rosendahl, Peter Blomstrand and Tino Ebbers.

Short CV

PhD student, Linköping University, since May 2023.

Modality Leader at MR, Ryhov County Hospital, February 2015-present. Master of Science (I year), Radiography, Gothenburg University, May 2015. Radiographer, Ryhov County Hospital, May 2004-January 2015.

Bachelor of Science, Radiography, Jönköping University, December 2007. Radiographer exam, Jönköping University, December 2003.



Imaging expert performing segmentation of the left ventricle in different softwares.





Dissertations

- During 2024 five of the CMIV PhD students have finished their studies and 0 defended their theses. The PhD students and the research school are an important part of CMIV, and we are proud to present their theses here.
- In addition, one student concluded his research with a licentiate degree.

LINKÖPING UNIVERSITY, DEPARTMENT OF BIOMEDICAL ENGINEERING

Diffusion MRI with generalised gradient waveforms: methods, models, and neuroimaging applications

■ The incessant, random motion of water molecules within biological tissues reveals unique information about the tissues' structural and functional characteristics. Diffusion magnetic resonance imaging is sensitive to this random motion, and since the mid-1990s it has been extensively employed for studying the human brain. Most notably, measurements of water diffusion allow for the early detection of ischaemic stroke and for the unveiling of the brain's wiring via reconstruction of the neuronal connections. Ultimately, the goal is to employ this imaging technique to perform non-invasive, in vivo virtual histology to directly characterise both healthy and diseased tissue.

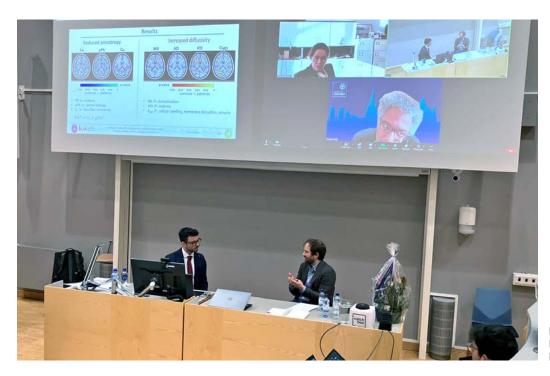
Recent developments in the field have introduced new ways to measure the diffusion process in clinically feasible settings. These new measurements, performed by employing generalised magnetic field gradient waveforms, grant access to specific features of the cellular composition and structural organisation of the tissue. Methods based on them have already proven beneficial for the

assessment of different brain diseases, sparking interest in translating such techniques into clinical practice. This thesis focuses on improving the methods currently employed for the analysis of such diffusion MRI data, with the aim of facilitating their clinical adoption.

The first two publications introduce constrained frameworks for the estimation of parameters from diffusion MRI data acquired with generalised gradient waveforms. The constraints are dictated by mathematical and physical properties of a multi-compartment model used to represent the brain tissue, and can be efficiently enforced by employing a relatively new optimisation scheme called semidefinite programming. The developed routines are demonstrated to improve robustness to noise and imperfect data collection. Moreover, constraining the fit is shown to relax the requirements on the number of points needed for the estimation, thus allowing for faster data acquisition.

In the third paper, the developed frameworks are employed to study the brain's white matter in patients previously hospitalised for COVID-19 and who still suffer from neurological symptoms months after discharge. The results show widespread alterations to the structural integrity of their brain, with the metrics available through the advanced diffusion measurements providing new insights into the damage to the white matter.

The fourth paper revisits the modelling paradigm currently adopted for the analysis of diffusion MRI data acquired with generalised gradient waveforms. Hitherto, the assumption of free diffusion has been employed to represent each domain in a multi-compartmental picture of the brain tissue. In this work, a model for restricted diffusion is considered instead to alleviate the paradoxical assumption of free but compartmentalised diffusion. The model is shown to perfectly capture restricted diffusion as measured with the generalised diffusion gradient waveforms, thus endorsing its use for representing each domain in the multi-compartmental model of the



Deneb Boito and the opponent, Professor Frederik Laun, Erlangen, Germany.

LINKÖPING UNIVERSITY, DEPARTMENT OF BIOMEDICAL AND CLINICAL SCIENCES

Self-supervised deep learning and EEG categorization

Deep learning has the potential to be used to improve and streamline EEG analysis. At the present, classifiers and supervised learning dominate the field. Supervised learning depends on target labels which most often are created by human experts manually classifying data. A problem with supervised learning is intra- and interrater agreement which in some instances are far from perfect. This can affect the training and make evaluation more difficult.

This thesis includes three papers where self-supervised deep neural networks were developed. In self-supervised learning, the input data to the networks themselves contain structures that are used as targets for the training and no labeling is necessary.

In paper I, deep neural networks were trained to increase the number of-, or to recreate missing EEG-channels. The performance was at least on the same level as that of spherical interpolation, but unlike in the case of interpolation, missing data does not have to be identified manually first.

Papers II and III involved developing deep neural networks for clustering analysis. The networks produced two-dimensional representations of EEG data and the training strategy was based on the principle of t-distributed stochastic neighbor embedding (t-SNE).

In paper II, comparisons were made to parametric t-SNE and EEG-features obtained from time-frequency methods. The deep neural networks produced more distinct clustering when tested on data annotated for epileptiform discharges, seizure activity, or sleep-wakefulness.

In paper III, the newly developed method was used to compare annotations of epileptiform discharges. Two experts performed independent annotations and classifiers were trained on these, using supervised learning, which in turn produced new annotations. The agreement when comparing two sets of annotations was not larger between the two experts than between an expert and a classifier. The analysis showed that differences in the annotations by the



experts influenced the training of the classifiers. However, the clustering analysis indicated that although it was not always the exact same waveforms that were assessed as epileptiform discharges, they were often similar.

The work thus resulted in different methods to process and analyze EEG data, which may have practical usefulness. Traditional agreement scores only assess the exact agreement. However, they reveal nothing about the nature of disagreement. Cluster analysis can provide a means to perform this assessment.

Christian Simonsson

LINKÖPING UNIVERSITY, DEPARTMENT OF BIOMEDICAL ENGINEERING

Mathematical Modelling of MASLD – Towards Digital Twins in Liver Disease

Unhealthy dieting and a sedentary lifestyle are causing an increased prevalence of obesity related complications. One such complication is metabolic dysfunction-associated steatotic liver disease (MASLD) the manifestation of metabolic dysregulation and insulin resistance in the liver. Today, MASLD effect a third of the world's population. One of the main characteristics of MASLD is accumulation of ectopic lipids in the liver, also denoted steatosis. Steatosis is not inherently dangerous but is an indication of metabolic dysregulation,

and long-term MASLD can progress into severe conditions such as chronic hepatic inflammation denoted metabolic dysfunction-associated steatohepatitis (MASH), liver scarring (cirrhosis), and primary liver cancer (hepatocellular carcinoma, HCC). Moreover, these conditions can be further aggravated by alcohol consumption. The increase in potential patients with MASLD will have an enormous burden on future healthcare. Thus, future healthcare has a need for innovative solutions to lessen this burden. Such solutions should be capable



Chairman of the CMIV Research School, Twan Bakker, is handing over the CMIV diploma following the successful PhD defense of Christian Simonsson.

of personalized and preventive measures, cost-effective high throughput screening methods, and frameworks integrating all available patient data, for all stages of MASLD. Today, some of these methodologies already exist, however there is still a need for ways to integrate different liver biomarkers into a user-friendly framework, with strong personalization and predictive capabilities. For this purpose, data-driven mathematical modelling is of use. Data-driven mathematical models

has proven useful for such integration in other disease areas such as stroke. In this thesis, I have created and explored several mathematical models aimed at exploring different aspects of MASLD, as well as developed several models using data from example: our own collected magnetic resonance imaging (MRI) data from patients suffering from chronic liver disease or HCC, and pre-clinical mouse data of insulin resistance progression. The studies presented in this thesis

investigate diet-driven insulin resistance development, steatosis development and screening, as well as lifestyle interventions for alcohol and dietary habits, and liver function evaluation at late-stage liver disease. Thus, this thesis presents a possible fundament to create a so-called digital twin of MASLD – a highly personalized model capable of making predictions based on lifestyle.

Iulian Emil Tampu

LINKÖPING UNIVERSITY, DEPARTMENT OF BIOMEDICAL ENGINEERING

Deep learning for medical image analysis in cancer diagnosis

Medical imaging is one of the cornerstones of clinical diagnosis, providing insights into the anatomy and physiology of organs and tissues for screening, initial diagnosis, treatment planning, and follow-up. Utilizing both invasive and non-invasive techniques, medical imaging employs various contrast mechanisms to capture details of the tissue structure and the functionality of biological systems at different spatial and temporal resolutions, and dimensionalities. The ever-growing volume of medical image data driven by screening programs, digitalization, and the push towards precision medicine has highlighted the need for automatic image analysis methods to reduce the workload of healthcare personnel in reviewing these images.

Deep learning (DL), a subset of artificial intelligence (AI), comprises of methods that learn representations from data to perform various predictive tasks. Although DL was introduced in the mid-1960s, it has only been successfully applied for computer vision tasks in the past two decades, becoming the standard method for natural image processing. Additionally, the versatility of DL in processing data from diverse sources (such as speech, text, and climate) has encouraged its application in the medical domain as well.

This thesis explores the application of DL-based methods for medical image analysis, focusing on cancer diagnosis at various treatment planning stages, including preoperative, intraoperative, and postoperative procedures. Methods were developed and applied to three medical

imaging modalities: optical coherence tomography (OCT) for intraoperative diagnosis, magnetic resonance imaging (MRI) for pre-operative diagnosis and radiotherapy treatment planning, and histopathology whole-slide images (WSI) for postoperative final diagnosis, addressing tasks such as detection, semantic segmentation, and classification for thyroid diseases and pediatric and adult brain tumors.

In summary, the outcomes of this thesis highlight the potential of deep

learning-based methods for medical image analysis in the context of cancer diagnosis. These works demonstrate the versatility of deep learning in processing medical images from various sources and at different spatial resolutions and dimensionalities. Appropriate dataset curation, method validation and interpretation, and translational research are needed to promote the integration of deep learning-powered tools in the clinic.



Iulian Emil Tampu is nailing his thesis three weeks before the dissertation. This is a Swedish tradition which makes it publicly available. LINKÖPING UNIVERSITY, DEPARTMENT OF HEALTH, MEDICINE AND CARING SCIENCES

Examination of Coronary Artery Disease with Computed Tomography: Stenosis

Evaluation and Calcium Score

Computed tomography (CT) is increasingly utilized for evaluating patients with suspected coronary artery disease (CAD). Advancements in CT technology have the potential to enhance diagnostic accuracy and streamline clinical workflows for this patient group.

The overarching objective of this thesis was to investigate the role of CT in the assessment of CAD. Specifically, studies focused on evaluating emerging technologies: Stenosis evaluation with transluminal attenuation gradients (TAG) (study I), an AI-based calcium scoring CT (CSCT) software prototype (study II), photon-counting detector (PCD) CT for CSCT evaluations (study III) and a commercially available AI-based CSCT software was evaluated using a large dataset from the Swedish Cardiopulmonary bioImage Study (SCAPIS) (study IV).

Studies I and II evaluating TAG and the CSCT software prototype were

based on clinical patient data, while the PCD-CT evaluation (study III) used CT data of cadaveric hearts and the commercially AI-based CSCT software was evaluated using data of SCAPIS study subjects (study IV). The performance of TAG was compared to invasive fractional flow reserve (FFR) measurements (study I), while CSCT AI-based softwares were benchmarked against semi-automated coronary artery calcification (CAC) scoring by human readers (study II and IV). In study III, the PCD-CT performance regarding CAC quantification was compared to results from energy-integrating detector (EID) CT.

TAG did not demonstrate any value for the evaluation of coronary artery stenosis degree (study I). A result that is in alignment with other studies in the field. The evaluations of CSCT software demonstrated strong correlations and excellent agreement with standard



Dr. Lilian Henriksson with the CMIV Research School diploma, together with her supervisor, Professor Anders Persson, following her successful PhD defense.

reference measures (studies II and IV), along with significant time-saving potential (study II). PCD-CT showed strong correlation and agreement with EID-CT for CSCT evaluations using the well-established Agatston score, indicating that these measurements can be converted to the forthcoming detector technology for CT (study III).

Johan Jönemo Licenciate Degree

LINKÖPING UNIVERSITY, DEPARTMENT OF BIOMEDICAL ENGINEERING

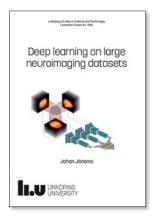
Deep learning on large neuroimaging datasets

Magnetic resonance imaging (MRI) is a medical imaging method that has become increasingly more important during the last 4 decades. This is partly because it allows us to acquire a 3D-representation of a part of the body without exposing patients to ionizing radiation. Furthermore, it also typically gives better contrast between soft tissues than x-ray based techniques such as CT. The image acquisition procedure of MRI is also much more flexible. One can vary the signal sequence, not only to change how different types of tissue map to different intensities, but also to measure flow, diffusion or even brain activity over time.

Machine learning has gained great impetus the last decade and a half. This

is probably partly because of the work done on the mathematical foundations of machine learning done at the end of last century in conjunction with the availability of specialized massively parallel processors, originally developed as graphical processing units (GPUs), which are ideal for training or running machine learning models. The work presented in this thesis combines MRI and machine learning in order to leverage the large amounts of MRI-data available in open data sets, to address questions of clinical relevance about the brain.

The thesis comprises three studies. In the first one the subproblem which augmentation methods are useful in the larger context of classifying autism, was



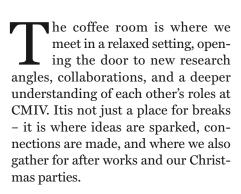
investigated. The second study is about predicting brain age. In particular it aims to construct light-weight models using the MRI volumes in a condensed form, so that the model can be trained in a short time and still reach good accuracy. The third study is a development of the previous that investigates other ways of condensing the brain volumes.



Twan Bakker and Kajsa Tunedal



Sandra Rudin.





Dennis Carlsson and Henrik Ekman.



Simon Park and Sohaib Ayaz Qazi.



Mattias Ekstedt, Patrik Nasr and Nils Dahlström.



An enjoyable after work event featuring pizza in the coffee room and a lively foosball tournament.







CT

CT 1 - Siemens Healthineers NAEOTOM Alpha. This is a first-generation dual source CT scanner with photon counting technology. The photon counting detectors have 4 main advantages compared to conventional (scintillator based) CT detectors. The pixels of the detectors are much smaller than before without radiation dose penalty. This leads to images with spatial resolution at a new level. Each photon's energy is measured and therefore images are created without electronic noise. The energy information of the photons can be used for advanced spectral applications, such as k-edge imaging. Moreover, the detector is more sensitive for low-energy photons, which makes it possible to reduce the radiation dose and contrast media dosage drastically.

CT 2 – Siemens Healthineers SOMATOM Force. This CT enables routinely performed exams at low kV settings (70–90 kV), even in adults. This is due to the system being equipped with powerful generators and X-ray tubes. The low kV settings allow for substantial reductions in contrast medium dose. Improvements have been made on the detector side as well with an increased number of detector rows and upgraded collimation. The SOMATOM Force renders images with high spatial resolution and soft-tissue contrast. It contains two X-ray sources and two detectors, which can be used simultaneously. This in combination with a broader detector enables faster scans. High speed scanning is necessary for cardiac examinations as well as for restless patients. The two X-ray sources also provide the possibility for dual energy examinations with improved spectral separation.

MRI

MR 1 – The Siemens 3.0T Prisma has a 60 cm bore and gradients with 80mT/m and 200 T/m/s simultaneously, which facilitate fMRI and DTI studies in a 64 receive channels head coil. The coil concept also offers high coil density using parallel transmit technology called TimTX TrueShape for cardiac, abdominal and musculoskeletal examinations.

MR 2 – The Philips Ingenia 3.0T has a 70 cm bore. It is equipped with Xtend gradient system (up to 45mT/m and 200 T/m/s) and two parallel RF transmission channels (Multitransmit 4D), which adapt the RF signals to each patient. Multitransmit facilitates an increased image uniformity, contrast, and consistency, as well as faster imaging. A full range of receiver coils is available with analog-to-digital converters inside the coils (dStream RF). This samples the MR signal directly in the coil on the patient and sends it to the reconstructor via a fiber-optic cable.

MR 3 – The Philips Achieva 1.5T has a 60 cm bore and is equipped with Nova Dual gradients (up to 66 mT/m and 160 T/m/s), and the latest software release and upgraded to dStream resulting in up to 40 % higher SNR, and a dynamic range that exceeds 185 dB.

Advanced fMRI research is possible using video glasses with built-in eyesight correction as well as eye-tracking, and it is also possible to combine these measurements with simultaneous multichannel MR-EEG. Other specialty equipment includes several MR-elastography (MRE) systems for both 1.5 T and 3 T, based on both electrodynamic and gravitational transducers. Our MRE-capability is best in class and can be used to quantify changes of the biomechanical properties of pathologies, as is caused by fibrosis and inflammation. We have also access to a unique installation of multinuclear MR spectroscopy, allowing us to investigate both static and dynamic energy metabolism in tissues. The latter is highly facilitated by our MR-compatible MR-ergometers for quantitative cardiac and muscle research.

A full research agreement with Philips Medical Systems and Siemens Healthineers allows all possible clinical as well as critical technical research applications.

DIGITAL PATHOLOGY AND ANNOTATION

For histo-pathology CMIV has a glass scanner from Hamamatsu. The Nanozoomer 2.0HT convert glass slides into high-resolution digital data by highspeed scanning and has a capacity of scanning up to 210 glasses automatically. In addition, three workstations with touch screens are installed for annotation work.



PACS

Sectra radiology PACS is a comprehensive workstation, designed to optimize the workflow. It ensures quick and easy access to patient data and images and provides instant access to all the tools needed integrated on the desktop – including RIS and clinical applications. A number of advanced diagnostic workstations are available for clinical and research purposes.

VISUALIZATION

CMIV has its own Virtual Reality theatre with a capacity of 90 persons. The theatre is built around Barco dp4k-30L 6P Laser projector (21 000 lumens light output), with 4K resolution (4 096 Å~ 2 160). The Barco Laser 3D has a native 6-primary color-3D system. The system uses a Barco E2 Image processor, 4K Native 12 bits/color 3D input/output. The computer to screen connections are run by the Lightware mx-33R Digital Crosspoint matrix. The Wirecast 7.3 Recorder system allows recording and online streaming. During 2018 Wranne was upgraded to an advanced Zoom room enabling remote meetings and education. In addition to the theatre there is also a 55" Sectra visualization table and a wall mounted 85" Sectra visualization monitor with ten fingers multi-touch. The Visualization Table is a large interactive screen with an image display system that enables interaction with 3D human body images rendered from CT or MR.

COMPUTING AND STORAGE

CMIV maintains dedicated server facilities, ensuring secure handling of sensitive data, complex research calculations, advanced analyses, and robust NAS backup solutions. Building on our existing infrastructure, 2024 saw significant upgrades to enhance computational power and storage capacity and improve overall system resilience. We are utilizing newer, more powerful servers to handle increasingly demanding workloads. Alongside this, we have expanded our data storage capabilities, providing more space for our growing data needs. To ensure continuous operation and protect against power failures, we have installed a new, reliable power supply system for the entire infrastructure.

Infrastructure Management & Monitoring - CMIV has implemented Dell OpenManage to streamline server management and automate common tasks. To enhance system visibility and proactively identify potential issues.

Backup & Recovery - Recognizing the importance of robust data protection, we have significantly strengthened our backup and recovery capabilities. A new Veritas Backup Exec server was deployed to centralize backup operations and improve recovery times.

CMIV is the host of the AIDA
Data Hub infrastructure. In 2024, this
was extended with the Verdi system,
providing hardware for the AIDA Data
Hub Data Science Platform, supporting
both sensitive and non-sensitive data
and serves users with a wide range of
expertise. It provides CPU and GPU
compute resources, as well as long-term
primary storage with a total capacity of
3.2 PB on spinning disks and 153 TB on
solid state drives.

AIDA Data Hub also provides an Nvidia DGX-2 based system for training AI models using sensitive personal data.







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Publications

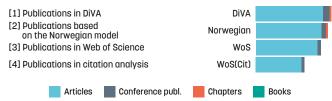
The CMIV research efforts lead to a steady stream of scientific publications. An overview of the 2024 production is given in the following pages. As papers from CMIV researchers may be primarily registered under other affiliations the listing is not complete, but still shows a good representation of CMIV. The CMIV researchers have presented their work at conferences all over the world during the year, however, conference abstracts are not included in this list unless published as a conference paper.

Bibliometric Analysis

1. Basis for analysis, 2020-2024

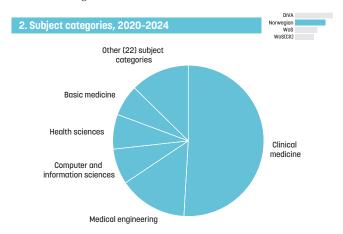
The analysis is based on sources [1]-[4], listed below. Different sources are used for different parts of the analysis. A criterion for inclusion is that publications have been registered in DiVA for the time period covered in the analysis. Publication types that are included in the analysis are:

- Refereed journal articles and reviews
- Scholarly book chapters
- Scholarly books
- Refereed conference publications



- [1] Publications in DiVA according to the selection stated above.
- [2] Publications in [1] included in the Norwegian model.
- [3] Publications in [2] indexed in Web of Science.
- [4] Publications in [3] where we have access to normalized citation data.

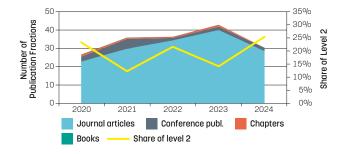
At each new section of the analysis, the symbol in the top right corner will mark the selection being used.

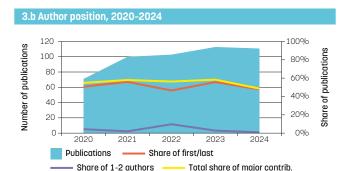


Displayed subject categories are those registered with each publication in DiVA, and are based on Standard för svensk indelning av forskningsämnen 2011 (Swedish Research Subject Standard 2011), updated 2016, SCB/UKÄ. In the compilation, subject categories at the three-digit level have been used.

3.a Norwegian model, 2020–2024						
Number of publications	Number of publication fractions	Share of level 2				
463	156.0	21%				
27	13.5	1 %				
8	3.5	0 %				
0	0.0	0 %				
	Number of publications 463 27 8	Number of publication fractions 463 156.0 27 13.5 8 3.5				

Share of level 2, total: 19 %

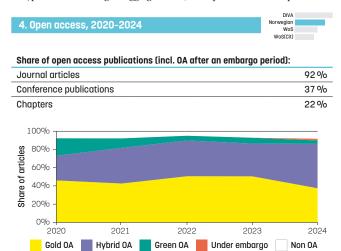




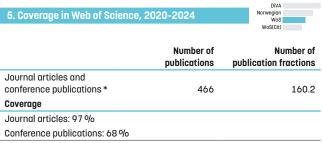
Publication fraction refers to the share of a publication originating from the department. For example, if two out of four authors are affiliated with the department, the fraction is 0.5.

In the Norwegian model, the included publication channels are divided into two levels – 1 (scientific) and 2 (scientific and leading in its field of research). Level 2 publication channels comprise a maximum of 20 percent of channels in their research field.

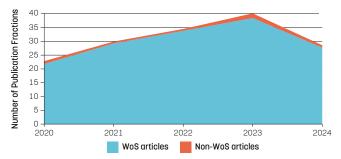
Share of level 2 refers to the share of fractionalized publications in level 2 journals/publishers. At a higher aggregate level, the expected share is 20 percent.



Open Access (OA) publications have been identified with the help of data from Unpaywall (unpaywall.org). The diagram shows articles according to Open Access type. OA data for articles has been supplemented with data from our own customized algorithm. Gold Open Access is defined as articles published in journals openly accessible in their entirety. Hybrid Open Access is defined as openly accessible articles published in subscription-based journals. Green Open Access is defined as the accepted version of articles published in online repositories.



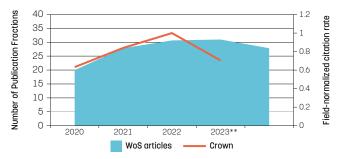
^{*}Articles, reviews, letters, proceedings papers in WoS.



The analysis is based upon Clarivate Analytics Web of Science. For a citation analysis to be relevant and reliable, a sufficient basis is required. To give an indication of the coverage of journal articles in the database, the number of publications/fractions in the database is displayed. All citation indicators are fractionalized, i.e. the number of authors affiliated with the department is taken into account. Self-citations are excluded.



Field-normalized citation rate (crown): 0.92 Share of highly cited articles (top 10 %): 9 % Share of uncited articles: 16 % Number of articles in Q1-journals (2020-2024): 177 Share of articles in Q1-journals (2020-2024): 44 %

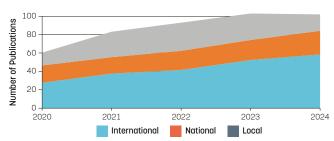


- *Articles, reviews and letters in WoS.
- **The results for last year's articles should be interpreted with great caution. The citation rate for newer articles is generally low, leading to individual items causing high impact on the average rate.

When publication fractions are less than 10, the citation indicators are not displayed. If the basis is small, individual items can have a high impact on averages.

- Field-normalized citation rate (Crown): a measure of impact of articles included in the analysis that provides a comparison with the international average for the same subject area, year and type of article, where 1 is the global average. Field normalized rate of citation is fractionalized, i.e. the number of authors affiliated with the department is taken into account. Self-citations are excluded. The average field normalized citation rate for universities in Sweden during 2016–2019 was 1.12, according to basic funding allocation data from 2021 from the Swedish Research Council.
- Share of highly cited articles (top 10 percent): share of publications in the top 10 percent of the most highly cited publications in the research subject within the time period, i.e. publications with high impact.
- Share of uncited articles: indicates how citations are distributed, i.e. if citations are evenly distributed among articles, or if a small number of articles account for the majority of citations.
- Field-normalized journal citation rate (Journal crown): A measure of impact
 of the journals chosen for publication. It provides a comparison for the average number of citations for the journals chosen for publication with the global
 average number of citations for journals in the same field. I.e, a value of 0.9
 means that the chosen journals for publication are on average cited 10% less
 than journals in the same field(s).
- SNIP: normalized journal indicator based on data from Scopus.



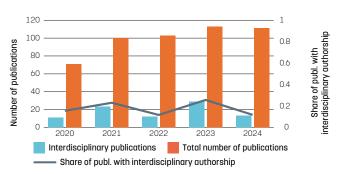


Share of publications in WoS where department authors have co-authored with international, national or local collaborators (academic as well as non-academic). Local co-authors refers to other LiU authors. This category also includes single authors. International collaborations are also displayed, since studies have shown a higher citation rate for publications that are products of such collaborations. According to the Leiden ranking for 2023, the share of international collaborations for LiU was 61.4 percent during 2018–2021, which is low compared to other universities in Sweden.

8. Interdisciplinary authorship, 2020-2024 Norwegian Was Was(Cit) Publications with interdisciplinary authorship*



*Publications with authors from more than one faculty



9. Altmetrics Policy Scientific News Open blogs media Patents documents syllabi X YouTube Wikinedia Number of referenced 0 339 publ. Share of referenced publ. 6% 11% 1% 0% 64% 1% 1% Total number of references 51 603 Q 3 0 4155 5

The analysis is based on publications in DiVA in 2020–2024 with a digital object identifier (DOI) or an ISBN. 98 % of publications have any of these identifiers.

Alternative metrics (or altmetrics) is a new way of measuring the impact of scholarly publications and shows the dissemination and impact of publications in social media and other channels.

The company Altmetric has developed tools to identify references to research publications in online channels, such as social media (blogs, Twitter, Facebook, discussion forums etc.), news media, patent databases etc. See www.altmetric. com for further information regarding methods and content.

Some publications can share identifiers (such as ISBN for individual chapters published in the same book). In such cases, all references to each publication are included.

CMIV affiliated researchers are written in bold.

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hroughout the fiscal year, CMIV was engaged in several ongoing grant-funded research projects.

One of the key initiatives, AIDA – Analytic Imaging Diagnostics Arena, supported by VINNOVA, launched nine projects, three clinical fellowships, and three evaluation projects, all funded by AIDA. Meanwhile, SciLifeLab continued and expanded its funding for the AIDA data hub.

Several major research projects continued, including:

- SCAPIS & SCAPIS2 (both funded by the Swedish Heart-Lung Foundation)
- EUCAIM (EU Digital Europe Programme & VINNOVA)
- Bigpicture (EU Horizon 2020)
- Incubator for National AI Validation Platforms in Diagnostic Imaging (VAI-x) (VINNOVA)

- ASHA "Using Standardized Health Data as an Accelerator to Strengthen Future Healthcare" (funded by VINNOVA and the Vice-Chancellor's strategic initiatives)
- Focus Area: Data-Driven Health and Health Care (VINNOVA)

Additionally, two new projects were launched in 2024:

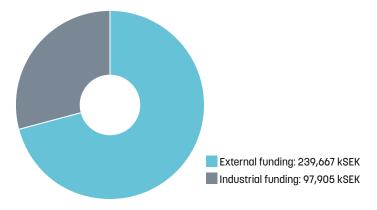
- MeDigiT4 (funded by Visual Sweden)
- Precision Panorama (funded by LiU Cancer)

CMIV continued to receive support from the Faculty of Medicine and Health Sciences and the Faculty of Science and Engineering for its research and work in digital pathology. Region Östergötland also maintained its support for research on the photon-counting detector.

ECONOMIC SUMMARY	2020	2021	2022	2023	2024
Total revenue	55,007	57,384	58,794	58,306	57,516
EXPENSES					
Staff expenses	-22,480	-23,660	-23,907	-23,973	-24,619
Cost of premises	-6,647	-6,474	-6,372	-6,727	-11,030
Misc. Operating expenses	-17,928	-19,551	-20,489	-22,667	-21,857
Depreciation expenses	-7,848	-6,878	-6,897	-4,564	-4,603
Financial expenses	-11	-4	-10	-685	-668
Total expenses	-54,913	-56,568	-57,675	-58,616	-62,776
Result of operations	95	815	1,119	1,119	-5,260

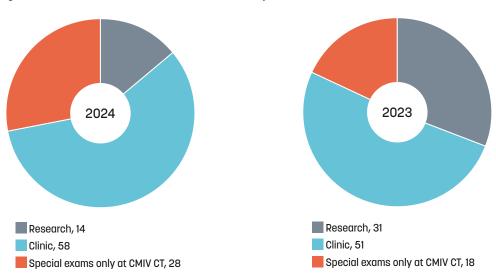
Research funding at CMIV 2010–2024

CMIV receives funding from research organizations and industry, both for the R&D platform and for specific research projects. Additionally, affiliated researchers secure their own funding; however, these grants are not included here.



CT Research and Clinic (%)

All data deriving from clinical exams on the CMIV's CTs may also be used for research in accordance with ethical permits from the Swedish Ethical Review Authority.



Distribution of Research on the MR Scanners (%)

