ProCardio Center for Innovation

Norwegian Centre for Research-based Innovation

# PRECISION HEALTH CENTER FOR OPTIMIZED CARDIAC CARE

## Annual Report 2023


OSLO UNIVERSITETSSYKEHUS


UiO : University of Oslo


SØRLANDET SYKEHUS


NTNU
Norwegian University of
Science and Technology


Baker
HEART & DIABETES INSTITUTE


simula


DIPS


GE HealthCare


Medtronic


sesam

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# SUMMARY

Dear colleagues, partners, and friends.

Our third year as ProCardio was successful. We have worked on our projects with engagement and skills, and we achieved considerable results in 2023. Thank you to every single one of you.

Twelve new talented members joined ProCardio in 2023. This is more than ever. Siri Holm Solberg started as our new center coordinator. We welcomed five new PhD/Postdoc fellows (Bendik Skinningsrud, Cecilie Bugge, Sigrun Ådnegard Skarstad, Jireh Tang and Nikhil Arora), three study nurse/research assistants (Roger Håland, Ashay Singh and Daniel Haas), and Nickolas Forsch, Morgan Jakobsen and Tormod Selbakk joined us from Simula, GEHC and CVUS respectively. Warmest welcome to all.

In 2023, ProCardio published 47 scientific papers and had 77 scientific communications/abstracts. These are impressive numbers.

Center PhD fellows Eivind Westrum Aabel successfully defended his PhD theses during 2023, and he was celebrated accordingly. Congratulations and thanks for your great work for ProCardio.

We had two meetings for all ProCardio Center members. First, the spring workshop in March, which this time was in Simula's offices in central Oslo. It is great to see our partners working environment. In September, we had our "traditional" meeting at Holmen Fjordhotell. Both events were well attended, and we again concluded that this is the way to bring collaboration to the next level. We attended international conferences with EHRA in Barcelona and ESC in Amsterdam as important examples. ProCardio members were active with abstracts, presentations, networking, and learning.

Thank you all, together we are enriching ProCardio. I look forward to a continued productive, exciting, and joyful collaboration.

*Director Kristina Haugaa*

# OBJECTIVES AND RESEARCH PLANS

The center was established to create a clinically driven, validated ICT platform for cardiology that will enable a major change in individualized healthcare, providing the best possible treatment and risk prevention by using big data and artificial intelligence. Based on leading edge research, this platform will facilitate fusion and analysis of rich and diverse data, integrating a wealth of available information into the workflow of clinical cardiology, and tailor individual care to prevent over- and under-treatment.

The most substantial impact of the ProCardio on Norwegian and European societies will be its impact on healthcare. In spite of recent advances leading to decreased mortality rates, cardio vascular disease remains the most common cause of death in Norway accounting for more than one in four deaths.

The envisioned uptake of ProCardio tools will have substantial impact for individual patients with metrics such as cost per Quality Adjusted Life Year gained. Even more important, these improvements will benefit patients by

1) improved selection criteria

2) individually optimized treatment

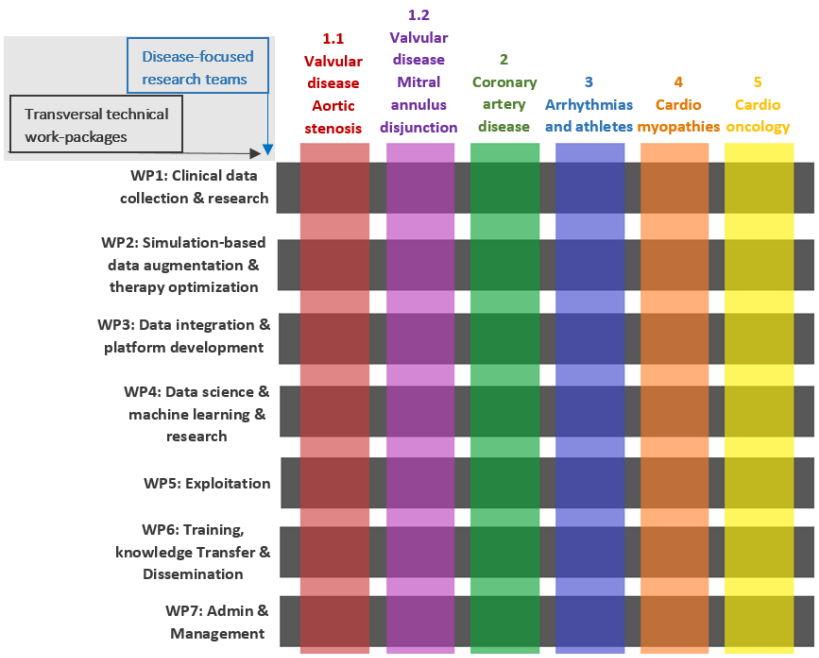
3) more accurate follow-ups

4) reduced hospitalization stays and procedures

5) personalized advise on health bringing activities e.g. exercise

ProCardio will have governing structures and operating mechanism that will guarantee a targeted effort to produce results that can be exploited by the partners and lead to value creation in Norway, through the engaged industrial end-users. The center is also strongly in line with the strategies of research partners (NTNU, SRL, UiO, OUS) who are all member of the NHT cluster. OUS director of Innovation is invited as part of the management team to ensure continuous focus on innovations. Lastly, clinical partners participating in ProCardio will benefit from sizeable value pools from more effective cardiac care.

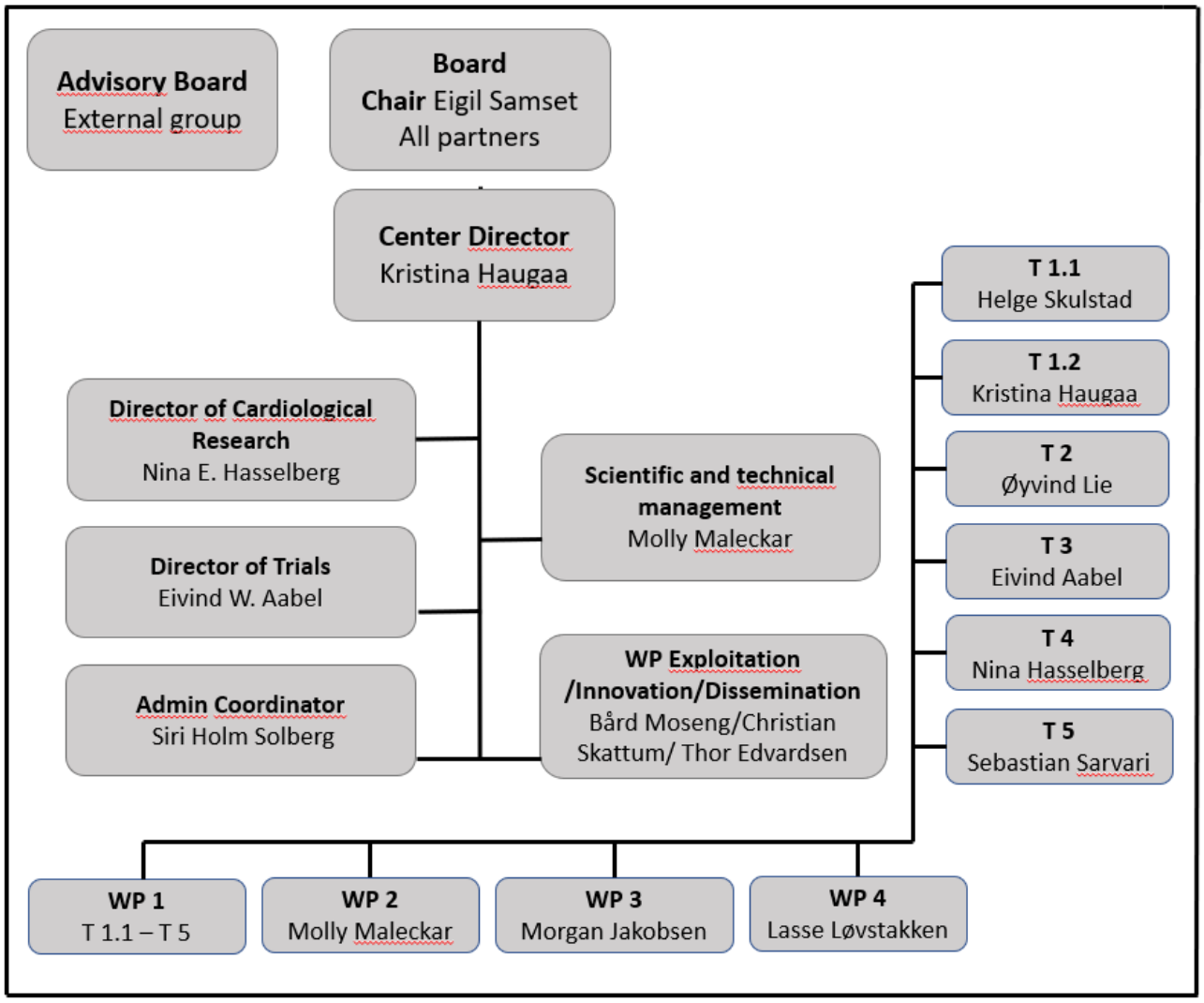
In order to foster an application-driven mindset and to uncap technical synergies across ongoing projects, ProCardio methodology was designed to focus on a bidimensional approach concept of having “vertical” research teams focusing on a target cardiac disease while the technical work will be coordinated “horizontally” to enable crosspollination of breakthroughs and integration of knowledge in a single platform. Lastly, common management, coordination and knowledge-transfer mechanisms will work across the entire center.



# ORGANISATION

ProCardio is hosted by Oslo University Hospital. In addition to the host institution, the consortium consists of ten partners from both research and industry. ProCardio is located at the Oslo University Hospital, Rikshospitalet, with the physical hub located at Domus Medica (DM4/The University of Oslo) at Sognsvannveien 9 (entrance from Gaustadalléen 34).

The center director, Kristina Haugaa, is responsible for the center management. She is assisted by the management team. Each clinical task group (T) is lead by clinical research and innovation deputies, liaising with WP leaders which ensures transversal synchronization of technical work among the different teams. Task group leaders are Helge Skulstad (T1.1), Kristina Haugaa (T1.2), Øyvind Lie (T2), Eivind Westrum Aabel (T3), Nina Hasselberg (T4) and Sebastian Sarvari (T5). In parallel exploitation, dissemination and innovation activities will be supervised by designated managers, Bård Moseng (GEVU), Thor Edvardsen (UiO) and Christian Skattum, our representative from OUS Dept. of Innovation. Dr. Mary Maleckar from SRL acts as a Scientific & Technical Manager coordinating the work of the technical teams. Siri Holm Solberg functioned as Administrative Coordinator.



# BOARD OF DIRECTORS

ProCardio is governed by a Board of Directors, for which representatives have been appointed by each of the partners. The Board comes together twice a year to discuss the Center's development, financial aspects, and administrative issues. Many of the board members participate actively in the Center's research activity and their expertise is of uttermost importance for the development of future technology within ProCardio. The Center's Board of Directors consists of the following members appointed by the consortium participants:

- Eigil Samset, GE Healthcare, Chair
- Bjørn Bendz, OUS
- Axel Borge, Sesam
- Liv Bollvåg, DIPS
- Mirco de Melis, Medtronic
- Rune Wiseth, NTNU
- Jan G. Bjålie, UiO
- Samuel Wall, Simula
- Bård Moseng, GE Vingmed
- Harald Brunvand, Sørlandet Sykehus HF
- Tom Marwick, Baker Institute

# PARTNERS

The ProCardio Center for Innovation is comprised of 11 partners with OUS being the host partner. Each partner represents a unique and required element in the research and development chain leading to the industrial innovations targeted by ProCardio.

OSLO UNIVERSITETSSYKEHUS

**Partner name:** Oslo University Hospital

**Knowledge:** 1) Dept of Cardiology at OUS is the largest interventional department in the Nordic countries with more than 4100 PCIs and 1600 ablations every year, 2) Front line cardiac research player and world-class clinical expertise; 3) hosted the SFI Center of Cardiological Innovation, which was a highly successful SFI

**Resources:** a) Infrastructures to host the ProCardio center, b) administrative support towards daily run of the center, c) image and EMR data (>1000 patients)

UiO : University of Oslo

**Partner name:** University of Oslo

**Knowledge:** 1) Oldest and largest research and educational institution in medicine in Norway, 2) K.G. Jebsen Centre for Cardiac Research is a global reference in the field of cardiology, combining outstanding PIs with an extensive international network of research partners

**Resources:** a) PhD training for OUS-hosted researchers

Baker
HEART & DIABETES INSTITUTE

**Partner name:** The Baker Heart and Diabetes Institute

**Knowledge:** 1) Outstanding diabetes & cardiac research center, with global visibility, contributing to ProCardio with strong complementary expertise in the field of cardio-oncology

**Resources:** a) Extensive clinical database of multi-modal data

**Partner name:** Norwegian University of Science and Technology

**Knowledge:** 1) Acknowledged as a SFI center for Innovative Ultrasound Solutions (CIUS); 2) Extensive know-how on medical imaging technology, in particular ultrasound; 3) expertise in artificial intelligence and machine learning algorithms; 4) Centre of excellence for translational medical research at the interface of epidemiology, genetics, statistics, bioinformatics and systems biology

**Resources:** a) Extensive databases with follow up echocardiographic studies and outcome data; b) Computational infrastructure to train and run resource-intensive AI algorithms; c) Databases on genetic markers to be coupled with cardiac imaging in HUNT database and its digital infrastructure, and also a substantial number of other omics data such as NMR-based metabolomics, CVD related protein arrays, transcriptomics and other targeted protein biomarkers.

**Partner name:** Sørlandet Hospital HF

**Knowledge:** 1) Leading clinical and experimental research expertise in the area of myocardial function; 2) Extensive hands-on experience on clinical trials to assess new diagnostic technologies and therapies (e.g. we established the IMPROVE study)

**Resources:** a) image data and EMR data (>2000 patients); b) inclusion of cardiac patients with heart failure and myocardial infarction in ongoing and future research projects.

**Partner name:** Simula Research Laboratory AS

**Knowledge:** 1) Host of several SFF, SFI, and EU networks focused on excellence in biomedical computing and computing in cardiology, 2) Mathematical growth models for cardiac physiology, growth, and remodeling, 3) data-driven models and analysis for risk prediction; 4) Computational Cardiology Models for biophysical simulation

**Resources:** a) Access to large computational cluster facilities for training and deployment of resource-intensive algorithms and models

**Partner name:** Medtronic Inc

**Knowledge:** 1) World's largest medical technology company, offering a large breadth and depth of innovative therapies, including forefront treatments for cardiac and vascular diseases; 2) extensive expertise in clinical trial protocol development and implementation; 3) VBHC approaches for therapy optimization and chronic care programs; 4) Manufacturing of devices (both for delivering therapies as well for diagnostic purposes (sensors)

**Resources:** a) access to state-of-the-art medical devices; b) capable of designing and building custom-made devices addressing the needs of individual or groups of patients according to the specifications provided by a physician/project.

**Partner name:** GE Healthcare and GE Vingmed Ultrasound

**Knowledge:** 1) World class design and manufacturing of diagnostic imaging and monitoring systems; 2) Extensive expertise in cardiology diagnostics, artificial intelligence development for imaging and waveforms 3) Deep market understanding 4) GE's center of excellence on ultrasound engineering; 5) World-class know-how in cardiovascular ultrasound acquisition, processing and analysis, speckle-tracking and strain imaging, artificial intelligence in ultrasound, 3D visualization and quantification; 6) Extensive insight on regulatory requirements and ultrasound market intelligence

**Resources:** a) Fast-track integration of innovations into commercial products and application to other imaging modalities beyond ultrasound b) provide ultrasound equipment and software to the center to ensure successful execution of clinical projects and data acquisition.

**Partner name:** DIPS AS

**Knowledge:** 1) Leading supplier of patient electronical medical records software solutions to Norwegian hospitals; 2) Expertise in eHealth, data integration activities and IT platform development

**Resources:** a) access to DIPS Arena - a fully integrated patient record system including closed loop medication, charting, booking and planning, electronic document workflow, CPOE, multimedia and reporting.

**Partner name:** Sesam AS

**Knowledge:** 1) Development of GDPR compliant data management solutions; 2) Data privacy expertise; 3) Creation of interfaces and standards for sharing of data in of Health analytics

**Resources:** a) access to the Sesam Data Integration Hub Platform-as-a-service, via an in-kind platform subscription; b) consulting services around architecture, along with assistance to connect data sources, transforming data and delivering data where it is needed.

# COOPERATION BETWEEN PARTNERS

The partners at ProCardio bring key competences to the joint projects, enabling everyone in ProCardio to effectively pursue the collective goals. To ensure effective dissemination of management goals and coordination of efforts among the partners, an integrated meeting schedule has been established. This includes weekly meetings within individual project teams, biweekly meetings among management and PhD-students, and bimonthly meetings among T- and WP-leaders. The supervisory board meets bi-annually, in sync with the planned training and dissemination workshops.

ProCardio holds two annual workshops, one in the spring and one in the fall, focusing on innovation, research and collaboration.

## Spring workshop March 14th.

The spring workshop, hosted by Simula on March 14th, featured a presentation by Inven2 on the innovative path and the significance of product development. Inven2 provided insights into the functioning of a technology transfer office and the process of submitting disclosures of inventions (DOFIs) to Inven2. Center innovation manager, Christian Skattum, outlined the various types of innovations occurring in a hospital setting. Following this, participants were grouped and tasked with presenting a DOFI. The workshop showcased numerous excellent proposals and the best idea was recognized.

## Fall workshop September 14th- 15th.

The ProCardio Fall meeting took place at Holmen Fjord Hotel, featuring project updates from all partners and subsequent group work sessions. The event also included an update on funding opportunities by the Research Counsil of Norway, valuable insights into natural language processing by DIPS and the latest advances in artificial intelligence by NTNU. The meeting facilitated collaborative workshops in the area of NLP, AI models in Echo/CVI, DCM (planning RCT), high frame rate ultrasound, automatic detection of MVP and NeuECG. Additionally, the highly competitive quiz competition remains a time-honored tradition at the event.

# SCIENTIFIC ACTIVITIES AND RESEARCH

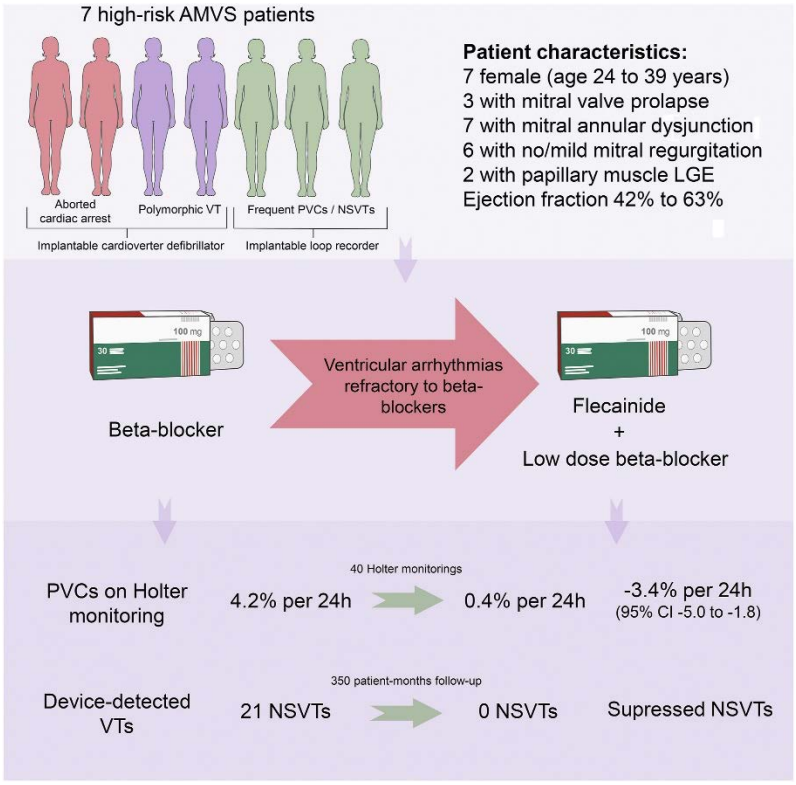
## Flecainide in patients with arrhythmic mitral valve syndrome: A case series

*Aabel EW, Dejgaard L, Chivulescu M, Helle-Valle T, Edvardsen T, Hasselberg NE, Hegbom F, Lie ØH, Haugaa KH*

Patients with arrhythmic mitral valve syndrome are at risk of ventricular arrhythmias, including premature ventricular complexes (PVC) and non-sustained ventricular tachycardias (NSVT). There is no established medical therapy to suppress ventricular arrhythmias other than conventional betablocker therapy, which is often unsuccessful and not evaluated in randomized controlled trials.

In our retrospective case series, we used additional flecainide therapy in 7 high-risk arrhythmic mitral valve syndrome patients with ventricular arrhythmias unresponsive to beta-blockers alone. Patients were monitored continuously by implantable cardioverter defibrillator or implantable loop recorder. Results showed 21 NSVT during 90 patient-months on betablocker alone, and 0 NSVT during 250 patient-months with added flecainide. Holter monitoring revealed a 3.4 % absolute reduction in PVC burden with flecainide. Flecainide did not exacerbate arrhythmia burden in any patient.

We concluded that adding flecainide to betablocker therapy may effectively treat ventricular arrhythmias in high-risk patients with arrhythmic mitral valve syndrome.



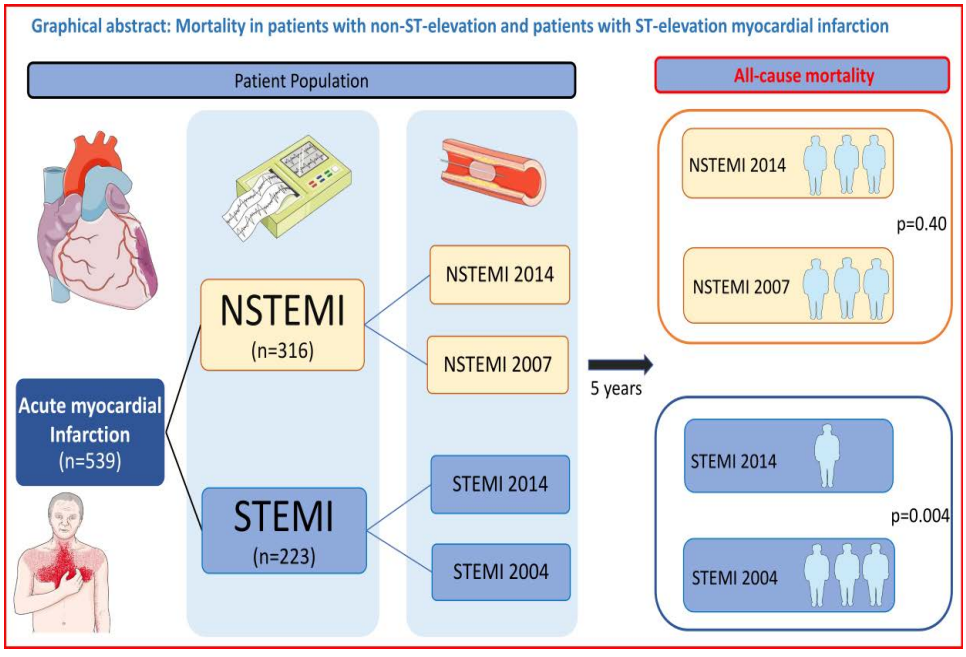

*Graphical abstract from the published article in the high impact journal Heart Rhythm (doi: 10.1016/j.hrthm.2022.12.024).*

# Mortality in patients with acute coronary syndrome – a prospective 5-year follow-up study

*Nguyen TM, Melichova D, Aabel EW, Lie Ø, Klæboe LG, Grenne B, Sjøli B, Brunvand H, Haugaa KH, Edvardsen T*

Outcomes among patients presenting with ST–elevation myocardial infarction (STEMI) have improved markedly during the last two decades because of a combination of improved prehospital triage, early invasive revascularization with percutaneous coronary intervention (PCI), and aggressive secondary preventive treatment strategies. However, short- and long-term outcomes have not improved in patients with non-ST-segment elevation myocardial infarction (NSTEMI) at the same rate seen in STEMI patients. There are limited contemporary data comparing long-term follow-up after revascularization the last decades. Our objective was to compare long-term outcomes in patients with NSTEMI and STEMI between two time periods. This prospective follow-up study consecutively included a total of 539 patients, both NSTEMI and STEMI during two time periods, 2014-2015 and 2004-2009. The primary outcome was all-cause mortality and patients were followed up for a period of 5 years.

The main finding of our study was that after one decade of AMI treatment, mortality in patients with NSTEMI remained unchanged while mortality in STEMI patients decreased. Possible reasons for improvement of outcomes in STEMI patients are due to reduction in ischemic time and optimal medical therapy. Occurrence of reinfarction and heart failure rehospitalizations in STEMI patients decreased, while the rate of reinfarction in NSTEMI patients remained unchanged. The findings in our study supports further appropriate selection of NSTEMI patients at risk for immediate revascularization may potentially improve long-term mortality.



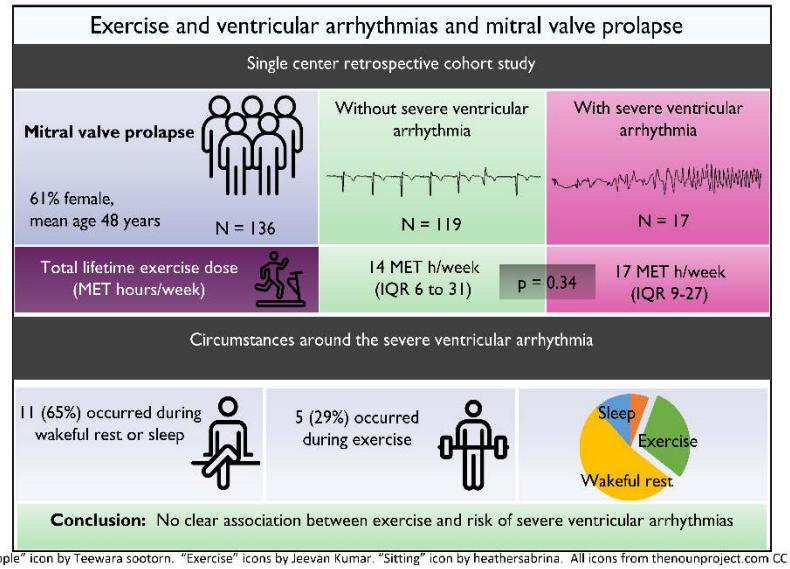

*The study patients were part of a prospective, observational, multicentre sub-study of the Norwegian IMPROVE study and was published October 2023 in Journal of Clinical Medicine, JCM/MDPI.*

# Lifetime exercise dose and ventricular arrhythmias in patients with mitral valve prolapse

*Five CF, Hasselberg NE, Aaserud LT, Castrini I, Vlaisavljevic K, Lie Ø, Rootwelt-Norberg C, Aabel EW, Haugaa KH*

Patients with mitral valve prolapse (MVP) have high risk of life-threatening ventricular arrhythmias (VA). Data on the impact of exercise on arrhythmic risk in these patients is lacking. We explored whether lifetime exercise dose was associated with severe VA and with established risk factors in patients with MVP. Furthermore, we explored the circumstances at the VA event.

In this retrospective cohort study, we included patients with MVP and assessed lifetime exercise dose as metabolic equivalents of task (MET)hours/week. Severe VA was defined as sustained ventricular tachycardia or fibrillation, aborted cardiac arrest, and appropriate shock by a primary preventive ICD.




"People" icon by Teewara sootorn. "Exercise" icons by Jeevan Kumar. "Sitting" icon by heathersabrina. All icons from thenounproject.com CC BY 3.0

We included 136 MVP patients (48 years [IQR 35-59], 61% female) and 17 (13%) had previous severe VA. The lifetime exercise dose did not differ in patients with and without severe VA (17MET hours/week [IQR 9-27] vs. 14MET hours/week [IQR 6-31], p=0.34). Lifetime exercise dose >9.6MET hours/week was a borderline significant marker for severe VA (OR 3.38, 95% CI 0.92-12.40, p=0.07), while not when adjusted for age (OR 2.63, 95% CI 0.66-10.56, p=0.17). VA events occurred most frequently during wakeful rest (53%), followed by exercise (29%) and sleep (12%).

We found no clear association between moderate lifetime exercise dose and severe VA in patients with MVP. We cannot exclude an upper threshold for safe levels of exercise. Further studies are needed to explore exercise and risk of severe VA.

*This study was published in the renowned journal Europace on 18th October 2023.*

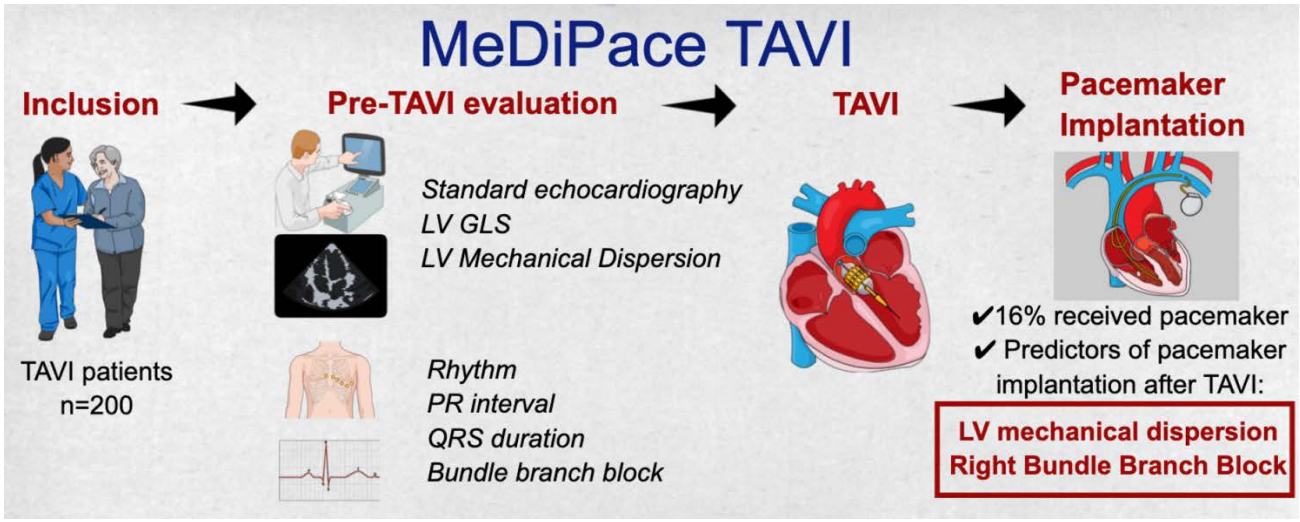
# Left Ventricular Mechanical Dispersion as a Predictor of need for Pacemaker implantation after TAVI
# The MeDiPace TAVI STUDY

*Kaya E, Andresen K, Lie ØH, Aaberge L, Haugaa KH, Edvardsen T, Skulstad H*

Conduction disturbances that require permanent pacemaker (PM) implantation are common after TAVI. Left ventricular (LV) mechanical dispersion by speckle tracking echocardiography is a marker of fibrosis, which can cause alterations in the conduction system. We hypothesized that LV mechanical dispersion can be a predictor of need for PM implantation after TAVI.

In this study, we consecutively enrolled 200 TAVI patients. Transthoracic echocardiography and electrocardiography examinations were recorded before TAVI to evaluate global longitudinal strain (GLS), LV mechanical dispersion and conduction disturbances. After TAVI, we collected the PM implantation information to detect the factors that are associated with it and tried to find the predictors of PM implantation. We found that LV mechanical dispersion predicted the need for PM after TAVI independently of GLS, QRS duration, RBBB and first-degree AV block. We also built a compound model of LV mechanical dispersion and RBBB to find the incremental predictive value of LV mechanical dispersion over RBBB.

The preliminary data was presented in the spring meeting of Norwegian society of cardiology in 2022 and was awarded with the best abstract prize. It was also presented in ESC 2022. Finally the study is published in the high impact journal Eur Heart J Cardiovascular Imaging in November 2023. We have also conducted a follow-up study on the same patient group, which is also soon to be submitted to relevant journals for publication.




*Graphical abstract from the journal EHJ-CVI. (DOI: 10.1093/ehjci/jead315)*

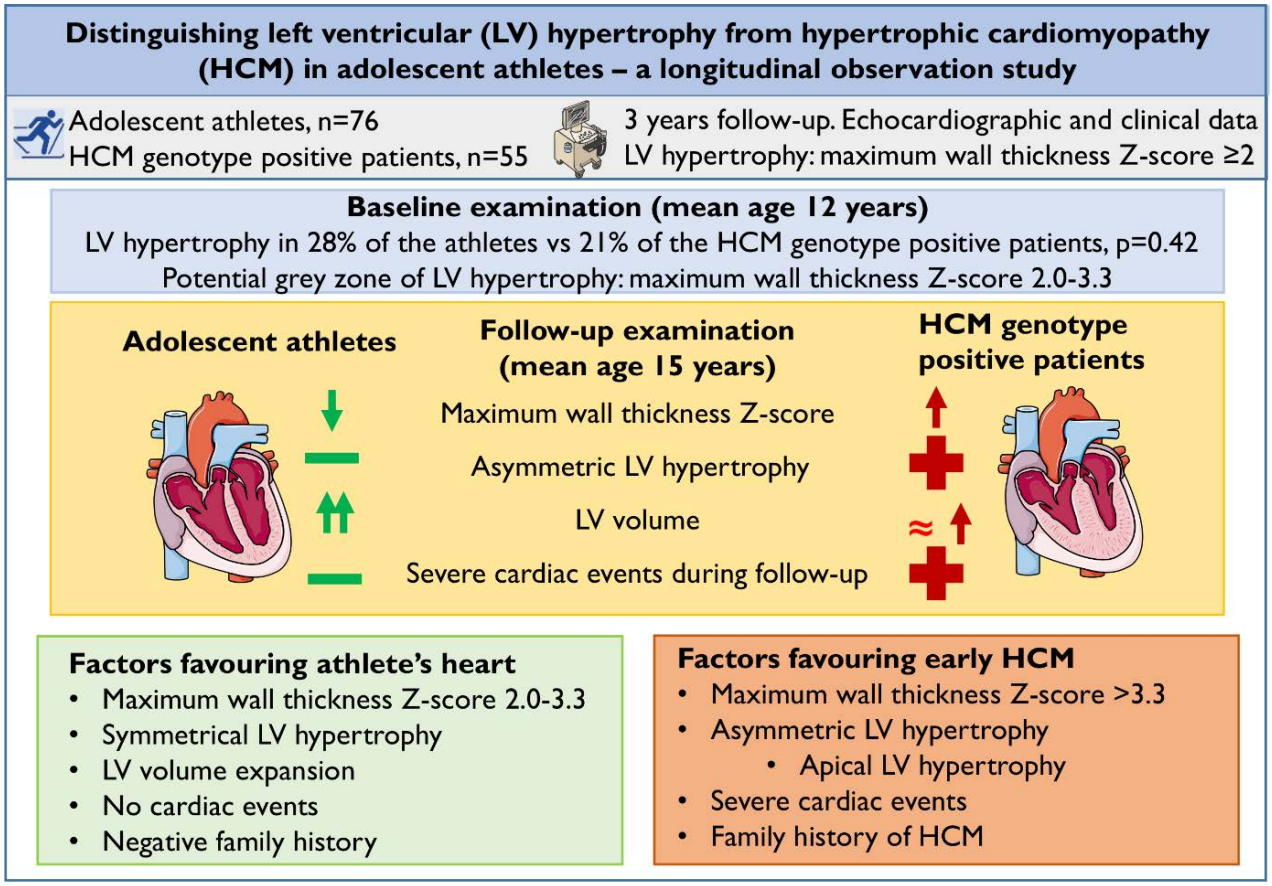
# Distinguishing left ventricular hypertrophy from hypertrophic cardiomyopathy in adolescents: a longitudinal observation study

*Forså MI, Smedsrud MK, Haugaa KH, Bjerring AW, Früh A, Sarvari SI, Landgraff HW, Hallén J, Edvardsen T*

Distinguishing exercise-induced cardiac left ventricular (LV) hypertrophy from hypertrophic cardiomyopathy (HCM) is important, as athletes with HCM may have an increased risk of sudden cardiac death. There is a lack of data on this distinction in adolescent athletes. We therefore performed a longitudinal observation study where we used echocardiography to compare development of LV hypertrophy during adolescence in 76 athletes and 55 HCM genotype positive patients. The study aimed to explore the phenotype, progression, and potential grey zone of LV hypertrophy. We used paediatric reference values (Z-scores) to evaluate echocardiographic parameters.

We found LV hypertrophy in a similar proportion of athletes and HCM patients in early adolescence. LV hypertrophy progressed only in the HCM genotype positive patients. We identified a potential grey zone of LV hypertrophy ranging from septum thickness Z-score 2.0-3.3. Athletes had larger LV volumes throughout the study period. Our results indicate that evaluating progression of wall thickness and volume may help clinicians distinguish physiological LV hypertrophy from early HCM.

The article was published in the high impact journal European Journal of Preventive Cardiology. An abstract was presented at the EACVI Congress in Barcelona in May 2023 and at the Norheart Symposium in Oslo in August 2023.




*Graphical abstract from the published article.* [https://doi.org/10.1093/eurjpc/zwad361](https://doi.org/10.1093/eurjpc/zwad361)

# Echocardiographic Reference Ranges of Global Longitudinal Strain for All Cardiac Chambers Using Guideline-Directed Dedicated Views

*Nyberg J, Jakobsen EO, Østvik A, Holte E, Stølen S, Lovstakken L, Grenne B, Dalen H.*

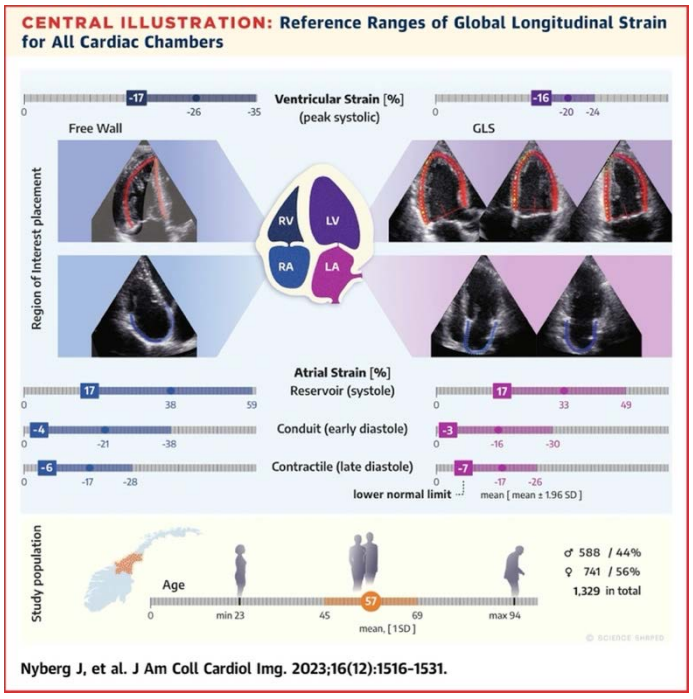
Myocardial deformation by echocardiographic strain imaging is a key measurement in cardiology, providing valuable diagnostic and prognostic information. The aim of this study was to establish echocardiographic reference ranges, including lower normal limits of global strains for all 4 cardiac chambers from a large healthy population and to evaluate the influence of subject-specific characteristics on strain.

In total, 1,329 healthy participants from HUNT4Echo, the echocardiographic substudy of the 4th wave of the Trøndelag Health Study, were included. Echocardiographic recordings specific for each chamber were optimized according to current recommendations. Two experienced sonographers recorded all echocardiograms using GE HealthCare Vivid E95 scanners. Analyses were performed by experts using GE HealthCare EchoPAC.

The reference ranges for left ventricular (LV) global longitudinal strain and right ventricular free-wall strain were −24% to −16% and −35% to −17%, respectively. Correspondingly, left atrial (LA) and right atrial (RA) reservoir strains were 17% to 49% and 17% to 59%. All strains showed lower absolute values with higher age, except for LA and RA contractile strains, which were higher. The feasibility for strain was overall good (LV 96%, right ventricular 83%, LA 94%, and RA 87%). All chamber-specific strains were associated with age, and LV strain was associated with sex.

Reference ranges of strain for all cardiac chambers were established based on guideline-directed chamber-specific recordings. Age and sex were the most important factors influencing reference ranges and should be considered when using strain echocardiography.

*Activity completed, link: https://www.jacc.org/doi/full/10.1016/j.jcmg.2023.08.011*



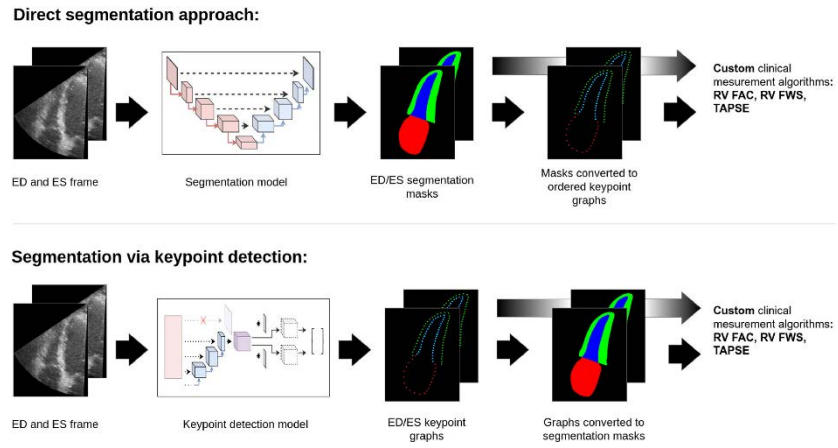
# Automated Segmentation and Quantification of the Right Ventricle in 2-D Echocardiography

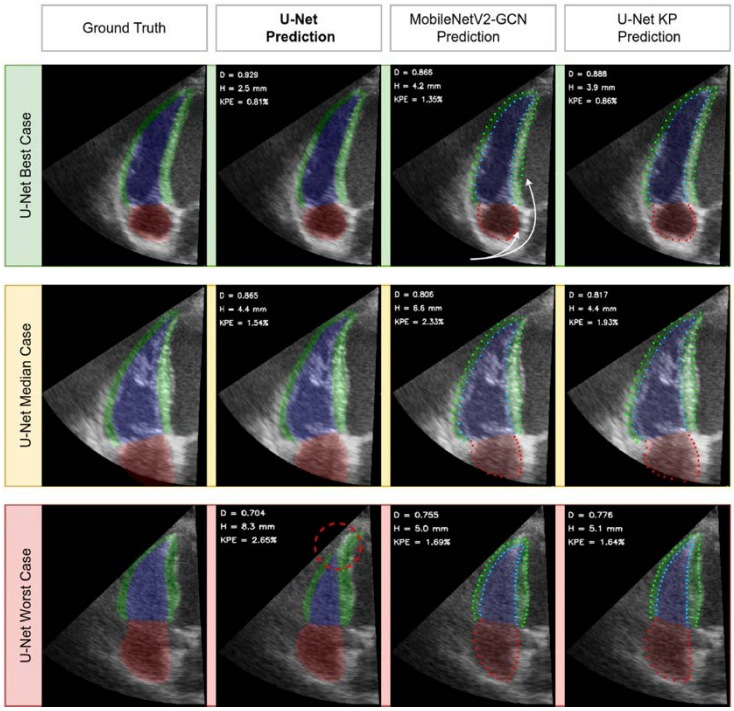
*Chernyshov A, Grue JF, Nyberg J, Grenne B, Dalen H, Aase SA, Østvik A, Lovstakken L*

In the work described we developed deep learning methods for automated segmentation and extraction of key clinical paremeters from the right ventricle. In particular, we explored a keypoint detection approach to segmentation that guards against erratic behavior often displayed by current segmentation models.

We used a data set of echo images focused on the right ventricle from 250 participants to train and evaluate several deep learning models. We proposed a compact architecture (U-Net KP) employing the keypoint approach, designed to balance high speed with accuracy and robustness. All featured models achieved segmentation accuracy close to the inter-observer variability. When computing the metrics of right ventricular systolic function from contour predictions of U-Net KP, we obtained the bias and 95% limits of agreement of 0.8 ± 10.8% for the right ventricular fractional area change measurements, –0.04 ± 0.54 cm for the tricuspid annular plane systolic excursion measurements and 0.2 ± 6.6% for the right ventricular free wall strain measurements. These results were also comparable to the semi-automatically derived inter-observer discrepancies of 0.4 ± 11.8%, –0.37 ± 0.58 cm and –1.0 ± 7.7% for the aforementioned metrics respectively.

In conclusion, given the appropriate data, automated segmentation and quantification of the right ventricle in 2-D echocardiography proved feasible with existing methods. Further, keypoint detection architectures may offer higher robustness and information density for the same computational cost.

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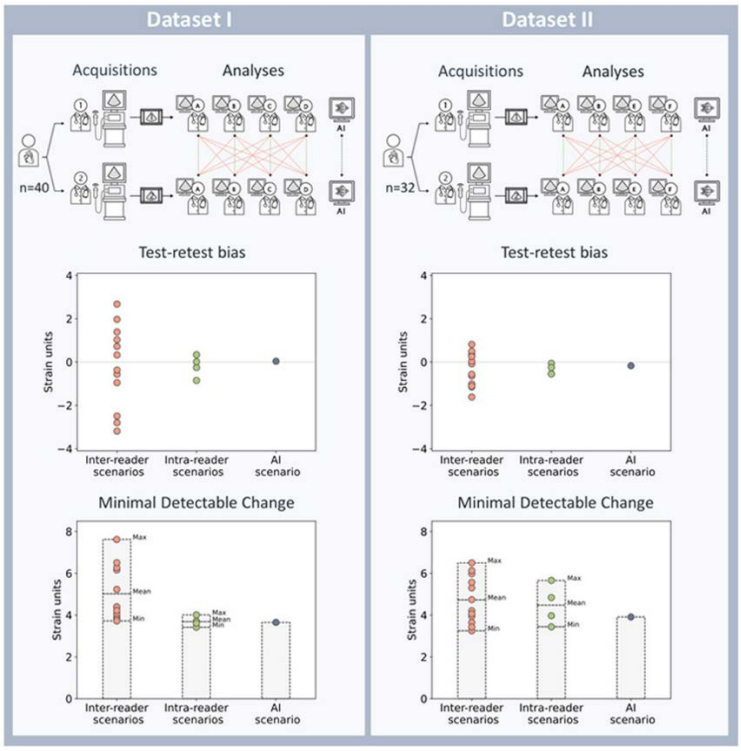
https://doi.org/10.1016/j.ultrasmedbio.2023.12.018

# Deep Learning for Improved Precision and Reproducibility of Left Ventricular Strain in Echocardiography: A Test-Retest Study

*Salte IM, Østvik A, Olaisen SH, Karlsen S, Dahlslett T, Smistad E, Eriksen-Volnes TK, Brunvand H, Haugaa KH, Edvardsen T, Dalen H, Lovstakken L, Grenne B.*

Assessment of left ventricular (LV) function by echocardiography is hampered by modest test-retest reproducibility. We developed a novel artificial intelligence (AI) method based on deep learning whch provides fully automated measurements of LV global longitudinal strain (GLS) and may improve the clinical utility of echocardiography by reducing user-related variability.




The aim of this study was to assess within-patient test-retest reproducibility of LV GLS measured by the novel AI method in repeated echocardiograms recorded by different echocardiographers and to compare the results to manual measurements.

Two test-retest data sets (n = 40 and n = 32) were obtained at separate centers. Repeated recordings were acquired in immediate succession by 2 different echocardiographers at each center. For each data set, 4 readers measured GLS in both recordings using a semiautomatic method to construct test-retest interreader and intrareader scenarios.

Activity completed, link: https://doi.org/10.1016/j.echo.2023.02.017

Agreement, mean absolute difference, and minimal detectable change (MDC) were compared to analyses by AI. In a subset of 10 patients, beat-to-beat variability in 3 cardiac cycles was assessed by 2 readers and AI. Test-retest variability was lower with AI compared with interreader scenarios (data set I: MDC = 3.7 vs 5.5, mean absolute difference = 1.4 vs 2.1, respectively; data set II: MDC = 3.9 vs 5.2, mean absolute difference = 1.6 vs 1.9, respectively; all $P < .05$). There was bias in GLS measurements in 13 of 24 test-retest interreader scenarios (largest bias, 3.2 strain units). In contrast, there was no bias in measurements by AI. Beat-to-beat MDCs were 1.5, 2.1, and 2.3 for AI and the 2 readers, respectively. Processing time for analyses of GLS by the AI method was 7.9 ± 2.8 seconds.

In conclusion, our fast AI method for automated measurements of LV GLS reduced test-retest variability and removed bias between readers in both test-retest data sets. Thus, by improving the precision and reproducibility, AI may increase the clinical utility of echocardiography.

# Mitral annual disjunction and arrhythmias: insights from left ventricular shape analysis

*Monopoli G, Aabel EW, Ribe M, Castrini AI, Hasselberg N, Haugaa K, Forsch N, Balaban G, Maleckar MM*

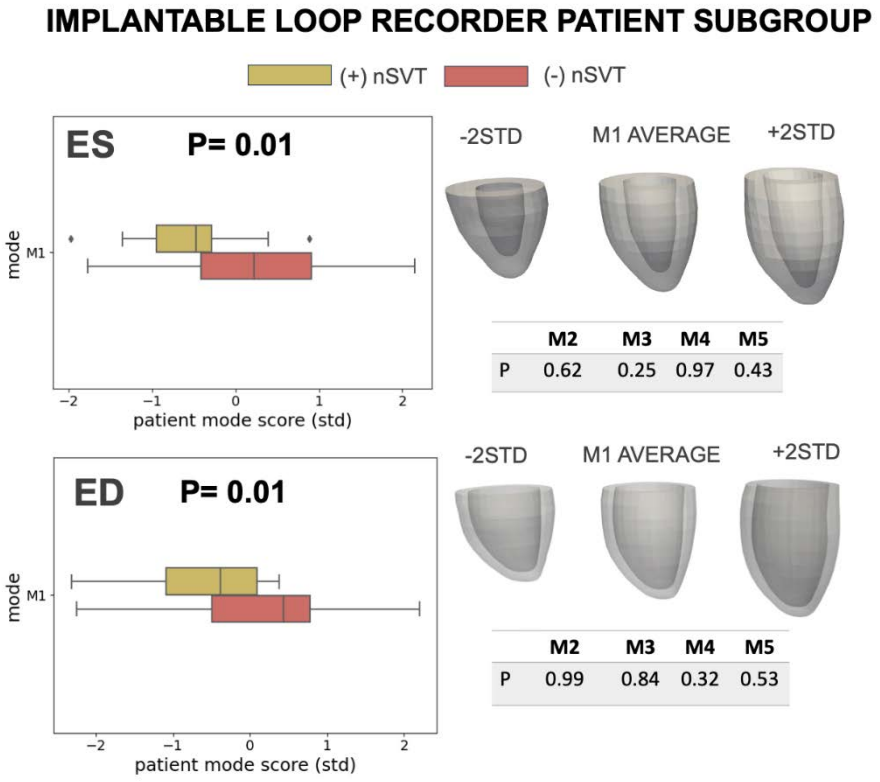
Background. Mitral annular disjunction (MAD) is a structural variation of the heart valve, characterized by an abnormal separation between the posterior mitral leaflet and the atrial wall. Although it is commonly found in the general population, MAD has been linked to arrhythmic events.

Motivation. Abnormal motion of the basolateral left ventricular wall during systole is thought to lead to morphofunctional remodelling, potentially promoting arrhythmogenesis.

Methods. Our study investigates the association between MAD and arrhythmias by performing statistical shape analysis on 3D geometries of the left ventricle (LV) at both end diastole (ED) and end systole (ES) using a custom pipeline. *Data:* Short-axis CMR scans of 78 patients from Oslo University Hospital with arrhythmia outcomes, including patients with implantable loop recorders (ILR). Statistical Analysis: Principal component analysis to generate modes of variation. Statistical analysis to compare differences in LV shape modes between patients with (+) and without (-) non-sustained ventricular tachycardia (nSVT) from ILR (16 and 28 patient, respectively) and between those without (-) (n= 52) and with (+) a history of aborted cardiac arrest (ACA) (n=9).

Results. There are statistically significant differences in both shape modes 1 and 3 in (+) nSVT patients (Figure) as compared to patients without recorded nsVT.

Conclusions. 1.Our study unveils potential biomarkers linked to vulnerability in MAD patients.2. It paves the way for future motion tracking research in this context.



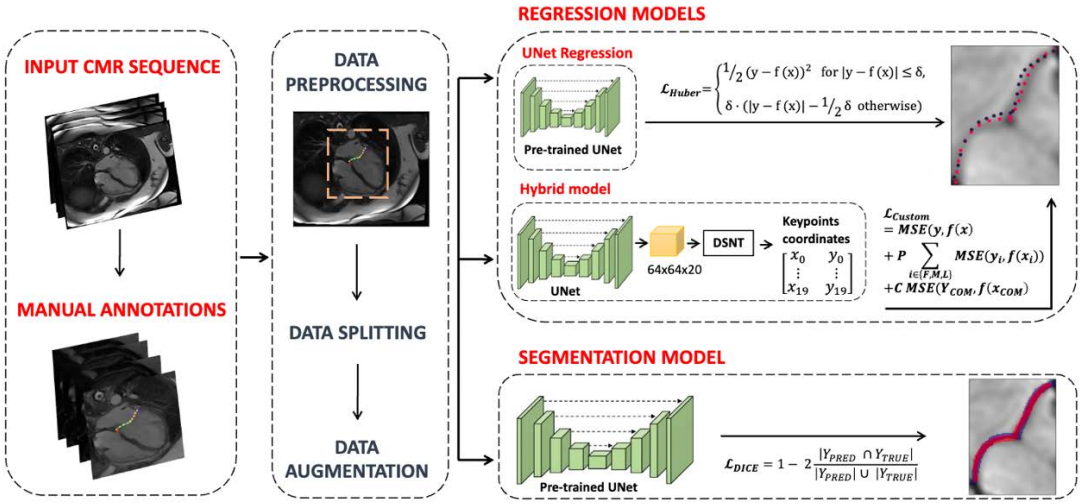

Presentation at cincinatti conference

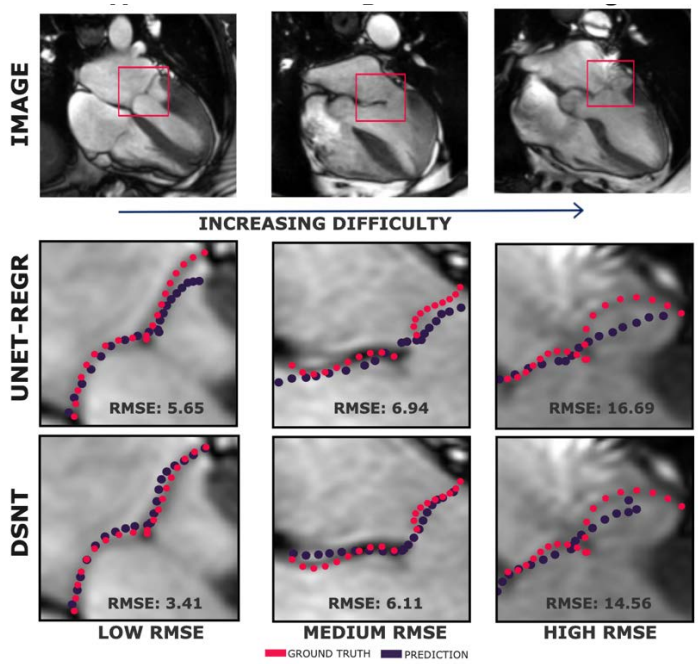
# DeepValve: an automatic detection pipeline for the mitral valve in Cardiac Magnetic Resonance Imaging

*Monopoli G, Forsch N, Balaban G, Maleckar MM*

Early detection of mitral valve (MV) structural complications is a crucial clinical need. Key advances in deep learning-based segmentation have not yet been leveraged for MV detection in cardiac magnetic resonance imaging (CMR), a promising opportunity towards assisted MV disease diagnostics.

To address this gap, we introduce DeepValve, an automated pipeline for MV detection using CMR. DeepValve builds on existing approaches by comparing known methodologies (U-Net architectures, fine-tuned for regression and segmentation analysis) and introducing a novel hybrid model (Unet-DSNT), adapted from a recent automatic segmentation study in echocardiography. We have proposed new metrics tailored for quality assessment of predicted thin structures based on Procrustes analysis and present accurate prediction results, comparing quality of predictions as varying with e.g., model and image quality.



# INTERNATIONAL COOPERATION

ProCardio works with an international perspective where the research methods are of international interest and the innovation projects target the global market. The ProCardio partnership includes two partners outside Norway (Medtronic, the Netherlands and the Baker Heart and Diabetes Institute, Australia) in addition to GE HealthCare, which is a global institution.

- Host partner Oslo University Hospital (OUS) is participating in several international multicentre studies.
- ProCardio OUS is part of the international multicentre pharmacological study Odessey, where the new and ground-breaking drug Mavacamten is tested in patients with hypertrophic cardiomyopathy – a disease thoroughly investigated in ProCardio. ProCardio OUS recruited the first Nordic patient in the study and is the biggest including center in Norway. In addition to OUS, GE HealthCare are also involved in the study. Center manager Kristina Haugaa is the study's principal investigator in Norway.
- ProCardio is part of an international research collaboration, led by Dr. Sabbag from Chaim Sheba Medical Center, Israel. The collaboration's research interest is patients with arrhythmogenic mitral valve prolapse, one of ProCardio's main focus areas in terms of disease category.
- In 2023, ProCardio OUS established a research collaboration with University of Minneapolis, Minnesota as part of Norwegian Centennial Chair (NOCC) program. In this transatlantic project "LaMinOs", researchers in Minneapolis and Oslo will perform translational research in Lamin A/C cardiomyopathy.

*Prof Kristina Haugaa, ProCardio, Dr. Forum Kamdar , Universtiy of Minneapolis, and Dr. Nina Hasseberg, ProCardio.*

- Procardio has an ongoing study on ischemic heart disease in collaboration with the University of Copenhagen, Rigshospitalet, Nationalt Genom Center, Denmark, NTNU and deCODE, Iceland.
- ProCardio OUS participates in an international cardiomyopathy registry established by Dr Lakdawala at Brigham and Women's Hospital, Boston Massachusetts, USA.
- Kristina Haugaa has a central role in an international registry group established by the European Heart Rhythm Association (EHRA) (national heart associations from 57 countries).
- ProCardio OUS collaborates with universities in Milan, Italy, and Utrecht/Maastricht, the Netherlands in connection with ultrasound-guided risk stratification for sudden death in an EU-funded project (EMPATHY) ERA-CVD.
- ProCardio OUS participates in a Nordforsk-funded project on Personalized Medicine with participants from the Nordic countries.

- ProCardio OUS has a central part in the Nordic ARVC register. In 2023, Nina Hasselberg participated at the annual collaboration meeting in Copenhagen, and we have participated in several web-based meetings throughout the year.
- Within ProCardio we work with a Prototype of a wearable vest for electrophysiological utility (OUS – Medtronic, Maastricht, NL)
- GEVU has an extensive global network and is actively involved in international research collaborations. Several of these projects are directly linked to research in ProCardio by functional ultrasound imaging for the assessment of heart failure and the risk of sudden cardiac death.
- GE Vingmed Ultrasound (GEVU) arranged a workshop in Oslo Oct 25th on High Frame Rate imaging with participants from K.U. Leuven, NTNU/St. Olav, OUH to build international cooperation with the best academic, clinical, and technical teams in this area. Focus was on discussing state-of-the-art technology, current clinical experience, and to identify next steps for further collaboration.
- NTNU has an ongoing collaboration with KU Leuven and GE Vingmed Ultrasound on high frame rate imaging, and what is called shear wave imaging (SWI) or more broadly mechanical wave imaging (MWI). The aim of the collaboration is to: 1) Research the potential of measuring the velocity of short-lived mechanical waves in the myocardium produced by natural cardiac events such as valve closure and the atrial kick. 2) Innovate by developing measurement analysis tool for clinical use, as an App working in the GE HealthCare system.
- Simula has close collaborations with world-class research groups in the US and Europe, including University of California, San Diego (UCSD), University of California, San Francisco (UCSF), University of California, Berkeley, University of Washington, Seattle, King's College London, Imperial College London, the Turing Institute UK, the University of Utah, INRIA Sophia Antipolis, Karlsruhe Institute of Technology, Germany, and Copenhagen University, Denmark. Among other internationally-funded projects, Simula is a work-package leader for the large European project SimCardioTest (https://www.simula.no/research/projects/simulation-cardiac-devices-and-drugs-silico-testing-and-certification), focused on demonstration of a standardised and rigorous approach for in-silico clinical trials for cardiac therapies, creating an integrated and secure platform standardising & bridging model simulations, in-silico trials, and certification support.
- Simula has a particularly extensive collaboration with UCSD (called SUURPh) which focuses on research training and the exchange of PhD candidates within scientific data processing and biomedical applications, primarily related to cardiac physiology, running an annual international summer school which has quickly become a premier venue for education within computational cardiology. In addition, Simula has a close collaboration with UC Berkeley through the project SIMBER (The Simula Berkeley Education and Research Collaboration), funded through the INTPART programme. Collaboration with UC Berkeley has also included development of a spin out company, Organos, working on high-throughput human microphysiological systems for drug discovery and cardiac safety.

## International visiting researchers

- Mirakhmadjon Mirmaksudov is a researcher from Uzbekistan. He works as a cardiac electrophysiologist/cardiologist at the Republican Specialized Scientific Practical Medical Centre of Cardiology, Tashkent, Uzbekistan. He came to Oslo March 1st, 2023. At the Oslo University hospital, he is involved in a research project titled "Myocardial mechanics after His bundle pacing". His 1-year research stay in Oslo is funded by the European Association of Cardiovascular Imaging Research Grant 2022.
- Research Professor Mary (Molly) Maleckar from partner Simula was again invited as a Visiting Scholar to the Alan Turing Institute in London, U.K., where she collaborates with local and international researchers to develop their strategic platform and research on cardiac digital twins designed to advance diagnostic technologies, longitudinal care, and therapies for those suffering from diverse cardiovascular diseases together with collaborators from King's College London, Imperial College London, and the Turing Institute itself.
- Kristina Haugaa has acted as guest researcher at Karolinska Institute, Stockholm, Sweden. At Karolinska she has been following a project on cardiogenetics and sudden cardiac death.

# NEW MEMBERS

**Bendik Skinningsrud**, OUS
MD, PhD fellow
**Focus:** Covid-19 vaccine associated myocarditis

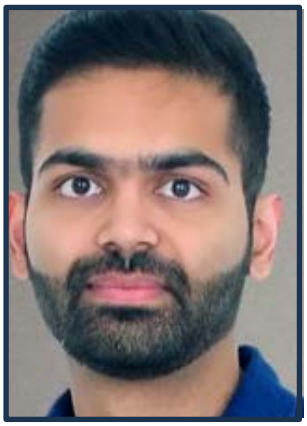
**Cecilie Bugge**, OUS
MD, PhD fellow
**Focus:** Ventricular arrhythmias in patients with arrhythmic valve syndrome

**Sigrun Ådnegard Skarstad**, OUS
MD, PhD fellow
**Focus:** Mangafodipir as an intracelluar contrast agent in cardiac MRI

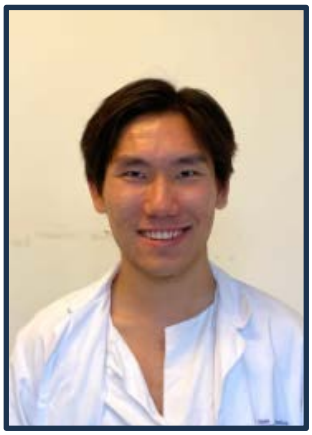
**Siri Holm Solberg,** OUS
PT/M.Sc. – Administrative coordinator

**Roger Håland,** OUS
Study nurse/Echotechnician

**Morgan Jakobsen**, GEHC
Senior Software Architect



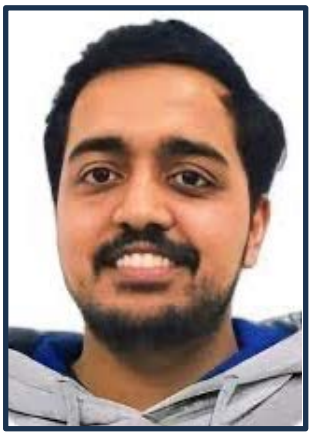
**Nikhil Arora,** NTNU
MD, Ph.D., PostDoc
**Focus:** Genetic epidemiology and cardiovascular disease



**Jireh Tang**, UiO
MSRP
**Focus:** Use of myocardial strain in patients with MI and HF

**Tormod Selbekk**, CVUS
Senior research manager
**Focus:** Clinical research within cardiovascular ultrasound

**Nickolas Forsch,** Simula
PhD, Senior Research Engineer
**Focus:** MAD/MVP, Deep valve project, mechanistic projects, software development



**Ashay Singh,** Simula
Temporary research assistant

**Daniel Haas,** Simula
Research assistant

**Focus:** DeepValve project for automatic detection of mitral valves and mitral valve disease from cardiac MRI

# COMMUNICATION AND DISSEMINATION ACTIVITIES

## EHRA European Heart Rhythm Association 2023

The annual meeting of the European Heart Rhythm Association (EHRA) convenes scientists, healthcare professionals and other stakeholders involved in arrhythmia management from all around the world.

The theme of EHRA 2023 was "20th anniversary, starting with a New EHRA", and the program was focusing on a comprehensive and pragmatic approach to the discipline, with lots of hands-on workshops and educational sessions.

Several ProCardio members attended the EHRA congress in Barcelona in the middle of April 2023.

*Drs Eivind Aabel, Tariq Ahmed, Nina Hasselberg and Linda Aaserud Tangen, all had scientific presentations at EHRA 2023, Barcelona.*

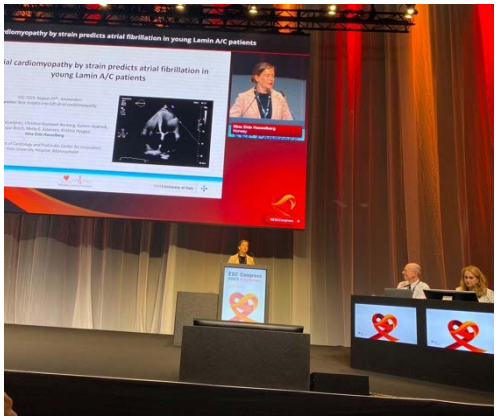
## European Society of Cardiology Congress 2023

The ESC Congress is the largest medical congress in Europe, gathering over 30.000 participants on-site and online. This year's theme was Heart Failure, relevant to all areas of cardiology and beyond. At this conference ProCardio professionals and partners were given the opportunity to discuss the latest research and advancements in the field. ProCardio members had a wide variety of duties at the conference, and were thus, able to share their findings, exchange ideas, and collaborate on future projects. Participation at the ESC is essential in order to contribute to the discussions and advancements in research and treatment.

One of the most important highlights this year was the presentation of the Guidelines for the management of cardiomyopathies. These are the first European guidelines on cardiomyopathies.


*ESC TV Stage: Professor Haugaa discussing the risk group for adverse effects during sports at a young age. Haugaa also chaired two abstract and poster sessions during the conference.*

*Several ProCardio members at the congress.*



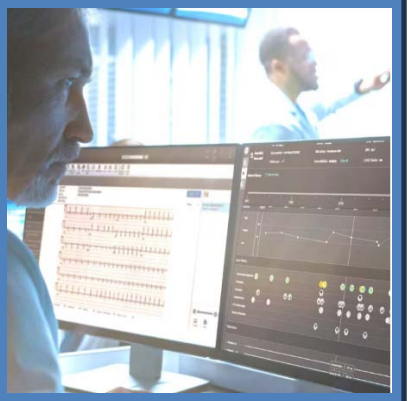
*Both Nina Hasselberg (picture) and Marit Kristine Smedsrud presented their research at ESC.*

### CardioVisio for Atrial Fibrillation

AT ESC 2023, GE HealthCare announced the launch of their digital tool CardioVisio for Atril Fibrillation (AFib).

By integrating and analyzing data over time and across various data sources, CardioVisio for AFib will assist the clinician in visualizing the history of the patient's heart and provides guideline-directed therapy recommendations.

*GE HealthCare Press release*



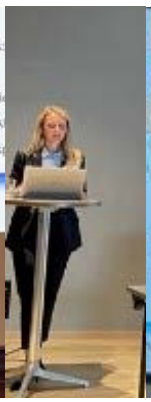
## 21st Annual Norwegian Symposium on Heart Research

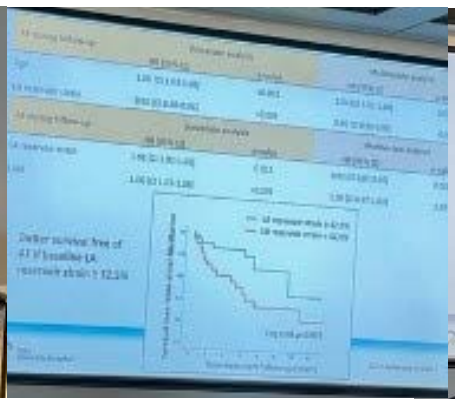
The 21st Annual Norwegian Symposium on Heart Research, organized by Department of Cardiology, Oslo University Hospital in collaboration with ProCardio and Norheart, took place at the end of August, lining up tightly after European Society of Cardiology Congress with its final day on the 28th.

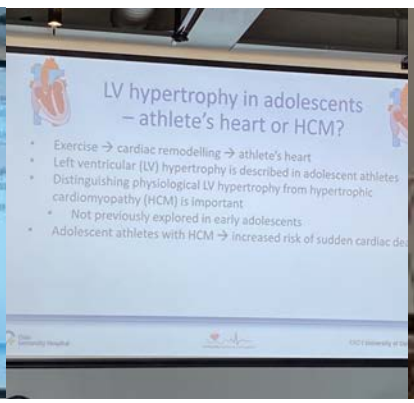
The expressive frame of Holmenkollen hosted a consistent group of young and senior cardiologists, researchers, and PhD students, who presented their projects during the abstract sessions.

Four fellows from ProCardio - Isotta Castrini, Christian Five, Marianne Forså and Jorun Tangen - displayed their work with abstracts on three different topics, including "Genetics and arrhythmias", "Cardiac function" and "Exercise and prevention".

In the opening session of the symposium "New therapeutic strategies" in cardiomyopathies and heart failure, Dr Nina Hasselberg, Center Director of Cardiological Research, Cardiologist, PhD, MD presented "Mavacamten; finally a breakthrough?"

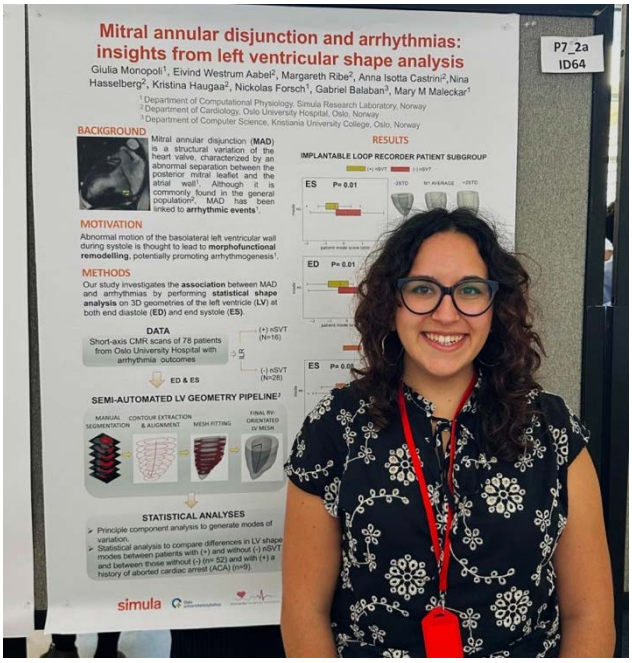







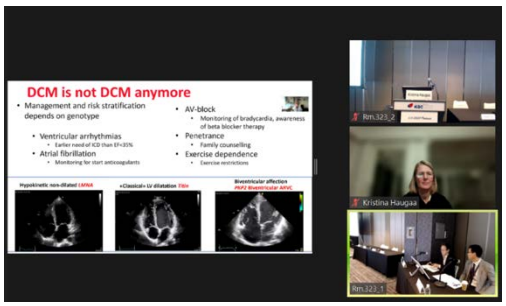

At the Gordon Research conference Cardiac Arrhythmia Mechanisms in Galveston, USA, several presentations and sessions were led by Simula researchers.


Molly Maleckar gave an invited talk at the 2023 Heart Rhythm Annual Scientific sessions in New Orleans, LA, in May, entitled: “Combining Simulation And Machine Learning To Accurately Predict Arrhythmic Risk In Post-infarction Patients»




Giulia Monopoli presented her poster “Mitral annual disjunction and arrhythmias: insights from left ventricular shape analysis” at the international Computing in Cardiology conference in October 2023 in Atlanta, GA. There was significant interest in this work. Lena Myklebust (and Julie Uv additionally presented conference talks at this conference in packed session, which also received a lot of interest from the audience.

***Norway Life Science – Building cardiology care for the future***
*Andreas Østvik (NTNU), Kristina Haugaa (OUS) and Bjørnar Grenne (NTNU)were invited to share their experience with successful research collaboration and the importance of artificial intelligence in heart ultrasound for improved patientcare care.*




***The 67th Annual Scientific Meeting of The Korean Society of Cardiology (KSC 2023).***
*Kristina Haugaa participated with a talk on multimodal evaluation of myocardium and valve– genetic cardiomyopathy.*

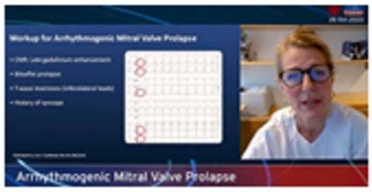


Hello Kristina Hermann,

The latest episode of ESC TV Today is available for you to watch on demand, when and where you want.

*Professor Haugaa was invited to ESC TV to give an update on arrhythmogenic mitral valve prolapse. The session was moderated by Professor Perry Elliot.*

## WHAT'S ON




**Arrhythmogenic mitral valve prolapse**

When should you be concerned about increased risk in these patients? And should you be looking out for mitral annular disjunction?


**Peripartum cardiomyopathy**

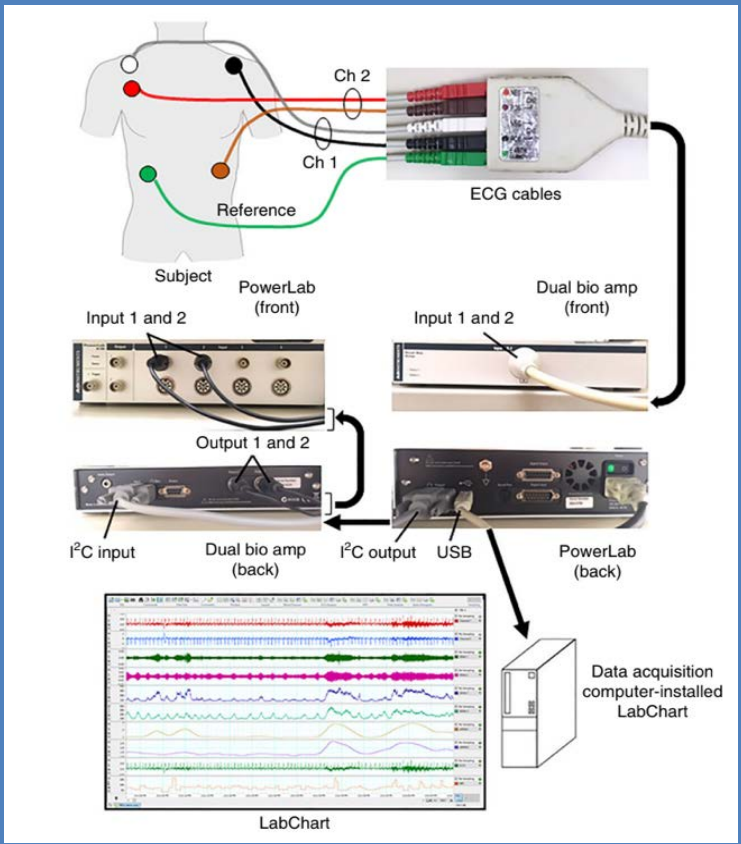
Get tips on the best ways to recognise this difficult to diagnose condition. How should mild cases be treated? What about more severe cases?

*From left: Simula coworkers Nickolas Forsch, Henrik Finsberg, Giulia Monopoli, discussinga ProCardio project. Kei Yamamoto and Gabriel Balaban can be seen in the background.*
*Foto: Bård Gudim*

*From left: Kei Yamamoto, Gabriel Balaban (Simula and ProCardio collaborator), and Ilse Van Herck (now at Mimiro), who work on simulations of blood flow in the atria, models to understand and to identify valvular disease, and heart failure simulations, respectively.*
*Foto: Bård Gudim*

## MVP Genetics

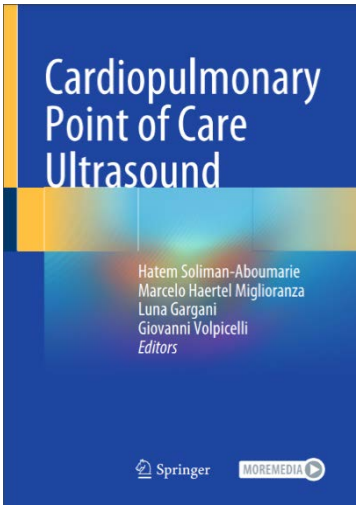
NTNU (K.G. Jebsen Center for Genetic Epidemiology) and ProCardio OUS are collaborating on performing bioinformatic analysis of the Whole Genome Sequencing data in patients with mitral valve prolapse (MVP). The project will look further into the genetic risk of mitral annular disjunction (MAD), which is commonly found in MVP patients. Eventually, the project will follow-up the findings by looking into big cohorts (like the HUNT-cohort) of genotyped participants with well characterized CVD-based incident outcomes.




## NeuECG

Medtronic and ProCardio members successfully completed a pilot study to confirm measurements of sympatic nerve activity in the NeuECG Project.

As the data are being analyzed, the next stages of a clinical study are in the planning.

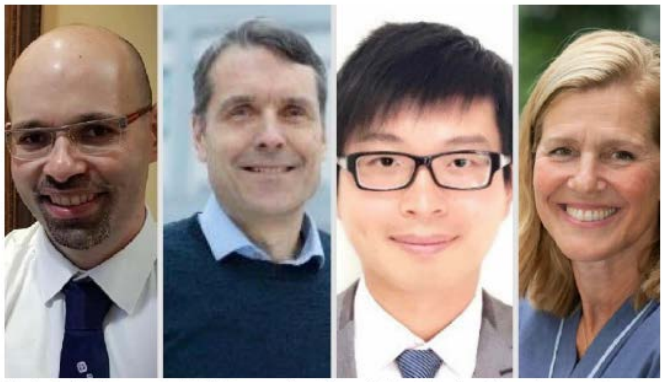



*Thor Edvardsen og Lars Gunnar Klæbo where the authors of the chapter* ***"Safety and Governance in Cardiopulmonary Ultrasound"***

PUBLISERING

# Disse forskerne publiserer mest i Norge

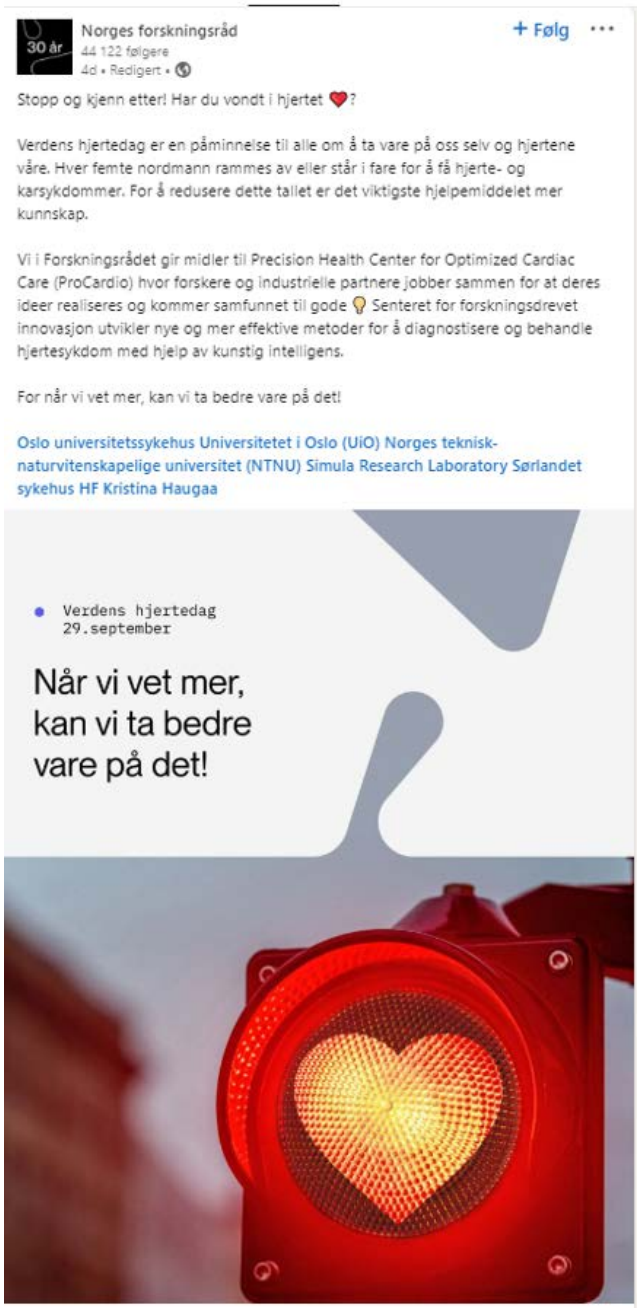
**Norges mest publiserende forsker har i snitt fått publisert to artikler i uka.**



Filippo Berto (t.v.), Ole A. Andreassen og Jerry Chun-Wei er de tre mestpubliserende forskerne. Kristina Ingrid Helena Hermann Haugaa er den nest mestpubliserende kvinnelige forskeren, på en 29. plass. NTNU, OUS, HVL

Kristina Haugaa is the second most publishing female researcher in Norway for the period 2019-2022. She is number 29 in total. The ranking is based on publication points and has been published by the research and education news site Khrono.

As Centre director and supervisor for research fellows and postdocs, she is involved in many projects, which results in many publications.






Kristina Haugaa er professor og seksjonsoverlege ved kardiologisk avdeling på Oslo universitetssykehus (OUS). Hun sier at hjertestans forekommer hos rundt 1-5 personer per 100 000 innbyggere under 35 år.

- Det er ikke veldig vanlig at man får hjertestans når man har HCM. Likevel er sykdommen angitt som den vanligste årsaken til plutselig hjertestans hos unge i USA, påpeker hun.

Typiske symptomer på sykdommen kan være hjertebank, hjertestans eller tungpustethet. Man kan ha sykdommen uten å vite det selv. Dette kan potensielt være farlig, ifølge overlegen.

- Cirka 1 av 500 har en genetisk defekt som disponerer for sykdommen, og cirka 30 prosent av disse utvikler en sykdom av betydning, sier Haugaa.

# AWARDS

ProCardio postdoctor and pediatric cardiologist Marit Kristine Smedsrud was in 2023 awarded two prizes for her article «Highly malignant disease in childhood-onset arrhythmogenic right ventricular cardiomyopathy» published in the European Heart Journal.


**Marie Spångbergs prize -** The most valuable original scientific article published by a Norwegian female doctor in 2022.

**Award for outstanding research article –** awarded from Oslo University Hospital, June 2023

The current study was the first in the world to examine the occurrence of serious events in the heart muscle in children with ARVC, as well as the usefulness of family investigation in early childhood for ARVC-related mutations.

*Marit Kristine and co-authors after the ceremony at OUS*

The study showed a high incidence of serious cardiac events in children with ARVC. Children who developed ARVC before the age of 12 years had a particularly malignant phenotype. In addition, a full 18% of the children included through family screening fulfilled the criteria for a definitive ARVC diagnosis before the age of 18. The results of the study showed that the prevalence of ARVC in childhood is underestimated and that the children who develop ARVC often have a highly malignant phenotype.

## The Students' teaching award to Professor Haugaa

The graduating class of the medical program distributes the teaching prize every semester. The honor goes to a teacher whom the students have particularly appreciated. In the spring of 2023, the award was shared between Haugaa and Stensrud Fløe.

# DISSERTATION

**Eivind Westrum Aabel**
**Prediction of arrhythmic risk in patients with mitral annular disjunction**
May 25, 2023

**Adjudication committee**

- First opponent:
  Professor Katja Zeppenfeld, Leiden University Medical Centre, The Netherlands
- Second opponent:
  Associate Professor Peter Moritz Schuster, University of Bergen
- Third member and chair of the evaluation committee:
  Associate Professor John-Peder Escobar Kvitting, University of Oslo

**Chair of the Defence**
Associate Professor Are Martin Holm, University of Oslo
**Principal Supervisor**
Professor Kristina Haugaa, University of Oslo
**Co-supervisor**
Øyvind Haugen Lie, Oslo University Hospital

**Summary**
Mitral annular disjunction is a gap between the mitral ring and the ventricular myocardium and is associated with mitral valve prolapse. A minority of these patients experience life-threatening ventricular arrhythmias, but the incidence of such arrhythmias is largely unknown and estimating risk is challenging. In the doctoral thesis “Prediction of arrhythmic risk in patients with mitral annular disjunction”, Dr. Eivind Westrum Aabel and colleagues assessed the incidence and explored possible risk markers of ventricular arrhythmias in patients with mitral annular disjunction.

The first study described the incidence of ventricular arrhythmia using continuous heart rhythm monitoring and shows a high rate of first-time ventricular arrhythmia and re-events. The second study assessed patients using cardiac magnetic resonance imaging and was the first study to describe the finding of concomitant right-sided annular disjunction. The third study described the prevalence of electro-cardiogram features and reported that T-wave inversion was associated with prior ventricular arrhythmia and diffuse myocardial fibrosis.

These observations improve our knowledge of risk stratification and provide clinicians caring for patients with mitral annular disjunction valuable information when evaluating the need for different follow-up strategies. External validation in larger prospective studies are important before fully implementing these observations in clinical practice.

# APPENDIX

| Funding | Amount* |
|---|---|
| The Research Council | 11 983 |
| The Host Institution (Oslo University Hospital) | 3 274 |
| Research Partners | |
| University of Oslo | 589 |
| Simula Research Laboratory | 520 |
| Norwegian University of Science and Technology | 1 485 |
| Sørlandet Hospital | - |
| Baker Heart and Diabetes Institute | - |
| Enterprise partners | |
| GE Healthcare | 1 288 |
| GE Vingmed Ultrasound | 3 924 |
| Medtronic | 477 |
| Sesam AS | 207 |
| DIPS AS | 1 695 |
| Other Public Funding | 3 465 |
| **Total** | 28 908 |

| Costs | Amount* |
|---|---|
| The Host Institution (Oslo University Hospital) | 13 958 |
| | |
| Research Partners | |
| University of Oslo | 589 |
| Simula Research Laboratory | 2 662 |
| Norwegian University of Science and Technology | 3 576 |
| Sørlandet Hospital | 532 |
| Baker Heart and Diabetes Institute | - |
| Enterprise partners | |
| GE Healthcare | 1 288 |
| GE Vingmed Ultrasound | 3 924 |
| Medtronic | 477 |
| Sesam AS | 207 |
| DIPS AS | 1 695 |
| | |
| **Total** | 28 908 |

# PERSONNEL

**Key Researchers**

| Name | Institution | Main research area |
|---|---|---|
| Kristina Hermann Haugaa | OUS | Cardiomyopathies,arrhythmias, cardiogenetics |
| Thor Edvardsen | UiO | Cardiac imaging |
| Helge Skulstad | OUS | Cardiac imaging |
| Sebastian Sarvari | OUS | Cardiac imaging, Cardiooncology |
| Øyvind Haugen Lie | OUS | Athletes and arrhythmias |
| Eigil Samset | GEHC | Data integration & platform development |
| Morgan Jakobsen | GEHC | Data integration & platform development |
| Attila Vojtek | GEHC | Data integration & platform development |
| Olivier Gerard | GE Vingmed | Data integration & platform development |
| Jurica Sprem | GE Vingmed | Data integration & platform development |
| Sten Roar Snare | GE Vingmed | Data integration & platform development |
| Benjamin Fermann | GE Vingmed | Data integration & platform development |
| Gunnar Hansen | GE Vingmed | Data integration & platform development |
| Bård Moseng | GE Vingmed | Data integration & platform development |

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| Cristiano Tiago | GE Vingmed | Data integration & platform development |
| Tormod Selbekk | GE Vingmed | Data integration & platform development |
| Molly Maleckar | Simula | Simulation-based data augmentation and therapy optimization |
| Joakim Sundnes | Simula | Simulation-based data augmentation and therapy optimization |
| Samuel Wall | Simula | Simulation-based data augmentation and therapy optimization |
| Gabriel Balaban | Simula/ Kristiania University College | Simulation-based data augmentation and therapy optimization |
| Hermenegild Arevalo | Simula | Simulation-based data augmentation and therapy optimization |
| Nickolas Forsch | Simula | Simulation-based data augmentation and therapy optimization |
| Trond Bertil Barstad | Sesam | Data integration & platform development |
| Stein Håvard Pedersen | Sesam | Data integration & platform development |
| Geir Atle Hegsvold | Sesam | Data integration & platform development |
| Ellis Igneri | Sesam | Data integration & platform development |
| Liv Bollvåg | DIPS | Data integration & platform development |
| Bjørn Fjukstad | DIPS | Data integration & platform development |
| Eivind Holt | DIPS | Data integration & platform development |
| Lasse Løvstakken | NTNU | Data science and machine learning |
| Håvard Dalen | NTNU | Data science and machine learning |
| Bjørnar Grenne | NTNU | Data science and machine learning |
| Kristian Hveem | NTNU | Data science and machine learning |
| Andreas Østvik | NTNU | Data science and machine learning |
| Espen Holte | NTNU | Data science and machine learning |
| Eivind Coward | NTNU | Data science and machine learning |
| Nikhil Arora | NTNU | Data science and machine learning |
| Harald Brunvand | SS | Coronary artery disease |
| Daniela Melichova | SS | Cardiomyopathies |
| Jarle Jotvedt | SS | Valvular disease |
| Pål Haugar Brekke | OUS/DIPS | Data integration & platform development |
| Richard Cornelussen | Medtronic | Biomedical engineering |
| Per Christiansen | Medtronic | Biomedical engineering |
| Mirco de Melis | Medtronic | Biomedical engineering |
| Anders Milch | Medtronic | Biomedical engineering |
| Gunnar Morne | Medtronic | Biomedical engineering |
| Kaspar Broch | OUS | Cardiac imaging, Heart failure |
| Darian Rijbic | OUS | Cardiac imaging, Myocardial function |
| Richard Massey | OUS | Cardiac imaging, Heart failure |
| Lars Aaberge | OUS | Invasive cardiology, Acute cardiovascular care |
| Thomas Helle Valle | OUS | Cardiac imaging, Myocardial function |
| Finn Hegbom | OUS | Electrophysiology |
| Mette-Elise Estensen | OUS | Cardiac imaging, Women's heart |
| Klaus Mubræch | OUS | Cardiac imaging |

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|---|---|---|
| Christian Eek | OUS | Invasive cardiology, Acute cardiovascular care |
| Njord Nordstrand | OUS | Acute cardiovascular care, Heart failure |
| Kari Melberg | OUS | Cardiac imaging, Cardiomyopathy |
| Jan Otto Beitnes | OUS | Cardiac imaging, Heart failure |
| Lars Dejgaard | OUS | Electrophysiology |
| Stian Ross | OUS | Electrophysiology |
| Erik Kongsgård | OUS | Electrophysiology |
| John Aalen | OUS | Cardiac imaging, Myocardial function |
| Torbjørn Holm | OUS | Electrophysiology |
| Kristin Nordvoll | OUS | Cardiogenetics |
| Elin Bjurstrøm | OUS | Cardiogenetics |
| Margareth Ribe | OUS | Cardiac imaging, Myocardial function |
| Roger Håland | OUS | Cardiac imaging, Myocardial function |
| Helen Storaker | OUS | Cardiac imaging, Myocardial function |
| Eystein Skjølsvik | OUS | Cardiomyopathies, Cardiogenetics |
| Johan Anzueles | OUS | Scientific programmer |
| Hans Gerhard Suheyl | OUS | Cardiac imaging |
| Tom Marwick | Baker Institute | Cardiooncology |

**Visiting Researchers**

| Name | Affiliation | Nationality | Sex M/F | Duration | Topic |
|---|---|---|---|---|---|
| Mirakhmadjon Mirmaksudov | OUS | Uzbekistan | M | 1 year | Myocardial mechanisms after His bundle pacing |

**Postdoctoral researchers with financial support from the Centre budget**

| Name | Nationality | Period | Sex M/F | Topic |
|---|---|---|---|---|
| Nina Hasselberg | Norwegian | 01.05.2021-30.04.2025 | F | Disease progression and risk assessment in familial cardiomyopathies and arrhythmogenic mitral valve prolapse |
| Gabriel Balaban | Norwegian | 01.04.2021-15.09.2023 | M | Disease progression and risk assessment in familial cardiomyopathies and arrhythmogenic mitral valve prolapse |

**Postdoctoral researchers working on projects in the centre with financial support from other sources**

| Name | Funding | Nationality | Period | Sex M/F | Topic |
|---|---|---|---|---|---|
| Marit Kristine Smedsrud | OUS | Norwegian | 01.04.21-28.03.25 | F | Early detection of genetic heart diseases – Prevention of sudden cardiac death in children |
| Eivind Westrum Aabel | UiO/NFR | Norwegian | 01.03.23-13.06.24 | M | Arrhythmias, cardiomyopathies, and clinical trials |
| Christine Rootwelt-Norberg | UiO/NFR/EU | Norwegian | 01.12.23-31.12.23 | F | Prevention of sudden cardiac death – Patient tailored recommendations in arrhythmogenic cardiomyopathy and long QT syndrome |
| Esra Kaya | OUS | Turkish | 01.01.23-31.12.23 | F | Aortic stenosis |

| PhD students with financial support from the Centre budget | | | | |
|---|---|---|---|---|
| **Name** | **Nationality** | **Period** | **Sex M/F** | **Topic** |
| Christian Kullmann Five | Norwegian | 06.09.2021-05.09.2024 | M | Disease progression and risk assessment in familial cardiomyopathies and arrhythmogenic mitral valve prolapse |
| Linda Tangen Aaserud | Norwegian | 01.11.2021-31.10.2024 | F | Athletes and arrhythmias |
| Artem Chernyshov | Russian | 06.09.2021-05.09.2024 | M | Functional Analysis of the Right Ventricle with Deep Learning |
| Mali Sæther | Norwegian | 01.02.2021-31.01.2024 | F | Cardiooncology |
| Henrik Agerup Kihdahl | Norwegian | 01.01.2022-31.12.2027 | M | Valvular disease, automated measurements, 50% PhD |
| Sverre Høie | Norwegian | 21.11.2022-20.11.2028 | M | Valvular disease 50% |
| Giulia Monopoli | Italian | 16.11.2022-15.11.2025 | F | MAD, image-based diagnostics, and mechanistic simulation 1 |
| Cecilie Bugge | Norwegian | 30.04.23-30.04.26 | F | Ventricular arrhythmias in patients with arrhythmic valve syndrome |

| PhD students working on projects in the Centre with financial support from other sources | | | | | |
|---|---|---|---|---|---|
| **Name** | **Funding** | **Nationality** | **Period** | **Sex M/F** | **Topic** |
| Kristoffer Andresen | OUS/HSØ | Norwegian | 01.06.2020-31.05.2026 | M | Triplane speckle-tracking echocardiography of the right ventricle |
| Marianne Inngjerdingen Forså | OUS/HSØ | Norwegian | 05.02.2018-31.08.2024 | F | Cardiac remodelling in children and adolescents |
| Jorun Tangen | OUS/UIO | Norwegian | 15.04.20-30.04.2024 | F | Improved prediction of clinical outcome in patients with myocardial infarction and heart failure |
| Mi Nguyen | OUS/HSØ | Norwegian | 01.12.2020-31.08.2024 | F | Outcome after myocardial infarction |
| Christine Rootwelt-Norberg | UiO/NFR/EU | Norwegian | 01.05.2019-31.01.2023 | F | Prevention of sudden cardiac death – Patient tailored recommandations in arrhythmogenic cardiomyopathy and long QT syndrome |
| Eivind Westrum Aabel | UiO/NFR | Norwegian | 01.01.2020-28.02.2023 | M | Arrhythmias and cardiomyopathies |
| Isotta Castrini | UiO/NFR | Italian | 01.08.2019-12.02.2024 | F | ARVC in pregnancy |
| Tove-Elizabeth Hunt | OUS/HSØ | Norwegian | 01.09.2016-31.12.2024 | F | Atrial fibrillation and sleep apnea |
| Sigrun Skarstad Ådnegard | OUS/NFR | Norwegian | 06.09.23-05.09.26 | F | Manganese as intracellular contrast medium in cardiac MRI |
| Bendik Skinningsrud | OUS/FHI/SLV | Norwegian | 19.09.23-01.10.26 | M | Covid-19 vaccine associated myocarditis in Norway |
| John Nyberg | NTNU | Swedish | 25.08.2021-24.08.2024 | M | Automated Measurements of Regional Left Ventricular Strain Based on Echocardiography and Artificial Intelligence in Patients with Ischemic Heart Disease |
| Lena Myklebust | SRL | Norwegian | 01.10.2019-30.11.2023 | F | Computational modeling of mitral annular disjunction |
| Katarina Vlaisaljevic | OUS/FHI/SLV | Serbisk | 01.03.2022-30.06.23 | F | Covid-19 vaccine associated myocarditis |

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|---|---|---|---|---|---|
| Benjamin Fermann | GE Vingmed/ UiO | Norwegian | 01.05.2020-30.04.2024 | M | Noninvasive analysis of cardiac function using automated workflows |
| Müjde Akdeniz | GE Vingmed/ MARCIUS | Turkish | 01.04.2020-31.03.2024 | F | Pattern recognition of functional disease characteristics |
| Cristiana Tiago | GE Vingmed/ MARCIUS | Portuguese | 01.03.2020-28.02.2023 | F | Fully Automatic Anatomical and Functional Analysis of the Left Ventricle in 3D Echocardiography using Deep Learning |
| Sigurd Vangen Wifstad | CIUS SFI, NFR | Norwegian | 01.12.20-01.03.24 | M | AI-based approaches for quantification of valve disease |

| **Master degrees** | | | |
|---|---|---|---|
| **Name** | **Sex M/F** | **Period** | **Topic** |
| Sigurd Zha | M | 09.01.2020-01.01.2023 | Deep learning for automated left ventricular outflow tract diameter measurements in 2D echocardiography |

# PUBLICATIONS

| | AUTHOR/AUTHORS | TITLE | JOURNAL |
|---|---|---|---|
| 1. | Aabel, EW; Chivulescu, M; Lie, ØH; Hopp, E; Gjertsen, E; Ribe, M; Helle-Valle, TM; Edvardsen, T; Hegbom, F; Dejgaard, LA; Haugaa, KH. | Ventricular arrhythmias in arrhythmic mitral valve syndrome-a prospective continuous long-term cardiac monitoring study. | Europace. 2023 Feb 16;25(2):506-516. |
| 2. | Aabel, EW; Dejgaard, L; Chivulescu, AM; Helle-Valle, TM; Edvardsen, T; Hasselberg, NE; Hegbom, F; Lie, ØH; Haugaa, KIHH. | Flecainide in patients with arrhythmic mitral valve syndrome: A case series. | Heart Rhythm. 2023 Apr;20(4):635-636 |
| 3. | Abdullah, R; Bjørnebekk, A; Hauger, LE; Hullstein, IR; Edvardsen, T; Haugaa, KH; Almaas, VM. | Severe biventricular cardiomyopathy in both current and former long-term users of anabolic-androgenic steroids. European | European Journal of Preventive Cardiology 2023 |
| 4. | Albatat, M; Finsberg, HN; Arevalo, H; Sundnes, J; Bergsland, J; Balasingham, I; Odland, HH. | Regional Left Ventricular Fiber Stress Analysis for Cardiac Resynchronization Therapy Response. | Ann Biomed Eng, 2023 Feb;51(2):343-351. |
| 5. | Andreassen, K; Rixon, CL; Hansen Haugsten, M; Hauge-Iversen, IM; Zhang, L; Sadredini, M; Murugan Erusappan, P; Sjaastad, I; Christensen, G; Haugaa, KIHH; Edvardsen, T; Lunde, IG; Stokke, MK. | Beneficial effects of exercise initiated before development of hypertrophic cardiomyopathy in genotypepositive mice. | Am J Physiol Heart Circ Physiol. 2023 Jun 1;324(6):H881-H892. |
| 6. | Arbelo, E; Protonotarios, A; Gimeno, JR; Arbustini, E; Barriales-Villa, E; Basso, C; Bezzina, CR; Biagini, E; Blom, NA; de Boer, RA; De Winter, T; Elliott, PM; Flather, M; Garcia-Pavia, P; Haugaa, KH; ….. ; Kaski, JP; ESC Scientific Document Group. | 2023 ESC Guidelines for the management of cardiomyopathies. | Eur Heart J. 2023 Oct 1;44(37):3503-3626. |
| 7. | Bergeman, AT; Lieve, KVV; Kallas, D; Bos, JM; Noguer, FRY; Denjoy, I; Zorio, E; Kammeraad, JAE; Peltenburg, PJ; Tobert, K; Aiba, T; Atallah, J; Drago, F; Batra, AS; Brugada, R; Borggrefe, M; Clur, SAB; Cox, MGPJ; Davis, A; Dhillon, S; Etheridge, SP; Fischbach, P; Franciosi, S; Haugaa, KH .... der Werf, Cv. | Flecainide Is Associated With a Lower Incidence of Arrhythmic Events in a Large Cohort of Patients With Catecholaminergic Polymorphic Ventricular Tachycardia. | Circulation. 2023 Dec 19;148(25):2029-2037. |
| 8. | Cosyns, B; Sade, LE; Gerber, BL; Gimelli, A; Muraru, D; Maurer, G, Edvardsen, T. | The year 2021 in the European Heart Journal: Cardiovascular Imaging Part II 2023. | Eur Heart J Cardiovasc Imaging. 2023 Feb 17;24(3):276-284. |
| 9. | Dodgson, CS; Beitnes, JO; Kløve, SF; Herstad, J; Opdahl, A; Undseth, R; Eek, CH; Broch, K; Gullestad, L; Aaberge, L; Lunde, K; Bendz, B; Lie, ØH. | An investigator-sponsored pragmatic randomized controlled trial of AntiCoagulation vs AcetylSalicylic Acid after Transcatheter Aortic Valve Implantation: Rationale and design of ACASA-TAVI. | Am Heart J. 2023 Nov: 265:225-232. |
| 10. | Edvardsen, T; Klaeboe, LG. | Safety and Governance in Cardiopulmonary Ultrasound, in Cardiopulmonary Point of Care Ultrasound. | Elsevier, 363-67, 2023. ISBN 978-3-031-29471-6. |
| 11. | Edvardsen, T. | Young athlete's growing heart: sex differences in cardiac adaptation to exercise training during adolescence. | Open Heart. 2023 Jan;10(1): e002155. |

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| 12. | Erevik, CB; Kleiven, Ø; Frøysa, V; Bjørkavoll-Bergseth, M; Chivulescu, AM; Klæboe, LG; Dejgaard, L; Auestad, BH; Skadberg, Ø; Melberg, TH; Urheim, S; Haugaa, KIHH; Edvardsen, T; Ørn, S. | Myocardial inefficiency is an early indicator of exerciseinduced myocardial fatigue. | Front Cardiovasc Med. 2023 Jan 11:9:1081664. |
| 13. | Eriksson, M; Haugaa, K; Revêchon, G. | Readily Available Tools to Detect Progerin and Cardiac Disease Progression in Hutchinson-Gilford Progeria Syndrome. | Circulation. 2023 Jun 6;147(23):1745-1747. |
| 14. | Five, CK; Hasselberg, NE; Aaserud, LT; Castrini, AI; Vlaisavljevic, K; Lie, Ø; Rootwelt-Norberg, C; Aabel, EW; Haugaa, KH. | Lifetime exercise dose and ventricular arrhythmias in patients with mitral valve prolapse. | Europace. 2023 Oct 5;25(10): euad309. |
| 15. | Forså, MI; Bjerring, AW; Haugaa, KIHH; Smedsrud, MK; Sarvari, S; Landgraff, HEW; Hallén, J; | Young athlete's growing heart: sex differences in cardiac adaptation to exercise training during adolescence | Open Heart. 2023 Jan;10(1):e002155. |
| 16. | Forså, MI; Smedsrud, MK; Haugaa, KH; Bjerring, AW; Früh, A; Sarvari, SI; Landgraff, HW; Hallén, J; Edvardsen, T. | Distinguishing left ventricular hypertrophy from hypertrophic cardiomyopathy in adolescents - a longitudinal observation study. | Eur J Prev Cardiol. 2023 Nov 22: zwad361. |
| 17. | Gronningsaeter, L; Estensen, ME; Skulstad, H; Langesaeter, E; Edvardsen, E. | Cardiorespiratory fitness in women after severe preeclampsia. | Hypertens Pregnancy. 2023 Dec;42(1):2245054. |
| 18. | Gronningsaeter, L; Langesaeter, E; Sørbye, IK; Quattrone, A; Almaas, VM; Skulstad, H; Estensen, ME. | High prevalence of preeclampsia in women with coarctation of the aorta. | Eur Heart J Open. 2023 Jul 27;3(4): oead072. |
| 19. | Halvorsen, S; Mehilli, J; Cassese, S; Hall, TS; Abdelhamid, M; Barbato, E; De Hert, S; de Laval, I; Geisler, T; Hinterbuchner, L; Ibanez, B; Lenarczyk, R; Mansmann, UR; McGreavy, P; Mueller, C; Muneretto, C; Niessner, A; Potpara, TS; Ristic, A; Sade, LE; Schirmer, H; Schüpke, S; Sillesen, H; Skulstad, H; Torracca, L; Tutarel, O; Van Der Meer, P; Wojakowski, W; Zacharowski, K; | ESC Scientific Document Group. 2022 ESC Guidelines on cardiovascular assessment and management of patients undergoing non-cardiac surgery Developed by the task force for cardiovascular assessment and management of patients undergoing noncardiac surgery of the European Society of Cardiology (ESC) Endorsed by the European Society of Anaesthesiology and Intensive Care (ESAIC). | G Ital Cardiol (Rome). 2023 Jan;24(1 Suppl 1):e1-e102. |
| 20. | Haugaa, KIHH; Castrini, AI. | Editorial: Sudden cardiac death in the young—Can illicit drug use explain the unexplained? | Heart Rhythm. 2023 Oct;20(10):1356-1357 |
| 21. | Herrera, NT; Zhang, X; Ni, H; Maleckar, MM; Heijman, J; Dobrev, D; Grandi, E; Morotti, S. | Dual effects of the smallconductance Ca2+ -activated K+ current on human atrial electrophysiology and Ca2+ - driven arrhythmogenesis: an in silico study. | Am J Physiol Heart Circ Physiol. 2023 Oct 1;325(4):H896-H908. |
| 22. | Kaya, E; Andresen, K; Lie, Ø; Aaberge, L; Haugaa, KH; Edvardsen, T; Skulstad, H. | Left Ventricular Mechanical Dispersion as a Predictor of need for Pacemaker implantation after TAVI. | Eur Heart J Cardiovasc Imaging. 2023 Nov 17:jead315. |
| 23. | Kirkels, FP; Rootwelt-Norberg, C; Bosman, LP; Aabel, EW; Muller, S; Castrini, AI; Taha, K; Osta N, van; Lie, ØH; Asselbergs, FW; Lumens, J; Te Riele, ASJM; Hasselberg, NE; Cramer, MJ; Haugaa, KH; Teske, AJ. | The added value of abnormal regional myocardial function for risk prediction in arrhythmogenic right ventricular cardiomyopathy. | Eur Heart J Cardiovasc Imaging. 2023 Nov 23;24(12):1710-1718. |
| 24. | Kirkels, FP; van Osta, N; Rootwelt-Norberg, C; Chivulescu, AM; van Loon, T; Aabel, EW; Castrini, AI; Lie, ØH; Asselbergs, FW.; Delhaas, T; Cramer, MJ; Teske, AJ; Haugaa, KIHH; Lumens, J. | Monitoring of Myocardial Involvement in Early Arrhythmogenic Right Ventricular Cardiomyopathy Across the Age Spectrum. | J Am Coll Cardiol. 2023 Aug 29;82(9):785-797. |
| 25. | Kjeldsberg, HA; Sundnes, J; Valen-Sendstad, K. | A verified and validated moving domain computational fluid dynamics solver with applications to cardiovascular flows. | Int J Numer Method Biomed Eng. 2023 Jun;39(6):e3703. |
| 26. | Lekva, T; Michelsen, AE; Roland, MCP; Norwitz, ER; Estensen, ME; Olstad, OK; Akkouh, IA; Henriksen, T; Bollerslev, J; Aukrust, P; Ueland, T. | Increased ferroptosis in leukocytes from preeclamptic women involving the long non-coding taurine upregulated gene 1 (TUG1). | J Intern Med. 2024 Feb;295(2):181-195. |
| 27. | Li, J; Sundnes, J; Hou, Y; Laasmaa, M; Ruud, M; Unger, A; Kolstad, TR; Frisk, M; Norseng, PA; Yang, L; Setterberg, IE; Alves, ES; Kalakoutis, M; Sejersted, OM; Lanner, JT; Linke, WA; Lunde, IG; Tombe PP, de; Louch, WW. | Stretch Harmonizes Sarcomere Strain Across the Cardiomyocyte. | Circ Res. 2023 Jul 21;133(3):255-270. |
| 28. | Müjde, A; Manetti, CA; Koopsen, T; Mirar, HN; Snare, SR; Aase, SA; Lumens, J; Šprem, J; Mcleod, KS. | Deep Learning for Multi-Level Detection and Localization of Myocardial Scars Based on Regional Strain Validated on Virtual Patients | IEEE Access 2023 (11), 15788-15798. |
| 29. | Neglia, D; Liga R; Gimelli A; Podlesnikar T; Cvijic M; Pontone G; Miglioranza MH; Guaricci AI; Seitun S; Clemente A; Sumin A; Vitola J; Saraste A; Paunonen C; Sia CH; Paleev F; Sade LE; Zamorano JL; Maroz-Vadalazhskaya N; Anagnostopoulos C; Macedo F; | EURECA Investigators. Use of cardiac imaging in chronic coronary syndromes: the EURECA Imaging registry. | Eur Heart J. 2023 Jan 7;44(2):142-158. |

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| | Knuuti J; Edvardsen T; Cosyns B; Petersen SE; Magne J; Laroche C; Berlè C; Popescu BA; Delgado V; | | |
| 30. | Nguyen, TM; Melichova, D; Aabel, EW; Lie, ØH; Klæboe, LG; Grenne, BL; Sjøli, B; Brunvand, H; Haugaa, KIHH; Edvardsen, T. | Mortality in Patients with Acute Coronary Syndrome—A Prospective 5-Year Follow-Up Study. | J Clin Med. 2023 Oct 18;12(20):6598. |
| 31. | Nilsen, TS; Sæter, M; Sarvari, S; Reinertsen, KV; Johansen, SH; Edvardsen, ER; Hallén, J; Edvardsen, E; Grydeland, M; Kiserud, CE; Lie, HC; Solberg, PA; Wisløff, T; Sharples, A; Raastad, T; Haugaa, KIHH; Thorsen, L. | Effects of Aerobic Exercise on Cardiorespiratory Fitness, Cardiovascular Risk Factors, and Patient-Reported Outcomes in Long-Term Breast Cancer Survivors: Protocol for a Randomized Controlled Trial. | JMIR Res Protoc. 2023 Mar 15;12:e45244. |
| 32. | Nyberg, JAT; Jakobsen, EO; Østvik, A; Holte, E; Stølen, S; Løvstakken, L; Grenne, BL; Dalen, H. | Determinants of left atrial reservoir strain in a large healthy population. | European Heart Journal - Cardiovascular Imaging, Volume 24, Issue Supplement_1, June 2023, jead119.217. |
| 33. | Pannone, L; Gauthey, A; Conte, G; Osei, R; Campanale, D; Baldi, E; Berne, P; Vicentini, A; Vergara, P; Sorgente, A; Rootwelt-Norberg, C; Della Rocca, DG; Monaco, C; Bisignani, A; Miraglia, V; Spolverini, M; Paparella, G; Overeinder, I; Bala, G; Almorad, A; Ströker, E; de Ravel, T; Medeiros-Domingo, A; Sieira, J; Haugaa, KH; Brugada, P, La Meir, AA; Auricchio, A; Chierchia, GB; van Dooren, S; de Asmundis, C. | Genetics in Probands With Idiopathic Ventricular Fibrillation: A Multicenter Study. | JACC Clin Electrophysiol. 2023 Aug;9(8 Pt 1):1296-1306. |
| 34. | Pezel, T; Coisne, A; Michalski, B; Soliman, H; Ajmone, N; Nijveldt, R; Stankovic, I; Donal, E; der Maaten, Jv; Papadopoulos, C; Edvardsen, T; Muraru, D; Petersen, SE; Cosyns, B; Bäck, M; Bertrand, PB; Haugaa, KH; Keenan, N; Donal, E; Cosyns, B. | EACVI SIMULATOR-online study: evaluation of transoesophageal echocardiography knowledge and skills of young cardiologists. | Eur Heart J Cardiovasc Imaging. 2023 Feb 17;24(3):285-292. |
| 35. | Rootwelt-Norberg, C; Christensen, AH; Skjølsvik, ET; Chivulescu, M; Vissing, CR; Bundgaard, H; Aabel, EW; Bogsrud, MP; Hasselberg, NE; Lie, ØH; Haugaa, KH. | Timing of cardioverterdefibrillator implantation in patients with cardiac laminopathies-External validation of the LMNA-risk ventricular tachyarrhythmia calculator. | Heart Rhythm. 2023 Mar;20(3):423-429. |
| 36. | Rootwelt-Norberg, C; Skjølsvik, E; Ek, T; Chivulescu, AM; Bogsrud, MP; Ribe, M; Aabel, EW; Beitnes, JO; Brekke, PH; Håland, TSF; Hasselberg, NE; Lie, ØH; Haugaa, KIHH. | Disease progression rate is a strong predictor of ventricular arrhythmias in patients with cardiac laminopathies: a primary prevention cohort study. | Europace. 2023 Feb 16;25(2):634-642. |
| 37. | Sabbag, A; Essayagh, B; Enriquez-Sarano, M; Haugaa, KH. | Arrhythmic risk assessment of mitral valve prolapse pre- and post-mitral surgery - Authors' reply. | Europace. 2023 Feb 16;25(2):778-779 |
| 38. | Salte, IM; Østvik, A; Olaisen, SH; Karlsen, S; Dahlslett, T; Smistad, E; Eriksen-Volnes, TK; Brunvand, H; Haugaa, KIHH; Edvardsen, T; Dalen, H; Løvstakken, L; Grenne, BL. | Deep Learning for Improved Precision and Reproducibility of Left Ventricular Strain in Echocardiography: A Test-Retest Study. | J Am Soc Echocardiogr. 2023 Jul;36(7):788-799. |
| 39. | Salte, IM; Østvik, A; Olaisen, SH; Karlsen, S; Dahlslett, T; Smistad, E; Eriksen-Volnes, TK; Brunvand, H; Haugaa, KIHH; Edvardsen, T; Dalen, H; Løvstakken, L; Grenne, BL. | Response to "Minimal Detectable Change and Reproducibility of Echocardiographic Strain: Implications for Clinical Practice". | J Am Soc Echocardiogr. 2023 Nov;36(11):1223-1224 |
| 40. | Sletten, OJ; Aalen, JM; Smiseth, OA; , Khan, FH; Fosså, A; Kiserud, CE; Villegas-Martinez, M; Hisdal, J; Remme, EW; Skulstad, H. | Mental stress reduces left ventricular strain: Can it lead to misinterpretation of cancer therapy-related cardiac dysfunction? | J Am Soc Echocardiogr. 2023 Nov 18:S0894-7317(23)00593-X. |
| 41. | Stankovic, I; Voigt, JU; Burri, H; Muraru, D; Sade, LE; Haugaa, KH; Lumens, J; Biffi, M; Dacher, JN; Marsan, NA; Bakelants, E; Manisty, C; Dweck, MR; Smiseth, OA; Donal, E. | Imaging in patients with cardiovascular implantable electronic devices - Part 2: Imaging after device implantation. | Eur Heart J Cardiovasc Imaging. 2023 Dec 21;25(1):e33-e54. |
| 42. | Stankovic, I; Voigt, JU; Burri, H; Muraru, D; Sade, LE; Haugaa, KH; Lumens, J; Biffi, M; Dacher, JN; Marsan; NA; Bakelants, E; Manisty, C; Dweck; MR; Smiseth, OA; Donal, E. | Imaging in patients with cardiovascular implantable electronic devices - Part 1: Imaging before and during device implantation. | Eur Heart J Cardiovasc Imaging. 2023 Dec 21;25(1):e1-e32. |
| 43. | Sundnes, J; Lee, LC; Wall, ST; Valdez-Jasso, D. | Editorial: Computational models of cardiovascular growth and remodeling. | Front. Physiol., 23 January 2023 |
| 44. | Telle, Å; Trotter, JD; Cai, X; Finsberg, H; Sundnes, J; Kuchta, J; Wall, ST. | A cell-based framework for modeling cardiac mechanics. | Biomech Model Mechanobiol. 2023 Apr;22(2):515-539. |
| 45. | Tfelt-Hansen, J; Garcia, R; Alberg, C; Merino, J; Krahn, A; Marijon, E; Basso, C; Wilde, AAM; Haugaa, KIHH. | Risk stratification of sudden cardiac dealth: A review. | Europace. 2023 Aug 25;25(8):euad203. |

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| 46. | Tiago, C; Snare, SR; Sprem, J; McLeod, K. A Domain | Translation Framework With an Adversarial Denoising Diffusion Model to Generate Synthetic Datasets of Echocardiography Images. | IEEE Access 2023 (11), 17594-17602. |
| 47. | Zha, SZ; Rogstadkjernet, M; Klæboe, LG; Skulstad, H; Singstad, BJ; Gilbert, A; Edvardsen, T; Samset, E; Brekke, PH. | Deep learning for automated left ventricular outflow tract diameter measurements in 2D echocardiography. | Cardiovasc Ultrasound. 2023 Oct 13;21(1):19. |

# DISSEMINATIONS

| | AUTHOR/AUTHORS | TITLE | EVENT |
|---|---|---|---|
| 1. | Al Wazzan, A; Taconne, M; Le, RV; Forsaa, MI; Haugaa, KH; Galli, E; Hernandez, A; Edvardsen, T; Donal, E. | Machine learning model including left ventricular strain analysis for sudden cardiac death prediction in hypertrophic cardiomyopathy. | European Association of Cardiovascular Imaging (EACVI) Congress 2023. |
| 2. | Chernyshov, A; Grue, JF; Østvik, A; Van de Vyver, G; Smistad, E; Løvstakken, L. | Automated Segmentation and Quantification of the Right Ventricle in 2D Echocardiography. | IEEE International ultrasonics symposium, 2023. |
| 3. | Dalen, H. | Bioprotese med høy hastighet. HALT? Hva gjør vi? | Kardiologisk høstmøte, NTNU, 2023. |
| 4. | Edvardsen, T. | Arrhythmogenic cardiomyopathy. | EACVI Teaching course, Tashkent, Uzbekistan, Mar 2023. |
| 5. | Edvardsen, T. | Cardiomyopathies – what´s new? Arrhythmogenic cardiomyopathy. | EACVI Teaching Course, Bucharest, Romania Oct 2023. |
| 6. | Edvardsen, T. | Highlights from the EACVI/ASE recommendations on coronary syndromes. | EACVI Teaching course, Tashkent, Uzbekistan, Mar 2023. |
| 7. | Edvardsen, T. | Imaging in recent European Society of Cardiology Guidelines – Cardio-oncology. | EACVI Teaching Course, Bucharest, Romania Oct 2023. |
| 8. | Edvardsen, T. | Mitral valve prolapse: how to identify patients at arrhythmic risk? | EACVI Teaching course, Tashkent, Uzbekistan, Mar 2023. |
| 9. | Edvardsen, T. | Multimodality Imaging in Arrhythmogenic Cardiomyopathies. | 19th International Congress of Update in Cardology and Cardiovascular Surgery. Istanbul, Tyrkia. |
| 10. | Edvardsen, T. | Myocardial function in asymptomatic severe aortic stenosis. | EACVI Teaching course, Tashkent, Uzbekistan, Mar 2023. |
| 11. | Edvardsen, T. | Myocardial function in asymptomatic severe aortic stenosis. | 19th International Congress of Update in Cardology and Cardiovascular Surgery. Istanbul, Tyrkia, Nov 2023. |
| 12. | Edvardsen, T. | Myocardial work and mechanical dispersion. | EACVI congress, Barcelona, Spain. May 2023, Org: EACVI. |
| 13. | Edvardsen, T. | New and Emerging Treatment Options for HCM. | EACVI congress, Barcelona, Spain. May 2023, Org: EACVI. |
| 14. | Edvardsen, T. | Up-to-date Assessment of Left Ventricular Systolic Function. | National Conference Uzbekistam, Samrakand, Uzbekistan, Oct 2023. Virtual. |
| 15. | Five, CK; Hasselberg, NE; Castrini, AI; Vlaisavljevic, K; Aaserud, LT; Lie, Ø; Rootwelt-Norberg, C; Aabel, EW; Haugaa, KH. | Long and short term associations of lifetime exercise dose and ventricular arrhythmias in patients with arrhythmic mitral valve prolapse. | The 21st Annual Norwegian Symposium on Heart Research, 2023. |
| 16. | Forså, M; Smedsrud, MK; Haugaa, KH; Bjerring, AW; Fruh, A; Sarvari, SI; Landgraff, HW; Hallén, J; Edvardsen, T. | Distinguishing left ventricular hypertrophy from hypertrophic cardiomyopathy in adolescents - a longitudinal observation study. | The 21st Annual Norwegian Symposium on Heart Research, 2023. |
| 17. | Forså, M; Smedsrud, MK; Haugaa, KH; Bjerring, AW; Fruh, A; Sarvari, SI; Landgraff, HW; Hallén, J; Edvardsen, T. | Distinguishing left ventricular hypertrophy from hypertrophic cardiomyopathy in adolescents - a longitudinal observation study. | European Association of Cardiovascular Imaging (EACVI) Congress, 2023. |
| 18. | Hasselberg, NE. | Atrial cardiomyopathy by strain predicts atrial fibrillation in young Lamin A/C patients. | ESC 2023 Amsterdam. |
| 19. | Hasselberg, NE. | Exercise and Pregnancy in familial cardiomyopathies – research and clinical aspects. | Leuven meeting on Myocardial Function Imaging 2023. |
| 20. | Hasselberg, NE. | What not to miss – the importance of laminopathy. | EHRA 2023 Barcelona. |
| 21. | Hasselberg, NE. | Mavacamten: Targeted therapeutics in cardiomyopathies - finally a breakthrough? | The 21st Annual Norwegian Symposium on Heart Research, 2023. |
| 22. | Haugaa, KH. | 2023 ESC Guidelines for the management of cardiomyopathies. | Karolinska university hospital, Torsdagsakademin, 2023. |

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| 23. | Haugaa, KH. | 2023 ESC Guidelines on Cardiomyopathies. | Annual Romanian cardiology conference, Sinaia, Romania. |
| 24. | Haugaa, KH. | 40 years of successful collaboration and innovation between a world leading med tech company and Norway's leading cardiology clinic. | Oslo Innovation conference, Ullevål Meet, February 2023. |
| 25. | Haugaa, KH. | Arrhythmias with mitral valve prolaps and mitral annular disjunction. | Scientific meeting, Karolinska institute, Stockholm, Sweden, 2023. |
| 26. | Haugaa, KH. | Arrhythmogenic right ventricular cardiomyopathy. | Belgian Heart rhythm conference. Brussels. Belgium, 2023. |
| 27. | Haugaa, KH. | Arrhytmic mitral valve prolapse Risk stratification - what is the evidence for management? | ESC TV, broadcasted, October 2023 |
| 28. | Haugaa, KH. | ARVC informasjon om sykdom og arvelighet. | Pasientkurs Rikshospitalet nov 2023. |
| 29. | Haugaa, KH. | ARVC risk och hur kan man träna? | Scientific meeting, Lund University Hospital, Sweden, 2023. |
| 30. | Haugaa, KH. | Arymogen mitralklaffprolaps Klinik och riskbedömning. | Svenska kardiovaskulära vårmøte, Stockholm, 2023. |
| 31. | Haugaa, KH. | Good exercise + bad genes = real risk. | Sportscardiology conferene, Lorne, Australia, 2023. |
| 32. | Haugaa, KH. | Hypertrofisk kardiomyopati. | LIS lege kurs, Bergen, Norway, 2023. |
| 33. | Haugaa, KH. | Hypertrofisk kardiomyopati. | LIS lege kurs, Fredrikstad, Norway, 2023. |
| 34. | Haugaa, KH. | Hypertrophic cardiomyopathy in 2023 Guidelines on cardiomyopathies. | International webinar, BMS, 2023. |
| 35. | Haugaa, KH. | Kardiomyopatier – vem ska nu gentestas, och när? | Svenska kardiovaskulära vårmøte, Stockholm, 2023. |
| 36. | Haugaa, KH. | Mitral annular disjunction, when to look, when to panic. | portscardiology conferene, Lorne, Australia, 2023. |
| 37. | Haugaa, KH. | Multimodal Evaluation of Myocardium and Valve: When & How? Genetic cardiomyopathy. | Korean cardiology conference, Seoul, Korea, web participation, 2023. |
| 38. | Haugaa, KH. | Multimodal imaging in arrhythmia Arrhythmogenic right ventricular cardiomyopathy. | Nordic Cardiac Imaging conference, Stockholm, 2023. |
| 39. | Haugaa, KH. | Norske anbefalinger for genetisk kardiologi. | Privatpraktiserande kardiologers forum, Oslo, Norge, 2023. |
| 40. | Haugaa, KH. | Plötslig hjärtdöd hos unga – Hur kan vi förhindra? | Scientific meeting, Karolinska institute, Stockholm, Sweden, 2023. |
| 41. | Haugaa, KH. | Procardio center for innovation. | TIK strategimøte, Holmen fjordhotell, 2023. |
| 42. | Haugaa, KH. | ProCardio center for research based innovation. | University of Oslo, Growth house, innvation conference, 2023. |
| 43. | Haugaa, KH. | Procardio how we did it. | UiO inspirasjonsseminar, 2023. |
| 44. | Haugaa, KH. | Reviving the heart, brain, and well-being after cardiac arrest Family screening: early genetic evaluation? | Invited lecture ESC conference, Amsterdam,2023. |
| 45. | Haugaa, KH. | Role of imaging to assess sudden cardiac death risk in cardiomyopathy patients Role of multimodality imaging in nonischemic cardiomyopathies. | EACVI webinar, March 2023. |
| 46. | Haugaa, KH. | When are PVCs pathologic? | Annual sportscardiology conference, Amsterdam, NL, 2023. |
| 47. | Haugaa, KH. | Who is at risk for sudden death during sports at young age? Red Flags and diagnostic steps. | ESC TV, onsite ESC conference, Amsterdam, NL, August, 2023. |
| 48. | Holmstrøm, V; Smistad, E; Nyberg, J; Østvik, A; Holte, E; Løvstakken, L; Dalen, H; Grenne, BL. | Deep Learning for Automated Analyses in the PLAX View. | Kardiologisk høstmøte, NTNU, 2023. |
| 49. | Løvstakken, L; Østvik, A; Pettersen, H; Sæbø, S; Olaisen, S. | AI-based measurments in echocardiography – technical advances and early clinical results. | Leuven Meeting on Myocardial Function Imaging, 2023. |
| 50. | Maleckar, MM. | Data-driven or model-driven? Using Simulations in Conjunction with Machine Learning for Clinical Applications. | AI Meets Medicine: Promises and limits - Heidelberg UKHD, September 15th, 2023. |
| 51. | Maleckar, MM. | In silico modeling of cardiovascular electrophysiology, mechanics, and flow: a Norwegian Center of research-based innovation. | Avicenna Society Member's webinar - August 29th, 2023. |
| 52. | Maleckar, MM. | Using Simulations in Conjunction with Machine Learning for Clinical Applications. | Heart Rhythm Society annual scientific sessions. AI in the clinic. May 21st, 2023. |

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| 53. | Monopoli, G; Aabel, EW; Ribe, M; Castrini, AI; Hasselberg, NE; Haugaa, KH; Forsch, N; Balaban, G; Maleckar, M. | Mitral annular disjunction and arrhythmias: insights from left ventricle shape analysis. | CinC 2023 - Session P7_2a, ID 64. |
| 54. | Myklebust, L; Uv, JJ; Maleckar, M; Arevalo, H. | Maximum Fibrosis Affects Reentry Morphology in 3D Ventricular Models. | CinC 2023 - Session S63, ID 98. |
| 55. | Nyberg, JAT; Jakobsen, EO; Østvik, A; Holte, E; Stølen, S; Løvstakken, L; Grenne, BL; Dalen, H. | Determinants of left atrial reservoir strain in a large healthy population | European Association of Cardiovascular Imaging (EACVI) Congress, 2023. |
| 56. | Nyberg, J; Grenne, B; Dalen, H. | Left atrial strain in a large healthy population. | Nordic Cardiac Imaging, 2023. |
| 57. | Ohnemus, S; Fullerton, K; Riebel, L; Maleckar, M; Timmermann, V; Balaban, G. | Automated Cardiac Constitutive Modelling: Deriving Strain Energy Functions with Evolutionary Regression. | CinC 2023 - Session P7_2a, ID 64. |
| 58. | Rootwelt-Norberg, C. | Erfaringer fra deltagelse i et ERA prosjekt. | Event - NFR ERA4 Health i Noreg, 2023. |
| 59. | Rootwelt-Norberg, C. | Medfødt hjertefeil og fysisk aktivitet. | Event - Pasientkurs/opplæring, 2023. |
| 60. | Sarvari, S; Sæter, M; Johannesen, SH; Thorsen, L; Reinertsen, KV; Haugaa, KH; Edvardsen, T; Nilsen, TS. | Cardiorespiratory Fitness And Left Ventricular Function In Breast Cancer Survivors A Decade After Epirubicin Treatment. | Global Cardio Oncology Summit, Madrid, Spain. |
| 61. | Sarvari, SI. | Imaging in Cardio-oncology. | 5. Nordic Cardiac Imaging meeting, 2023. |
| 62. | Sarvari, SI; Bjerring, AW; Bærug, I; Haugaa, KH; Kiserud, CE; Edvardsen, T; Smeland, KHB. | Long-term cardiac effects after modern treatment of Hodgkin's lymphoma. | Global Cardio Oncology Summit, Madrid , Spain, 2023. |
| 63. | Skulstad, H | Myocardial work seminar. | Oslo universitetssykehus, 2023. |
| 64. | Smedsrud, MK. | Childhood-onset arrhythmogenic right ventricular cardiomyopathy. | FFHB Forskningsstiftelsen, 2023. |
| 65. | Smedsrud, MK. | Genetiske kardiomyopatier. | Nasjonal fellesundervisning i barnekardiologi, 2023. |
| 66. | Smedsrud, MK. | Highly malignant disease in childhoodonset arrhythmogenic right ventricular cardiomyopathy. | The Marie Spångberg prize 2023. Presentation at the Norwegian Medical Association national board meeting. |
| 67. | Smedsrud, MK; Chivulescu, M; Forså, MI; Castrini, I; Aabel, EW; Rootwelt-Norberg, C; Bogsrud, MP; Edvardsen, T; Hasselberg, NE; Früh, A; Haugaa, KH. | Highly malignant disease in childhoodonset arrhythmogenic right ventricular cardiomyopathy. | The Oslo University Hospital prize for outstanding research article published in the second half-year of 2022. |
| 68. | Smedsrud, MK; Chivulescu, M; Forså, MI; Hasselberg, NE; Früh, A; Haugaa, KH. | Childhood-onset lamin A/C dilated cardiomyopathy. | AEPC 2023. |
| 69. | Smedsrud, MK; Chivulescu, M; Hasselberg, NE; Albinski, M; Barnes, A; Field, E; Früh, A; Kaski, JP; Haugaa, KH. | Lamin A/C dilated cardiomyopathy in children. | ESC 2023. |
| 70. | Smedsrud, MK; Chivulescu, M; Rootwelt-Norberg, C; Castrini, I; Aabel, EW; Five, CK; Hasselberg, NE; Früh, A; Haugaa, KH. | Lamin A/C dilated cardiomyopathy in childhood. | EHRA 2023. |
| 71. | Tangen, J; Nguyen, TM; Melichova, D; Klæboe, LG; Forså, MI; Andresen, K; Al Wazzan, A; Lie, Ø; Haugaa, KH; Brunvand, H; Edvardsen, T. | Dilated left atrium predicts mortality in patients with acute myocardial infarction. | The 21st Annual Norwegian Symposium on Heart Research, 2023. |
| 72. | Telle, Aa; Maleckar, M; Sundnes, J; Wall, ST; Boyle, PM. | Contractility And Local Stress Patterns Depend On Directionality Of Fibrosis Progression: Insights From Microscale Biomechanical Simulations. | American Heart Association 2023 Philadelphia. |
| 73. | Østvik, A; Grenne, B. | Artificial intelligence in heart ultrasound for improved patient care. | Norway Life Science, 2023. |
| 74. | Østvik, A; Grenne, B. | Morgendagens hjerteultralyd: Kan kunstig intelligens være den ekstra hånden helsevesenet trenger? | Helseteknologikonferansen, 2023. |
| 75. | Aaserud LT; Rootwelt-Norberg C; Five CK; Aabel EW; Castrini AI; Hasselberg N; Haugaa KH; Lie OH. | Disease progression in exercise-induced compared to desmosomal arrhythmogenic cardiomyopathy - a longitudinal cohort study. | EHRA, 2023. |

**ProCardio** Center for Innovation

**ProCardio Center for Innovation**
**Oslo University Hospital**
**Rikshospitalet**
**P.O Box 4950 Nydalen**
**0424 Oslo**

**www.heart-sfi.no**

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