ProCardio Center for Innovation

Centre for Research-based Innovation

The Research Council of Norway

Annual Report | 2021

ProCardio Center for Innovation

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SUMMARY

Dear colleagues, partners and friends,

Our first full year as ProCardio has passed. We should be proud of our Annual report 2021. The work performed by each of you is impressive and together we have managed to stay on track and to achieve considerable results in 2021. I am proud to see our projects progress. Thank you to every single one of you.

17 talented members joined ProCardio in 2021. Some work full or part time at the center and others are affiliated members through their research and participation in the center's work packages or administration. All members are equally important and will ensure our work in the next years. I wish to give you all the warmest welcome. Center PhD fellows Anders Wold Bjerring, Monica Chivulescu, Eystein Skjølsvik and Andrew Gilbert successfully defended their PhD thesis during 2021, all were preformed digitally.

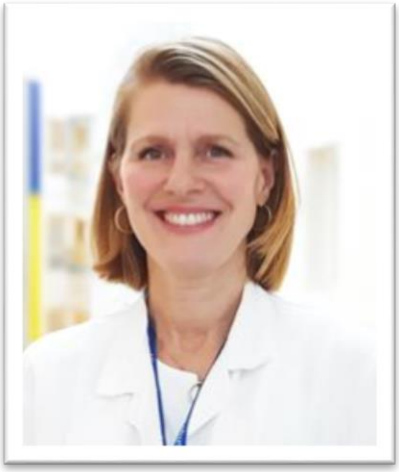
The year started with a two-day kick-off 6th-7th of January. Due to the pandemic, our kick-off unfortunately had to be done online. The meeting included introductions and presentations from all partners, as well as presentations about the collaboration in the center. There were also sessions for clinical and technical discussions in small groups. It is always a bit of a technical challenge when everything has to be kept online, but it worked very well in our case.

The absolute highlight, in my mind, was our fall meeting at Holmen Fjordhotell in September. For the first time, we could meet, talk, discuss, innovate, eat, drink and even swim together. Amazing. It became obvious that this is the optimal mode of contact. In 2022, we hope to attend more international congresses, further visits between partners and many more ProCardio in-person meetings. I look forward to a continued productive, exciting, and joyful collaboration.

Thank you all, together we are ProCardio.

Oslo 24.03.22

Kristina



Center 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

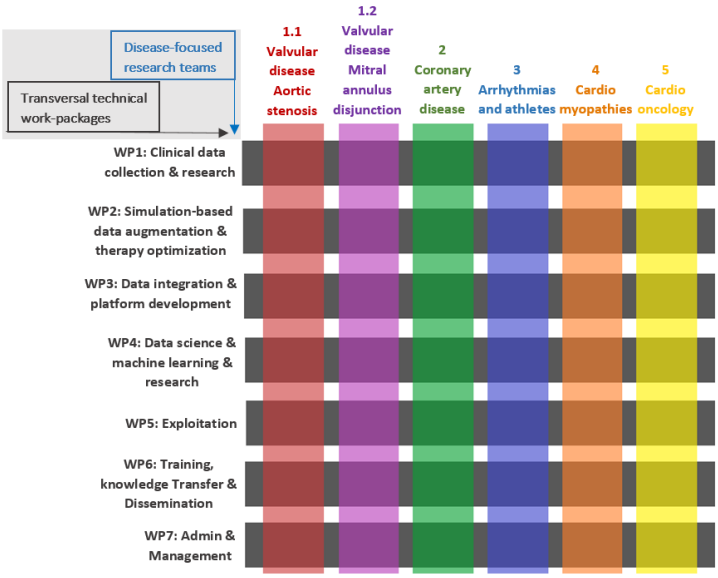
3) more accurate follow-ups

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.



The bidimensional model with vertical clinical targets and horizontal technical targets.

ORGANIZATION

ProCardio is hosted by Oslo University Hospital. The consortium consists of ten partners from both research and industry, in addition to the host institution. ProCardio is located at Oslo University Hospital, Rikshospitalet.

The University of Oslo, Domus Medica (DM4) at Sognsvannsveien 9 (entrance from Gaustadalléen 34), constitutes as the physical hub.

The center director, Kristina Haugaa is responsible for heading the center management. The center director will be assisted by the Scientific and Technical Manager who will be responsible for coordinating work of the teams.

Each clinical task group (T) is lead by clinical research and innovation deputies, liaising with WP leaders which ensure transversal synchronization of technical work among the different teams. In, parallel, exploitation, dissemination and innovation activities will be supervised by designated managers, Gunnar Hansen (GEVU), Thor Edvarsen (UiO) and a representative from OUS Dept. of Innovation, Christian Skattum. Dr. Mary Maleckar from SRL will act as a Scientific & Technical Manager and Maria Christine Ruud is the 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

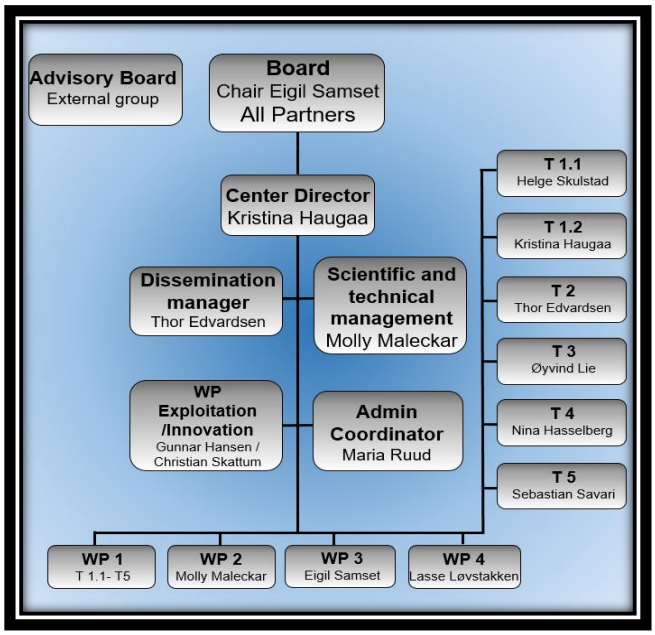
Hilde Nebb, UiO

Samuel Wall, Simula

Gunnar Hansen, GE Vingmed

Harald Brunvand, Sørlandet Sjukehus HF

Tom Marwick, Baker Institute



The organizational map of ProCardio

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.

Scientific partners:

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)

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

NTNU Norwegian University of Science and Technology

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.

simula

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

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

Industrial partners:

SØRLANDET SYKEHUS

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

DIPS

Partner name: DIPS AS

Knowledge: 1) Leading supplier of patient electronical medical records software solutions to Norwegian hospitals; 2) Expertize 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: GE Healthcare

Knowledge: World class design and manufacturing of diagnostic imaging and monitoring systems; 2) Extensive expertise in cardiology diagnostics, artificial intelligence development for imaging and waveforms, together with deep market understanding

Resources: a) Direct access to access to Edison AI Workbench; b) Fast-track integration of innovations into commercial products and application to other imaging modalities beyond ultrasound

Partner name: GE Vingmed Ultrasound

Knowledge: GE's center of excellence on ultrasound engineering; 2) World-class know-how in cardiovascular ultrasound acquisition, processing and analysis, speckle-tracking and strain imaging, artificial intelligence in ultrasound, 3D visualization and quantification; 3) Extensive insight on regulatory requirements and ultrasound market intelligence

Resources: a) provide ultrasound equipment and software to the center to ensure successful execution of clinical projects and data acquisition; b) Through the Developer Partnership Program industrial partners can benefit from a "fast track to innovation", which allows 3rd party solutions to distributed to the GEHC installed based through the GEHC Marketplace

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 the specifications provided by a physician/project

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. In order 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 as well as monthly meetings with center leaders and all members of ProCardio. The supervisory board meet bi-annually, in sync with the planned training and dissemination workshops.

The year started off with a kick-off in early January. Due to the current pandemic, the two-day event had to be held online. The meeting included presentations from all partners, as well as presentations about the collaboration in the center. There were also sessions for clinical and technical discussions in small groups. It is always a bit of a technical challenge when everything has to be kept online, but it worked very well.

Some of the participants at the January kick-off

As the year progressed and the infection rates dropped, the possibility for an in-person gathering was made possible. Finally, in September, all ProCardio members spent two days together at Holmen Fjordhotell in Asker, Norway at the ProCardio fall meeting.

Both days included workshops, presentations and competitions. A shared dinner Thursday evening was enjoyed by all.

PhD student Christine Rootwelt-Norberg presenting at the fall meeting

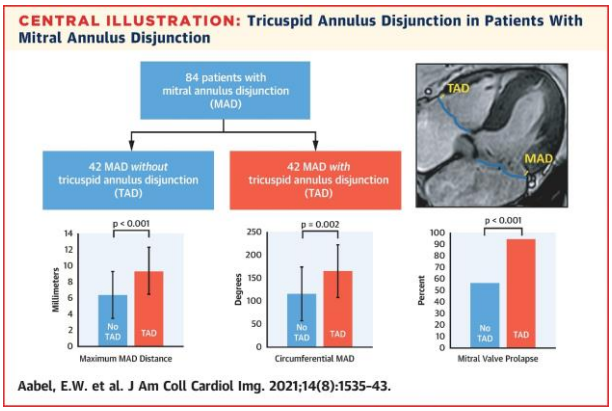
ProCardio members at the fall meeting dinner

SCIENTIFIC ACTIVITIES AND RESULTS

Tricuspid annulus disjunction – novel findings by cardiac magnetic resonance in patients with mitral annulus disjunction

Aabel EW, Chivulescu M, Dejgaard LA, Ribe M, Gjertsen E, Hopp E, Hunt TE, Lie ØH, Haugaa KH

Mitral annulus disjunction (MAD) is an abnormal feature of the hinge point of the mitral valve into the left ventricular myocardium, and can be present along the whole circumference of the mitral valve. This abnormal feature are mostly assessed by echocardiography or cardiac magnetic resonance imaging, and relates to life-threatening arrhythmias. However, annulus disjunction has never been described in the right side of the heart.



Central Illustration from the article published in the renowned journal "JACC Cardiovascular Imaging".

In this descriptive study, the authors collected cardiac magnetic resonance imaging from 84 patients with MAD and report, for the first time, the existence of right-sided annulus disjunction. However, tricuspid annulus disjunction was not associated with more ventricular arrhythmias. The study adds valuable knowledge for better understanding of this valve condition.

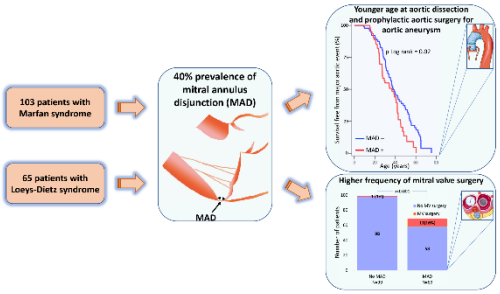
This study was published in the renowned journal "Journal of American College of Cardiology – Cardiovascular Imaging". The first author, presenting data from this study, received awards for best abstract on 19th "Annual Oslo Symposium on Heart Research" and best science presentation on "Fall Meeting of the Norwegian Cardiology Association".

Mitral annulus disjunction in Marfan and Loeys-Dietz syndromes

Chivulescu M, Krohg-Sørensen K, Scheirlynk E, Lindberg BR, Dejgaard LA, Lie ØH, Helle-Valle T, Skjølsvik ET, Estensen ME, Edvardsen T, Lingaas PS, Haugaa KH

Marfan and Loeys-Dietz syndromes are connective tissue disorders associated with aortic disease and degeneration of the mitral valve with prolapse. Mitral annulus is often involved in mitral valve prolapse leading to disjunction of the mitral annulus, an abnormal atrial displacement of the mitral valve leaflet hinge point.

In this study, the authors found that 40% of patients with Marfan and Loeys-Dietz syndromes had mitral annulus disjunction (MAD). Patients din disjunction underwent aortic surgery at younger age and mitral valve surgery more often. Therefore MAD was a marker of worse prognosis. Closer follow-up in connective tissue disorders´ patients with MAD could help in better planning surgery intervention.



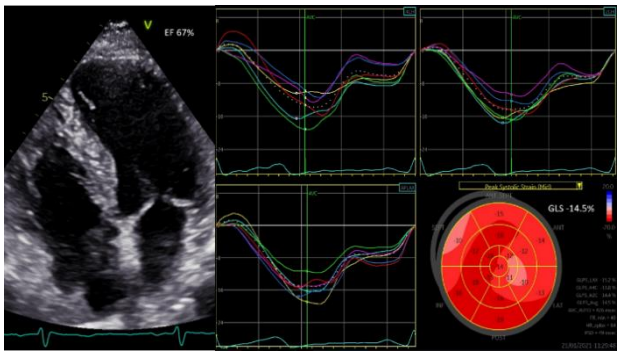
Central illustration summarizing main findings: aortic surgery at younger age and higher prevalence of mitral valve surgery in patients with mitral annulus disjunction

The results of the study were presentation orally at the largest Imaging Congress in Cardiology EuroEcho Best of Imaging 2020.

Reduced Cardiac Function by Echocardiography in a Minority of COVID-19 Patients 3 Months after Hospitalization

Tangen J, Aukrust P, Barratt-Due A, Skulstad H, Edvardsen T

Our prospective study included 92 patients hospitalized for COVID-19 and all were studied by echocardiography 3 months after hospitalization. All showed normal left ventricular (LV) function by LV ejection fraction. However, LV global longitudinal strain (GLS), was reduced in 15% of the patients.
Furthermore, we could not find any relationships between reduced GLS and disease severity (treatment at intensive care unit) or elevated high sensitivity cardiac troponin after 3 months. The majority of the patients with reduced GLS had arterial hypertension prior to COVID-19 infection; this might explain the impaired LV function, but we cannot exclude that this was caused by COVID-19.
J Am Soc Echocardiogr, doi: 10.1016/j.echo.2021.10.014



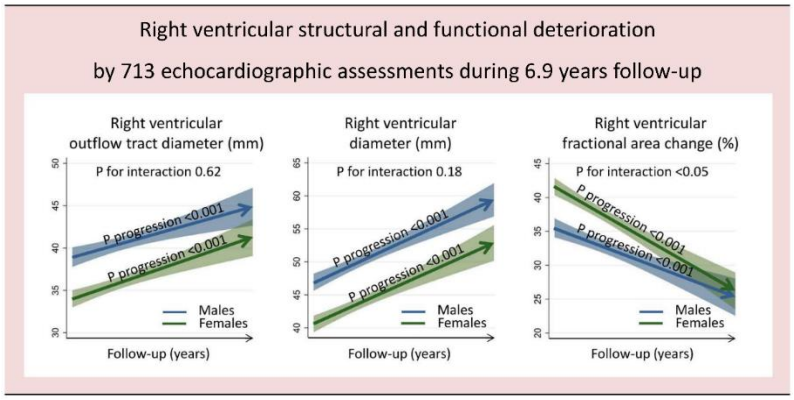
Patient with hypertensive heart disease, with normal LVEF and impaired LV GLS

Sex differences in disease progression and arrhythmic risk in patients with arrhythmogenic cardiomyopathy

Rootwelt-Norberg C, Lie ØH, Chivulescu M, Castrini AI, Sarvari SI, Lyseggen E, Almaas VM, Bogsrud MP, Edvardsen T, Haugaa KH

Arrhythmogenic cardiomyopathy is a genetic heart disease characterized by high risk of life-threatening arrhythmias. The severity of the disease varies greatly between patients, with some presenting in adolescents with cardiac arrest, while others go through life without any symptoms. Male patients are considered to be at higher risk of severe disease, but the mechanisms underlying this sex difference is not clearly understood.

This longitudinal cohort study compared the clinical disease manifestations in female and male arrhythmogenic cardiomyopathy patients followed at Oslo University Hospital, and was published in Europace in April 2021. Male patients had more pronounced disease and were more likely to experience life-threatening arrhythmias than females. However, males had also performed more exercise. Exercise is strongly associated with malignant outcome in arrhythmogenic cardiomyopathy. When adjusting for previous exercise dose, male sex was no longer a predictor of life-threatening arrhythmias. Furthermore, after implementation of exercise restrictions, disease progression during long-term follow-up was similar between males and females.

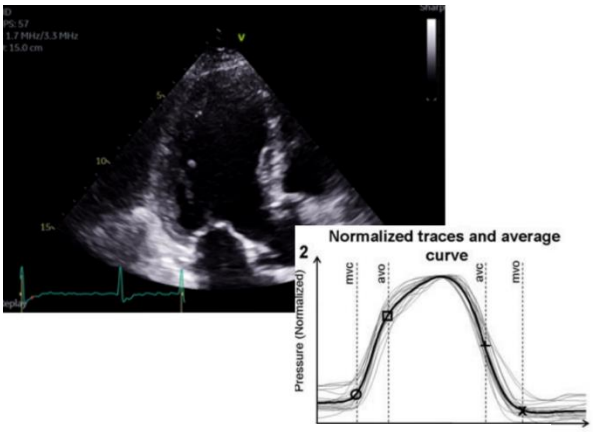


Male arrhythmogenic cardiomyopathy patients had worse disease at inclusion, but similar disease progression as females during follow-up

Automatic Valve Event Timing

Fermann BS, Østvik A

Automatic detection of valve events from 2D echocardiography is useful to make measurements more consistent with less inter-operator variability and improve the workflow in tools that rely on these measurements like Myocardial Work. While prior work has established machine learning methods to detect end-systole (aortic valve closure) and end-diastole (myocardial valve closure), we want to expand this to accurately identify valve openings as well. 2D APLAX images are collected and annotated with the four different valve events. A machine learning method will then be developed that incorporates both the temporal and spatial information in the 2D videos to accurately detect the valve events.

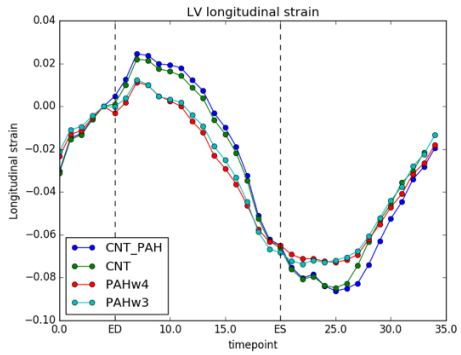


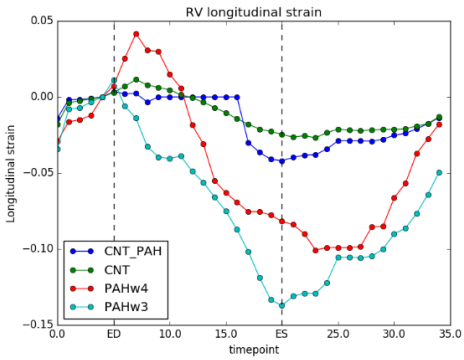
2D APLAX image used to detect valve event, as both left ventricular valves are visible there, bottom right shows the non-invasive pressure curve used in Myocardial Work, which requires valve events to scale.

Computer models of Pulmonary Arterial Hypertension and Right Ventricular Remodeling

Oscar Odeigah, Michael Bennington, Daniela Valdez-Jasso, Joakim Sundnes

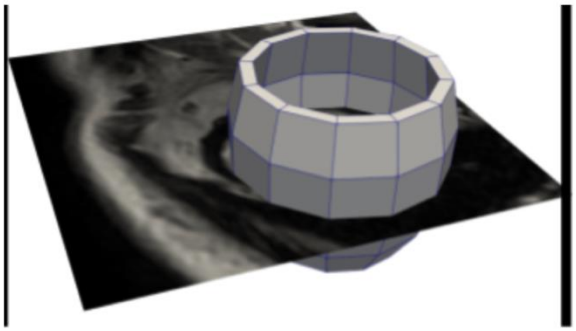
During early-stage pulmonary arterial hypertension (PAH), the right ventricle (RV) undergoes anatomical adaptation in the form of a thickened RV free wall, and material adaptation in the form of altered passive stiffness and contractility. The early-stage compensatory adaptations may help to preserve cardiac output but can later evolve into maladaptive remodelling and organ failure. The transition from compensatory to detrimental remodelling remains poorly understood. Using in vivo hemodynamic and morphological data from normotensive and hypertensive rats, we built idealized bi-ventricular finite element models representing different disease stages. RV wall thickness was based on ex vivo measurements, and passive material properties were prescribed based on planar biaxial mechanical data obtained from the same animals. Model simulations were then used to study how the presence of PAH affects the stress distribution in the right ventricular free wall, and how wall stress and RV function are altered by the induced changes in morphology, passive stiffness and contractility. Further numerical experiments were conducted to gain insight into the relative contribution of geometric and material adaptation to maintaining RV function in early-stage PAH, as well as the role of the septal wall. Such insights can facilitate a more comprehensive understanding of the compensatory remodelling that occurs during the disease progression.





Heart Shape as an Arrhythmia Predictor in Mitral Annular Disjunction

Balaban G, Aabel EW, Ribe M, Haugaa K, Maleckar M



Preliminary heart chamber geometry model fitted to a cardiac MRI scan of patient with mitral annular disjunction

Mitral annular disjunction is a heart condition characterised by a pathological heart morphology, where the mitral valve attachment points are located in the left atrium, rather than at their typical anatomical position in the valve plane. This condition has recently been associated with an increased risk of dangerous arrhythmia, and the mechanisms behind the disease and its arrhythmic risk are poorly understood. Are there any clues to be found by analyzing the overall heart shapes of the patients? The study authors intend to find out. Preliminary segmentations of MRI patients have been made, and a computational pipeline is being constructed.

Project in Progress

Can preprocedural echocardiography detect the risk for atrioventricular blockage after TAVI?

Kaya E, Klaeboe LG, Andresen K, Lie Ø, Aaberge L, Haugaa K, Edvardsen T, Skulstad H.

Aortic stenosis is a common valve disease and Transcatheter Aortic Valve Implantation (TAVI) is an effective therapy for patients with severe aortic stenosis. Complete atrioventricular block (AVB) that requires permanent pacemaker treatment is a common complication of TAVI and it is reported in up to one fifth of patients. Prediction of this complication could be important. Global longitudinal strain (GLS) and left ventricular mechanical dispersion (LVMD) by speckle tracking echocardiography (STE) are novel techniques that detect subtle changes in myocardial function and are found to be related to myocardial fibrosis. Thus, we aimed to investigate the association between LVMD and AVB development after TAVI.

A preliminary study has been performed where we retrospectively screened 168 consecutive patients after TAVI. Patients with abnormal ECG and changed conduction pre- and post-TAVI were excluded. Thus, data from 77 patients were analyzed. Of those, 16 patients needed a permanent pacemaker, and data from this group were compared to the remaining 61 patients. Baseline echocardiograms recorded before TAVI were used to assess GLS and LVMD by STE (Figure).

The preliminary results was published at the European Congress of Echocardiography in December 2021. We found that LVMD was increased in patients developing TAVI-induced complete AVB, although GLS showed that myocardial function was similar to patients who maintained post-procedural normal ventricular conduction. This finding may be important to identify myocardial properties associated with complete AVB after TAVI.

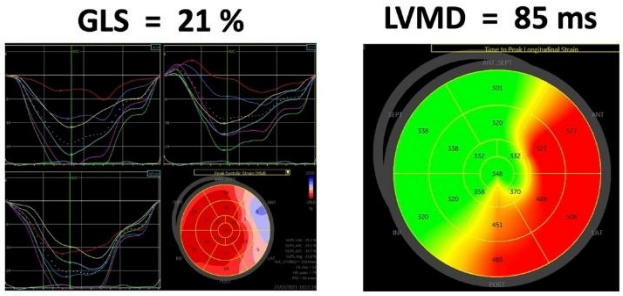


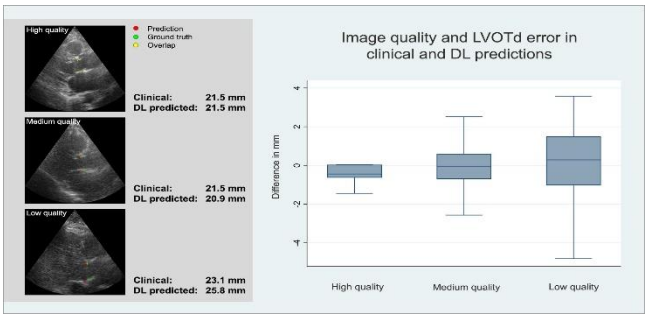
Figure: Normal global longitudinal strain (GLS) and increased Left Ventricular Mechanical Dispersion (LVMD) in a patient with total AVB.

A prospective study has been performed in 2021 and will be ended in 2022. This study will further explore if these findings can be used to determine the risk for needing a pacemaker or not after TAVI.

Deep learning for automated left ventricular outflow tract diameter measurements in 2D echocardiography

Sigurd Zha, Magnus Rogstadkjernet, Lars Gunnar Klæboe, Helge Skulstad, Thor Edvardsen, Eigil Samset, Pål H. Brekke

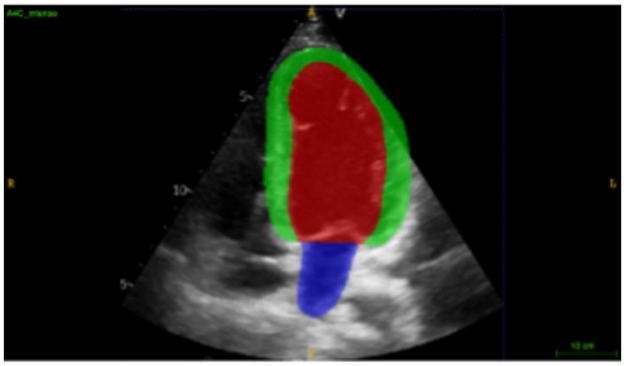
One of the main goals in Procardio is to develop tools for automatic calculate hemodynamic measurements like cardiac output (CO) and then also the severity aortic stenosis (AS). The first step in this calculation is automatic measurement of the left ventricular outflow tract diameter (LVOTd). In this project we investigated if LVOTd measurements from clinical echocardiographic exams could be used in a deep learning (DL) model to automatically perform LVOTd measurements with higher accuracy and consistency compared to current practice where the measurements are performed manually. Data was gathered as parasternal views with cardiologist annotated LVOTd coordinates were gathered from 1424 echocardiographic still images in 697 patients. The quality of the still image and annotated LVOT ground truth were individually graded as high, medium and low by experienced cardiologists to establish a rigorous training basis. Data was then randomly split into training, validation and testing sets (68%, 17%, 15%). A fully convolutional network based on the Resnet50 architecture was used in addition to a custom loss function with heatmap regression. Image augmentations were added to extend the dataset. The preliminary results were presented at the congress of European Society of Cardiology in august 2021 (figure).



In conclusion, the study has demonstrated that deep learning models are capable of measuring LVOTd with comparable accuracy to cardiologists. Even with a slightly lower precision when used on low quality echo images, DL-assisted LVOT measurement has a clear potential to increase repeatability and consistency of LVOTd measurements.

Heart Shape as a Disease Progression Marker in Lamin A/C

Balaban G, Castrini I, Hasselberg NE, Rootwelt-Norberg C, Løvstakken L, Haugaa K, Maleckar M



Automated segmentation of a 2D echocardiogram of a patient with Lamin AC cardiomyopathy, made with the deep learning tools of the Løvstakken research group. This represents a key step in achieving a fully automated analysis pipeline that can be scaled up to hundreds of patients.

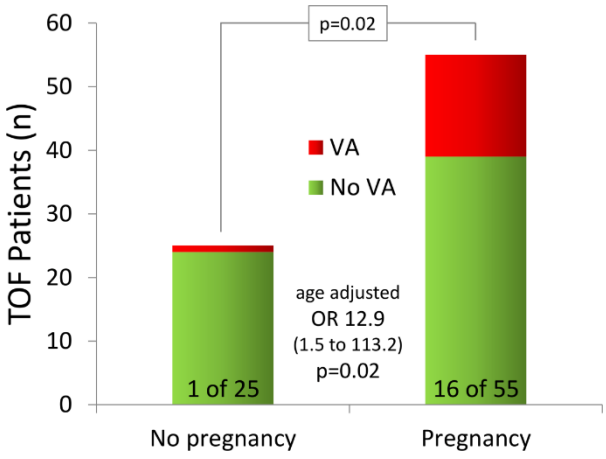
The 3D structure of the heart is often studied with MRI images with good in-plane resolution. Can we do the same with routine 2D echocardiography scans, which are faster and cheaper to acquire than MRI? The study authors seek to accomplish this in an intriguing cohort of genetic cardiomyopathy patients, whose hearts do not seem to undergo the usual dilation seen in other dilated cardiomyopathies. Three-dimensional heart shape analysis could provide novel insights into how the disease typically progresses, as well as new prognostic markers for heart failure and arrhythmia. The challenge of this study is increased by the longitudinal nature of the patient cohort, with repeated echo acquisitions available at irregular intervals for many patients. New methods and modelling techniques will be developed to make use of this exciting data.

Project in Progress

Impact of pregnancy and risk factors for ventricular arrhythmias in women with tetralogy of Fallot

Quattrone A, Lie OH, Nestaas E, de Lange C, Try K, Lindberg HL, Skulstad H, Erikssen G, Edvardsen T, Haugaa K, Estensen ME

Tetralogy of Fallot (TOF) is the most common cyanotic congenital heart disease, consisting in the combination of four cardiac defects: ventricular septal defect, right ventricular outflow obstruction, right ventricular hypertrophy and over-riding of the aorta. The modern corrective surgery has improved the life expectancy of children born with TOF to a survival of 72% forty years after surgical repair. However, sudden cardiac death and ventricular arrhythmia (VA) remain major concerns. Pregnancy is usually well tolerated in women with repaired TOF, while it is not clear whether the cardiovascular alterations related to pregnancy affect prognosis of TOF patients. We aimed to investigate the possible influence of pregnancy on the long term outcome on women operated for TOF.
Female patients over 18 years of age diagnosed for TOF and with history of complete surgical correction were investigated with both standard and strain echocardiography. Blood samples included heart failure marker as NT-proBNP. Pregnancy was associated with higher prevalence of VA, and the increased risk of VA was expressed by higher right ventricular mechanical dispersion and by with higher values of NT-proBNP. All those associations were shown to be independently of age.



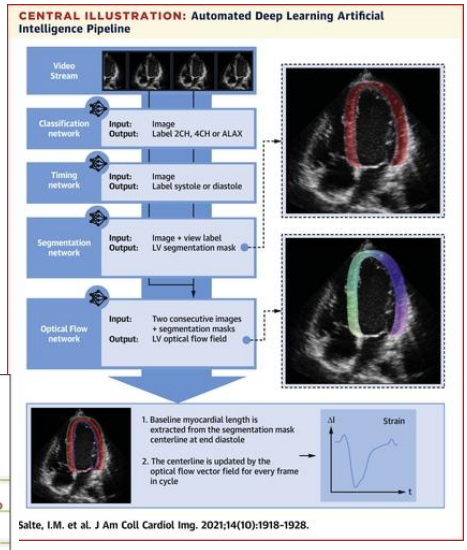
Prevalence of VA was higher in female patients corrected for TOF with history of pregnancy, also when adjusted for age at arrhythmic event. The red colored segments of two columns show that VA was significantly more represented in women who had experienced pregnancy compared to nulliparous. OR=odds ratio; TOF=tetralogy of Fallot; VA=ventricular arrhythmias.

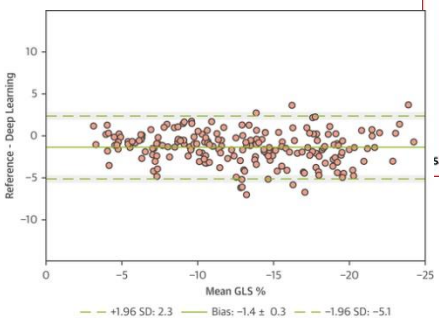
Artificial Intelligence for Automatic Measurement of Left Ventricular Strain in Echocardiography

Salte IM, Østvik A, Smistad E, Melichova D, Nguyen TM, Karlsen S, Brunvand H, Haugaa K, Edvardsen T, Løvstakken L, Grenne B

This study sought to examine if fully automated measurements of global longitudinal strain (GLS) using a novel motion estimation technology based on deep learning and artificial intelligence (AI) are feasible and comparable with a conventional speckle-tracking application. N=200 patients with a wide range of left ventricle (LV) function were included. Three standard apical cine-loops were analyzed using the AI pipeline. The AI method measured GLS and was compared with a commercially available semiautomatic speckle-tracking software.

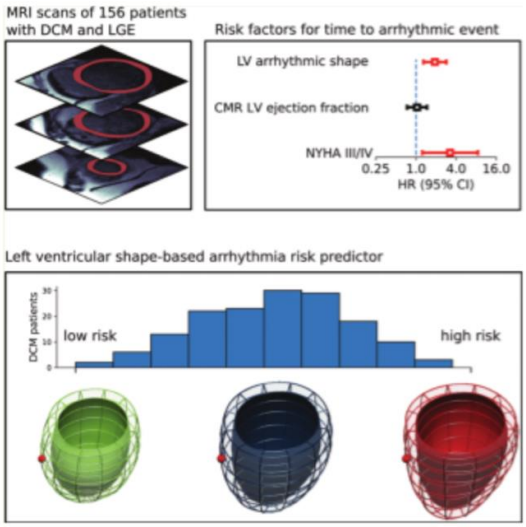
Through the range of LV function this novel AI method succeeds, without any operator input, to automatically identify the 3 standard apical views, perform timing of cardiac events, trace the myocardium, perform motion estimation, and measure GLS. Fully automated measurements based on AI could facilitate the clinical implementation of GLS.





Heart Shape as an Arrhythmia Predictor in Dilated Cardiomyopathy

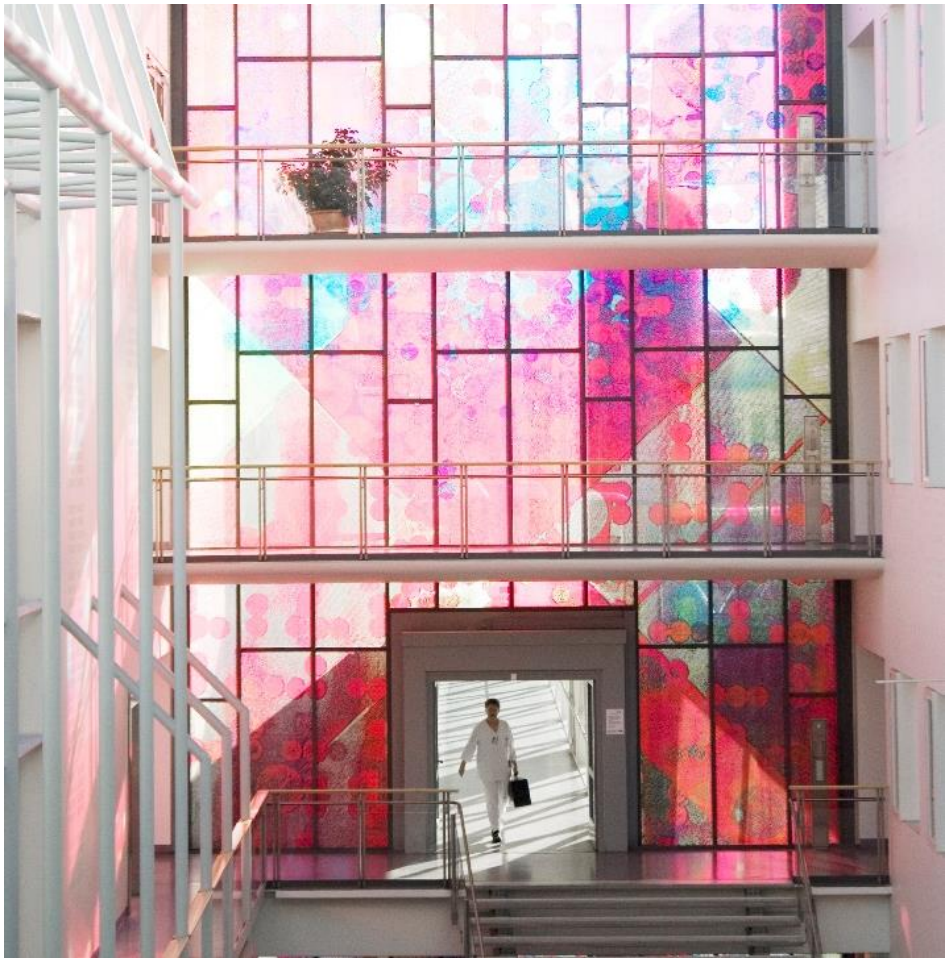
Balaban G, Halliday BP, Hammersley D, Rinaldi CA, Prasad SK, Bishop J, Lamata P



Graphical abstract from the published study

Can the shape of a patient's heart contain warning signs of impending arrhythmia and cardiac arrest? ProCardio member Dr. Balaban (Simula Research Laboratory) provides some preliminary evidence that this is the case in the disease dilated cardiomyopathy. Using a shape-based machine learning method, Balaban et al were able to derive an optimally prognostic end-diastolic left ventricular shape. The discovered prognostic marker was characterised by a paraboloidal longitudinal profile, with a relatively wide base, and was shown to predict major arrhythmic events up to several years in advance. The study represents the first effort to predict dangerous arrhythmic events using a comprehensive 3-D shape analysis.

Published in the Journal *EP Europace* Nov 2021.



INTERNATIONAL COOPERATION

ProCardio partners have long-standing collaborations with excellent collaborators at world-class institutions, such as the established relations and experience from previous multicenter trials with Johns Hopkins Hospital (Profs H Calkins and C James), Utrecht University, the Netherlands (Arco Teske), KU Leuven (Prof. JU Voigt), University of Milan, Italy (Prof L. Crotti and Prof Peter Schwartz), University of Montréal, Canada, among many others.

ProCardio will also benefit from several ongoing large projects, as well as other ongoing research efforts. Furthermore, two partners in the ProCardio Center for Innovation are international: Medtronic Inc (NED) and The Baker Heart and Diabetes Institute (AUS).

GE have been involved and supported an international multicenter study with Baker Heart and Diabetes Institute in Melbourne on the use of ultrasound based strain imaging for early detection of cardio-toxicity on cancer patient under treatment of chemo therapy. 27 hospitals participated in the study were patients were followed up during a 3-year period. The study generated new and important results which will be further investigated in ProCardio.

SimCardioTest

International collaboration through **Simula**'s collaboration in **SimCardioTest**, an Horizon Europe funded EU project (https://www.simcardiotest.eu/wordpress/). This includes profound collaboration with **10 partner organizations in 6 countries worldwide, including colleagues at INRIA (FR), UPF (ES), Boston Scientific (USA), and the VPH Institute (UK).**

SimCardioTest will challenge today's huge burden of cardiovascular diseases on the population worldwide with in-silico testing. It has the potential to transform the existing system of clinical trials, while reducing their costs and accelerating the availability of medical drugs/devices. Among other benefits, this testing platform shall demonstrate the possibility to perform experiments in controlled conditions and populations, repeat experiments as often as needed and test therapies for patient-specific pathologies.

SimCardioTest takes the mature field of cardiac simulations, which has previously demonstrated potential in generating clinically-relevant predictions, and brings it further through a web-based platform to perform standardised in-silico trials for testing the efficacy and safety of drugs and devices in the 3 concrete use cases. The first use case is related to the design of cardiac pacing leads, the second use case is based on left atrial appendage occluders (LAAO), and the third use case concerns drug safety and efficacy.

Data-driven ECG modeling – Danish collaborations at University of Copenhagen and beyond. Mary M. Maleckar (Simula Research Laboratory) collaborates, together with Michael Riegler (SimulaMet) with Prof. Jørgen Kanters and others at the University of Copenhagen (UCPH) on projects involving advanced ECG analysis, underpinned by biophysical cardiac simulations and deep learning/AI. UCPH projects also extend variously to topics in mechanisms of atrial fibrillation e.g., lifestyle factors, with Profs. Thomas Jespersen and Dominik Linz.

King's College London/Royal Brompton hospital. Artificial Intelligence in Ischaemic Heart Disease Cohort: Predicting Risk for Sudden Cardiac Arrest in Patients with Ischemic Heart Disease using Cardiac MRI and an Artificial Intelligence-based Synthetic Image Generator.

University of California San Diego (UCSD). In addition to ongoing activities with Prof. Andrew McCulloch's cardiomechanics lab in the department of bioengineering, Simula has a collaboration on pulmonary hypertension with Prof. Daniela Valdez-Jasso, and ongoing cellular-level mechanisms projects with Prof. Padmini Rangamani.

PARIS. An internationally funded project at Simula/computational cardiac modeling with clinical and computational collaborators, within the broad area of ProCardio interest.

The ProCardio host, Oslo University Hospital (OUS) is the leading center in several international multicenter studies. One of these studies is the Electromechanical Presages of Sudden Cardiac Death in the Young: integrating imaging, modelling and genetics for patient stratification (EMPATHY) project, OUS is collaborating with Maastricht University Medical Center, Cardiovascular Research Institute Maastricht (CARIM) (Prof. J. Lumens) and IRCCS Instituto Auxologico Italiano, Laboratory of cardiac arrhythmias of genetic origin (Prof. L. Crotti).

NEW MEMBERS

Mali Sæther
MD, PhD fellow
Focus: The effects of exercise on cardiovascular risk factor in breast cancer survivors

Linda Tangen Aaserud
MD, PhD fellow
Focus: Athletes and arrhythmias

Christian Kullmann Five
MD, PhD fellow
Focus: Disease progression and risk assessment in familial cardiomyopathies

Gabor Lossos
MSc, researcher
Focus: Cardio oncology dashboard and data

Bjørn-Jostein Singstad
MSc, researcher
Focus: machine learning and ECG for prediction of clinically relevant endpoints

Marit Kristine Smedsrud
MD, PhD, Postdoc fellow
Focus: Early detection of genetic heart diseases –Prevention of sudden cardiac death in children

Nina Eide Hasselberg
MD, PhD, Postdoctoral fellow
Focus: Disease progression and risk assessment in familial cardiomyopathies and arrhythmogenic mitral valve prolapse.

Gabriel Balaban
MSc, PhD, Postdoctoral fellow
Focus: Computational simulation of cardiac electromechanics, image-based statistical models, data augmentation and deep learning

Johan Anzules
BSc, researcher
Focus: Cardio oncology dashboard and data programming and arrhythmogenic mitral valve prolapse

NEW MEMBERS

Jurica Šprem
PhD
Focus: AI Tech Lead on research and development of AI within cardiovascular ultrasound at GE.

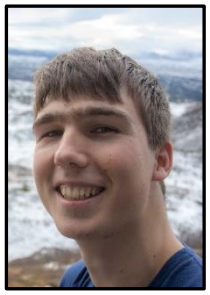
Oda Veflen Olsen
MSc
Focus: Project coordinator at GE.

Artem Chernyshov
MSc, PhD fellow
Focus: Automated functional imaging and analysis of the right ventricle with Deep Learning

Sten Roar Snare
PhD, Engineering Leader
Focus: Leading the CVUS team responsible for display and image analysis activities in CVUS.

Eivind Holt
Senior System Developer
Focus: Innovative solutions for providing relevant data. New data sources (patient data, IoT, other systems) and better user orientated integration.

John Nyberg
MD, PhD fellow
Focus: Automated Measurements of Regional Left Ventricular Strain Based on Echocardiography and Artificial Intelligence in Patients with Ischemic Heart Disease



Benjamin Strandli Fermann
SW Engineer / PhD fellow
Focus: Myocardial Work and various improvements to it, currently automated valve event timing for improved workflow.

Anders Milch
Sr. Field Clinical Research Specialist, BSc
Focus: Clinical studies on cardiac rhythm management devices at Medtronic

DISPUTATION

Anders Wold Bjerring
The early development of the Athlete's heart
January 29th 2021

Adjudication committee
First opponent: Senior Consultant, PhD, Stefano Caselli, Klinik Im Park – Herz Gefäss Zentrum Zürich, Switzerland
Second opponent: Senior Consultant, PhD, Erik Ekker Solberg, Diakonhjemmet Hospital
Third member and chair of the evaluation committee: Associate Professor Kirsten Krogh-Sørensen, University of Oslo

Chair of the Defence
Associate Professor Lars Fjellbirkeland, Faculty of Medicine, University of Oslo

Principal Supervisor
Consultant Cardiologist, PhD, Sebastian Imre Sarvari, Oslo University Hospital
Co supervisor
Professor Thor Edvardsen, University of Oslo

Summary
The athlete's heart is a term used to describe the changes in morphology and function seen in the hearts of athletes. While these changes can be substantial, our knowledge of the early development is limited. This is of particular importance as the Athlete's heart can mimic pathological conditions and in susceptible individuals, intense endurance exercise can be detrimental to cardiac health.

In his thesis «The early developement of the Athlete's Heart» Anders Wold Bjerring has followed a cohort of promising young cross-country skiers from age 12 to age 18 and described the changes in morphology and function using traditional and novel echocardiographic methods. Participants also underwent cardiopulmonary exercise tests and rigorous assessment of exercise regimes.

At age 12, the cross-country skiers already had both greater wall thickness and greater chamber volumes than controls. These changes continued throughout adolescence. At age 18, the cohort contained some of the most promising young cross-country skiers in Norway and most had undergone substantial cardiac changes.

Surprisingly, cardiac remodelling was not uniform in nature, but dynamic with distinct phases of concentric and eccentric remodelling. This was not predicted by the prevailing hypothesis but provides new insight into the development of the athlete's heart

DISPUTATION

Monica Chivulescu
Prediction of outcome in genetic cardiac diseases
October 4th 2021

Adjudication committee
First opponent: Associate Professor Martina Perazzolo Marra, University of Padova
Second opponent: Associate Professor Håvard Dalen, NTNU
Third member and chair of the evaluation committee: Professor Theis Tønnessen, University of Oslo
Chair of the Defence
Associate Professor Lars Fjellbirkeland, University of Oslo

Principal Supervisor
Professor Kristina Haugaa, University of Oslo
Co supervisor
Professor Thor Edvardsen, University of Oslo

Summary
Cardiac involvement is the main cause of decreased survival in patients with genetic cardiac diseases. Fatal arrhythmias at young age are a recognized cause of death in these patients. Better characterization of the outcome and identification of prognostic markers are necessary for early intervention and prevention of fatal events in these patients.

The aim of this thesis was to describe disease outcome in patients with genetic cardiac diseases associated with risk of sudden cardiac death at young age: arrhythmogenic cardiomyopathy, Brugada syndrome and inherited connective tissue disorders.

We found high disease penetrance in family members of patients with arrhythmogenic cardiomyopathy, similar structural disease progression between patients with arrhythmogenic cardiomypathy and their family members and higher arrhythmic risk in patients with structural disease progression.

There was a considerable overlap between Brugada syndrome and arrhythmogenic cardiomyopathy: 24% of patients with Brugada syndrome had electrical features and 84% had structural features of arrhythmogenic cardiomyopathy. Brugada syndrome patients with arrhythmogenic cardiomyopathy features had worse prognosis. Presence of right ventricular outflow tract dilatation along with syncope and spontaneous type I ECG improved detection of arrhythmic events in patients with Brugada syndrome.

Mitral annulus disjunction had a high prevalence in patients with inherited connective tissue disorders. Mitral annulus disjunction was associated with a more severe disease phenotype with aortic event (aortic dissection or prophylactic aortic surgery) at younger age and higher need for mitral valve surgery.

Overall, these findings indicate that a close follow-up might be necessary even in individuals previously thought to be at low risk. Presence of markers of high arrhythmic risk or severe disease phenotype should lead to closer monitoring and appropriate interventions in order to prevent fatal events.

DISPUTATION

Eystein Skjølsvik
Natural progression and arrhythmic risk in patients with cardiomyopathies
November 10th 2021

Adjudication committee
First opponent: Associate Professor Neal Kush Lakdawala, Brigham and Women's Hospital, USA
Second opponent: Professor Emeritus Terje Skjærpe, St. Olavs Hospital
Third member and chair of the evaluation committee: Professor Emeritus Ingebjørg Seljeflot, University of Oslo
Chair of the Defence
Researcher Cathrine Rein Carlson, University of Oslo

Principal Supervisor
Professor Kristina Haugaa, University of Oslo
Co supervisor
Professor Thor Edvardsen, University of Oslo

Summary
The most common familial dilated cardiomyopathy is due to lamin A/C gene mutations. Lamin A/C cardiomyopathy is a highly penetrant, and age dependent disease with a dismal prognosis. Competitive sports may worsen the prognosis, but evidence is limited and the effect of exercise is still unknown. The progression lamin A/C disease related to age is still unclear. We hypothesized that exercise worsen lamin A/C cardiomyopathy.

By cardiac imaging we studied how disease progression relates to exercise exposure and end stage heart failure. We observed that lamin A/C patients with greater exercise exposure had worse cardiac function and more atrial fibrillation than those with less. Lamin A/C disease starts at young age with electrical disease. Structural heart disease occurs from middle age. Right ventricular dysfunction and tricuspid regurgitation were associated with imminent end stage heart failure. Our findings may imply exercise restriction in lamin A/C disease. Assessment of right ventricular function and tricuspid regurgitation may be prognostic in lamin A/C disease.

Mitral valve prolapse (MVP) is common, and the prognosis is good. However in autopsy materials of sudden death in the young, MVP is disproportionally common. Mitral annulus disjunction (MAD) is a pathological atrial displacement of the mitral leaflet hinge-point. MAD may exist alone, but it's commonly associated with MVP and sudden death. We aimed to describe the clinical characteristics of MAD, explore the anatomy and its relation to MVP and severe ventricular arrhythmia. Palpitations were the most common symptom in MAD. MAD is easily recognizable by echocardiography and exists in varying degree along the posterior mitral-leaflet. Severe ventricular arrhythmias are related to younger age, scarring in the papillary muscle and the existence of MAD without concomitant MVP. The finding of MAD by echocardiograpy may be of prognostic significance.

HIGHLIGHTS

In September, all ProCardio members were finally able to meet in-person at Holmenkollen Fjordhotell.

The two-day event included presentations from all partners, a summary of the WP-progress as well as workshops, friendly competition and a shared dinner.

Norsk Cardiologisk Selskap were able to hold their annual fall meeting again 28.-30. October. PhD fellow Tove-Elizabeth Hunt presented her work “Effect of continuous positive airway pressure therapy on recurrence of atrial fibrillation after catheter ablation in patients with obstructive sleep apnea: A randomized controlled study”. PhD fellow Eivind Westrum Aabel won the session with best oral abstract presentation.

ProCardio co-hosted the Annual Oslo Symposium on Heart Research at Soria Moria Hotel 23.-24. September.

PhD fellow Eivind Westrum Aabel won the prize for best abstract in the session for Cardiac function and imaging with his abstract presentation titled “Tricuspid annulus disjunction is a common finding in patients with mitral annulus disjunction”.

The 19th Annual Oslo Symposium on Heart Research
Soria Moria Hotel, 23.-24.09.2021

Thursday September 23rd

11:30-12:00 Registration
12:00-12:00 Lunch

13.00-13.05 Welcome Kristina H. Haugaa, OUS/UiO

13:05-14:00 Novel diagnostic methods and treatment strategies
Chairs: Thor Edvardsen, UiO/OUS and Mathis K. Stokke, UiO/OUS

Kaspar Broch, OUS
Immunomodulation in heart failure
15 min +5

Bjørnar Grenne, St. Olav
Artificial intelligence in echocardiography
15 min +5

Kristina H. Haugaa, OUS/UiO
Arrhythmic mitral valve syndrome – research raises more questions than answers
10 min +5

14:00-16:00 Abstract Sessions:
Moderators decide about 15 min break during abstract presentations

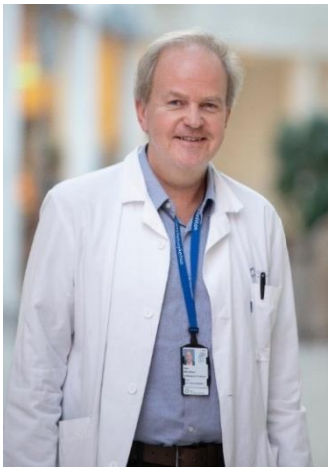
Biomarkers and translational science
- Biomarkers, Inflammation and cardiac remodeling
Panel: Stein Ørn, UiB, Kristin Aaker, UiB, Ivar Sjaastad, OUS/UiO, Finn Olav Levy, UiO, Catherine Carlson, OUS/UiO, Bill Leach, OUS/UiO, Geir Christensen, UiO/OUS, Maria Vistnes, UiO, Ragnhild Halvorsen, OUS, Kåre Olav Stensløkken, UiO, Ingebjørg Seljeflot UiO/OUS
Moderators: Eva R. Pedersen, UiB, Øystein Ellingsen, NTNU

Cardiac function and imaging
- Myocardial function and exercise
Panel: Ole Jakob Elle, UiT, Thor Edvardsen, UiO/OUS, Mette Erlensson, OUS, Henrik Schirmer, AHUS/UiO, Øystein Lie, OUS, Håvard Dalen, NTNU/ St. Olav, Sebastian Sarvari, OUS
Moderators: Eva Gerdts, HUS/UiB, Lars Gullestad, OUS/UiO

Genetic cardiac disease and arrhythmias
Panel: Nina Hasvedberg, OUS, Einar S. Dorsthen HUS, Vibeke Ahlman OUS, Ida G. Lunde OUS/UiO, Mathis K. Stokke, UiO/OUS, Kristina H. Haugaa, OUS/UiO
Moderators: Mai Tone Lennebakken UiB, Jan Pål Loennechen, St. Olav, NTNU

18:00 Dinner

ProCardio Center for Innovation | NORHEART | Oslo University Hospital



Professor Thor Edvardsen received the National Association for Public Health's Heart Research Prize for 2021. He received the prize due to international and national recognition for his research on new diagnostical imaging methods in early myocardial diseases.

In September, Kristina Haugaa, Nina Hasselberg and Christine Rootwelt-Norberg attended the ARVC Registry Jubileum Meeting, a 2-day-meeting in Trolleholm, Sweden.

Faculty of Medicine

Institute of Clinical Medicine

← About the institute ← News and events ← News ← 2022

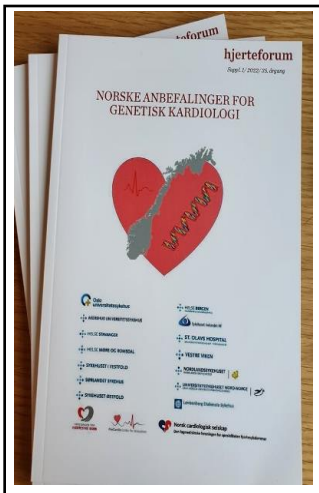
Christine Rootwelt-Norberg receives Young Investigator Award

Doctoral Research Fellow Christine Rootwelt-Norberg aims to become a leading professional in genetic cardiology. She recently received an award for her presentation at the EuroEcho conference.

Associate Professor Kristina Haugaa (left) and Doctoral Research Fellow Christine Rootwelt-Norberg (right) after she received the award. Image: Maria Ruud, ProCardio

EuroEcho is an annual conference in cardiology organised by the European Society of Cardiology. Each year, the Young Investigator Award is given to a young researcher

EuroEcho is an annual conference in cardiology organised by the European Society of Cardiology. Each year, the Young Investigator Award is given to a young researcher who participates at the conference. In December 2021, PhD fellow Christine Rootwelt-Norberg received the award for her presentation of the study "Disease progression rate is a strong predictor of ventricular arrhythmias in patients with cardiac laminopathies - a primary prevention cohort study"



In 2021, the booklet "Norwegian recommendations for genetic cardiology" was completed. This book provides a general consensus on the diagnostics, treatment and follow-up for genetic cardiac patients. This comprehensive collaboration was led by Kristina Haugaa.

NCS' research prize awarded ProCardio board member Rune Wiseth. Head of Cardiac Clinic at St. Olavs University hospital, Trondheim was awarded the prestigious Research Prize from the Norwegian Cardiac Society (NCS) during the national conference October 2021. The prize winner is a board member in ProCardio, representing Norwegian University of Science and Technology.

Årets koder: - Utviklere er ikke bare "kodeapekatter"

Utviklere har ansvar for å sette ned foten og tvinge kursen når planer og krav er lite fornuftige, mener vinneren av kode24-prisen Årets koder.

Eivind Holt anbefaler alltid nye utviklere å ha øynene åpne for områder i bedriften hvor kompetansen er svak. Foto: Sebastian Loraas /

DIPS' programmer, Eivind Holt won the award for Programmer of the year. The title is awarded by "Kode 24", an online newspaper for programmers in Norway. Amongst five nominees, Eivind Holt received the most votes to win the title.

PROCARDIO MEMBERS IN MEDIA

kristina Haugaa, Source: VG

Jorun Tangen, Source: Forskning.no

Kristina Haugaa, Source: Aftenposten

Anders Bjerring, Source: NRK

Axel Borge, Source: Finansavisen

Marit Kristine Smedsrud, Source: Foreningen for Hjertesyke Barn

Eigil Samset, Source: Youtube

APPENDIX

Annual Accounts 2021

Funding	Amount*
The Research Council	2 946
The Host Institution (Oslo University Hospital)	2 519
Research Partners	
University of Oslo	415
Simula Research Laboratory	461
Norwegian University of Science and Technology	751
Sørlandet Hospital	-
Baker Heart and Diabetes Institute	109
Enterprise partners	
GE Healthcare	2 846
GE Vingmed Ultrasound	2 747
Medtronic	558
Sesam AS	127
DIPS AS	361
Other Public Funding	3 524
Total	17 365

Costs	Amount*
The Host Institution (Oslo University Hospital)	7 484
Research Partners	
University of Oslo	415
Simula Research Laboratory	461
Norwegian University of Science and Technology	1 168
Sørlandet Hospital	-
Baker Heart and Diabetes Institute	109
Enterprise partners	
GE Healthcare	2 846
GE Vingmed Ultrasound	2 747
Medtronic	558
Sesam AS	127
DIPS AS	361
Total	17 365

**All figures in 1000 NOK*

Personnel

Researchers		
Name	**Institution**	**Main research area**
Kristina Hermann Haugaa	OUS	Cardiogenetics, arrhythmias
Helge Skulstad	OUS	Cardiac imaging
Sebastian Savari	OUS	Cardiac imaging, oncology
Øyvind Haugen Lie	OUS	Athletes and arrhythmias
Pål Haugar Brekke	OUS/ DIPS	Data integration & platform development
Kristoffer Russel	OUS	Invasive cardiology
Kaspar Broch	OUS	Heart failure
Lars Aaberge	OUS	Invasive cardiology and intensive cardiac care
Thomas Helle Valle	OUS	Myocardial function an cardiac imaging

Finn Hegbom	OUS	Elecrtophysiology
Mette-Elise Estensen	OUS	Congenital heart disease
Klaus Mubræch	OUS	Cardiac imaging
Christian Eek	OUS	Invasive cardiology and intensive cardiac care
Njord Nordstrand	OUS	Intensive cardiac care
Kari Melberg	OUS	Myocardial function and cardiac imaging
Jan Otto Beitnes	OUS	Cardiac imaging
Erlend Sturle Berg	OUS	Invasive cardiology
Lars Dejgaard	OUS	Electrophysiology
Vibeke Almaas	OUS	Cardiomyopathies
Bjørn Bendz	OUS	Invasive cardiology
Elin Bjurstrøm	OUS	Cardiogenetics
Kristin Nordvoll	OUS	Cardiogenetics
Margareth Ribe	OUS	Cardiac imaging
Ketil Lunde	OUS	Invasive cardiology
Jan Otto Beitnes	OUS	Cardiac imaging
Bjørn-Jostein Singstad	OUS	Scientific programming
Johan Abel Anzules	OUS	Scientific programming
Gabor Lossos	OUS	Scientific programming
Andreas Früh	OUS	Myocardial function and cardiac imaging
Thor Edvardsen	UiO	Cardiac imaging
Eigil Samset	GE	Data integration & platform development
Kristin McLeod	GE	Data integration & platform development
Olivier Gerard	GE	Data integration & platform development

Jurica Sprem	GE	Data integration & platform development
Sten Roar Snare	GE	Data integration & platform development
Magnus Reinfelt Krogh	GE	Data integration & platform development
Benjamin Ferrman	GE	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	Simulation-based data augmentation and therapy optimization
Hermenegild Arevaro	Simula	Simulation-based data augmentation and therapy optimization
Trond Bertil Barstad	Sesam	Data integration & platform development
Stein Håvard Pedersen	Sesam	Data integration & platform development
Gabriel Constantin Vig	Sesam	Data integration & platform development
Kolbjørn Vilnes	Sesam	Data integration & platform development
Geir Atle Hegsvold	Sesam	Data integration & platform development
Liv Bollvåg	DIPS	Data integration & platform development
Bjørn Fjugstad	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
Svein Arne Aase	NTNU	Data science and machine learning
Harald Brunvand	SS	Coronary artery disease

Gunnar Hansen	GE Vingmed	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
Tom Marwick	The Baker Heart and Diabetes Institute	Cardiac imaging, oncology

Visiting Researchers

Name	Affiliation	Nationality	Sex M/F	Duration	Topic
Esra Kaya	OUS	Turkish	F	1 year	Aortic stenosis
Feddo Kirkels	OUS	Dutch	M	< 1 year	Imaging and modelling of progression in arrhythmogenic cardiomyopathy

Postdoctoral researchers with financial support from the Centre budget

Name	Nationality	Start	Sex M/F	Topic
Nina Hasselberg	Norwegian	01.05.2021	F	Disease progression and risk assessment in familial cardiomyopathies and arrhythmogenic mitral valve prolapse
Gabriel Balaban	Czech-Canadian	01.04.2021	M	Disease progression and risk assessment in familial cardiomyopathies and arrhythmogenic mitral valve prolapse
Marit Kristine Smedsrud	Norwegian	01.04.21	F	Early detection of genetic heart diseases – Prevention of sudden cardiac death in children

PhD students with financial support from the Centre budget

Name	Nationality	Start	Sex M/F	Topic
Christian Kullmann Five	Norwegian	06.09.2021	M	Disease progression and risk assessment in familial cardiomyopathies and arrhythmogenic mitral valve prolapse
Linda Tangen Aaserud	Norwegian	01.11.2021	F	Athletes and arrhythmias
Artem Chernyshov	Russian	06.09.2021	M	Functional Analysis of the Right Ventricle with Deep Learning

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
Mali Sæther	OUS/HSØ	Norwegian	01.02.2021- 31.01.2024	F	The effects of exercise on cardiovascular risk factors in breast cancer survivors
Monica Chivulescu	OUS/HSØ	Romanian	20.07.2019- 04.10.2021	F	Prediction of outcome in genetic cardiac diseases
Marianne Inngjerdingen Forså	OUS/HSØ	Norwegian	05.02.2018- 04.12.2022	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	Norwegian	01.12.2020- 30.11.2023	F	Outcome after myocardial infarction
Alessia Quattrone	OUS/HSØ	Italian	01.02.2017- 01.03.2021	F	Risk stratification in adults operated for tetrelogy of Fallot
Christine Rootwelt-Norberg	UiO/NFR/EU	Norwegian	01.05.2019-16.02.2023	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- 31.03.2023	F	ARVC in pregnancy
Tove-Elizabeth Hunt	OUS/HSØ	Norwegian	01.09.2016- 31.08.2023	F	Atrial fibrillation and sleep apnea

Daniela Melichova	SS	Norwegian	01.04.2014-01.04.2023	F	Improved prediction of clinical outcome with the use of global strain and mechanical dispesrion in patients with myocardial infarction, heart failure, and patients who receive primary prophylactic internal cardioverter defibrillator
Andrew Gilbert	GE	American	02.05.2018- 04.07.2021	M	Automating Echocardiography Analysis using Deep Learning: Efficient measurement, workflow, and data generation
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	Simula	Norwegian	01.11.2020-01.11.2023	F	Personalized Virtual Heart Models for Diagnosis and Treatment Planning in Patients with Heart Failure
Anders Wold Bjerring	OUS/HSØ	Norwegian	01.03.2017 - 17.03.20	M	The early development of the Athlete's heart
Eystein Skjølsvik	OUS	Norwegian	09.11.2018 – 10.11.2021	M	Natural progression and arrhythmic risk in patients with cardiomyopathies

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
Magnus Rogstadtjernet	M	01.09.2019- 31.08.2022	A novel deep learning based method for left ventricular strain measurements: Repeatability and accuracy compared to experienced echocardiographers.

Scientific articles

A, Bularga; A, Saraste; R, Fontes-Carvalho; E, Holte; M, Cameli; B, Michalski; MC, Williams; T, Podlesnikar; A, D'Andrea; I, Stankovic; NL, Mills; R, Manka; DE, Newby; J, Schultz-Menger; KH, Haugaa; MR, Dweck. EACVI survey on investigations and imaging modalities in chronic coronary syndromes European heart journal cardiovascular Imaging 2021 1-7

A, Cohen; E, Donal; V, Delgado; M, Pepi; T, Tsang; B, Gerber; L, Soulat-Dufour; G, Habib; P, Lancellotti; A, Evangelista; B, Cujec; N, Fine; MJ, Andrade; M, Sprynger; M, Dweck; T, Edvardsen; BA, Popescu EACVI recommendations on cardiovascular imaging for the detection of embolic sources: endorsed by the Canadian Society of Echocardiography Eur Heart J Cardiovasc Imaging 2021 24-57

A, D'Andrea; MR, Dweck; E, Holte; R, Fontes-Carvalho; M, Cameli; HS, Aboumarie; HC, Diener; KH, Haugaa EACVI survey on the management of patients with patent foramen ovale and cryptogenic stroke European heart journal cardiovascular Imaging 2021 135-141

A, Gilbert; M, Marciniak; C, Rodero; P, Lamata; E, Samset; K, Mcleod. Generating Synthetic Labeled Data From Existing Anatomical Models: An Example With Echocardiography Segmentation IEEE Trans Med Imaging 2021 DOI: 10.1109/TMI.2021.3051806 pp. 2783- 2794

A, Ostvik; IM, Salte; E, Smistad; TM, Nguyen; D, Melichova; H, Brunvand; K, Haugaa; T, Edvardsen; B, Grenne; L, Lovstakken Myocardial function imaging in echocardiography using deep learning IEEE Trans Med Imaging 2021 1340- 1351 Vol. 5

A, Pelliccia; S, Sharma; S, Gati; M, Bäck; M, Börjesson; S, Caselli; JP, Collet; D, Corrado; JA, Drezner; M, Halle; D, Hansen; H, Heidbuchel; J, Myers; J, Niebauer; M, Papadakis; MF, Piepoli; E, Prescott; JW, Roos-Hesselink; Stuart A, Graham; RS, Taylor; PD, Thompson; M, Tiberi; L, Vanhees; M, Wilhelm. 2020 ESC Guidelines on sports cardiology and exercise in patients with cardiovascular disease European heart journal 2021 17-96

A, Quattrone; OH, Lie; E, Nestaas; Lange C, de; K, Try; HL, Lindberg; H, Skulstad; G, Erikssen; T, Edvardsen; K, Haugaa; ME, Estensen. Impact of pregnancy and risk factors for ventricular arrhythmias in women with tetralogy of Fallot Open Heart 2021 Vol. 1

A, Quattrone; OH, Lie; E, Nestaas; Lange C, de; K, Try; HL, Lindberg; H, Skulstad; G, Erikssen; T, Edvardsen; K, Haugaa; ME, Estensen. Long-term follow-up and sex differences in adults operated for tetralogy of Fallot. *Open heart*. 2021;8.

A, Svensson; PG, Platonov; KH, Haugaa; W, Zareba; HK, Jensen; H, Bundgaard; T, Gilljam; T, Madsen; J, Hansen; LA, Dejgaard; LO, Karlsson; A, Gréen; B, Polonsky; T, Edvardsen; JH, Svendsen; C, Gunnarsson Genetic Variant Score and Arrhythmogenic Right Ventricular Cardiomyopathy Phenotype in Plakophilin-2 Mutation Carriers Cardiology 2021 DOI: 10.1159/ 000519231

A, Vahanian; F, Beyersdorf; F, Praz; M, Milojevic; S, Baldus; J, Bauersachs; D, Capodanno; L, Conradi; Bonis M, De; Paulis R, De; V, Delgado; N, Freemantle; M, Gilard; KH, Haugaa; A, Jeppsson; P, Jüni; L, Pierard; BD, Prendergast; JR, Sádaba; C, Tribouilloy; W, Wojakowski. 2021 ESC/EACTS Guidelines for the management of valvular heart disease European journal of cardio-thoracic surgery : official journal of the European Association for Cardio-thoracic Surgery 2021 727-800

ACA, Azevedo; MVL, Barros; LG, Klaboe; T, Edvardsen; HS, Costa; GMM, Paixao; ORS, Junior; MCP, Nunes; MOC, Rocha. Association between myocardial mechanical dispersion and ventricular arrhythmogenicity in chagas cardiomyopathy Int J Cardiovasc Imaging 2021 2727- 2734 Vol. 9

AH, Christensen; PG, Platonov; A, Svensson; HK, Jensen; C, Rootwelt-Norberg; P, Dahlberg; T, Madsen; TC, Frederiksen; T, Heliö; KH, Haugaa; H, Bundgaard; JH, Svendsen. Complications of implantable cardioverter-defibrillator treatment in arrhythmogenic right ventricular cardiomyopathy Europace : European pacing, arrhythmias, and cardiac electrophysiology : journal of the working groups on cardiac pacing, arrhythmias, and cardiac cellular electrophysiology of the European Society of Cardiology 2021

AH, Christensen; PG, Platonov; HK, Jensen; M, Chivulescu; A, Svensson; P, Dahlberg; T, Madsen; TC, Frederiksen; T, Heliö; ØH, Lie; KH, Haugaa; J, Hastrup Svendsen and H, Bundgaard. Genotype-phenotype correlation in arrhythmogenic right ventricular cardiomyopathy-risk of arrhythmias and heart failure. *Journal of medical genetics*. 2021

AJS, Coats; SD, Anker; A, Baumbach; O, Alfieri; Bardeleben RS, von; J, Bauersachs; JJ, Bax; S, Boveda; J, Celutkiene; JG, Cleland; N, Dagres; T, Deneke; D, Farmakis; G, Filippatos; J, Hausleiter; G, Hindricks; EA, Jankowska; M, Lainscak; C, Leclercq; LH, Lund; T, McDonagh; MR, Mehra; M, Metra; N, MewtonB, Prendergast. The management of secondary mitral regurgitation in patients with heart failure: a joint position statement from the Heart Failure Association (HFA), European Association of Cardiovascular Imaging (EACVI) and European Association of Percutaneous Cardiovascular Interventions (EAPCI) of the ESC European Heart Rhythm Association (EHRA) Eur Heart J 2021 eurheartj/ ehab086 1254-69 Vol 13

AW, Bjerring; SD, Fosså; HS, Haugnes; R, Nome; TM, Stokke; KH, Haugaa; CE, Kiserud; T, Edvardsen; SI, Sarvari. The cardiac impact of cisplatin-based chemotherapy in survivors of testicular cancer: a 30-year follow-up Eur Heart J Cardiovasc Imaging 2021 443-450 4

AW, Bjerring; SI, Sarvari; T, Edvardsen; EE, Solberg. Should athletes be screened for heart disease? Tidsskr Nor Laegeforen 2021. DOI: 10.4045/ tidsskr.21.0491 Vol. 11

B, Cosyns; LE, Sade; BL, Gerber; A, Gimelli; D, Muraru; G, Maurer; T, Edvardsen. The year 2020 in the European Heart Journal-Cardiovascular Imaging: part II Eur Heart J Cardiovasc Imaging 2021 DOI: ehjci/jeab225

B-J, Hauge; EM, Muten; PH, Brekke. Multi-label ECG classification using Convolutional Neural Networks in a Classifier Chain Computing in Cardiology 2021

C, Rootwelt-Norberg; ØH, Lie; M, Chivulescu; AI, Castrini; SI, Sarvari; E, Lyseggen; VM, Almaas; MP, Bogsrud; T, Edvardsen; KH, Haugaa. Sex differences in disease progression and arrhythmic risk in patients with arrhythmogenic cardiomyopathy Europace 2021 1084- 1091 Vol. 7

C, de Lange; A, Quattrone; K, Try; AH, Bakke; A, Borger Kvaslerud; K, Haugaa and ME, Estensen. Is experienced pregnancy in women with repaired tetralogy of Fallot related to diffuse myocardial fibrosis? *International journal of cardiology*. 2021; 344:95-102

D, Melichova; TM, Nguyen; IM, Salte; LG, Klaeboe; B, Sjøli; S, Karlsen; T, Dahlslett; IS, Leren; T, Edvardsen; H, Brunvand; KH. Melichova D, Haugaa; TM, Nguyen; IM, Salte; LG, Klaeboe; B, Sjøli; S, Karlsen; T, Dahlslett; IS, Leren; T, Edvardsen; H, Brunvand; KH, Haugaa. Strain echocardiography improves prediction of arrhythmic events in ischemic and non-ischemic dilated cardiomyopathy Int J Cardiol 2021 56-62

E, Agricola; F, Ancona; E, Brochet; E, Donal; M, Dweck; F, Faletra; P, Lancellotti; H, Mahmoud-Elsayed; NA, Marsan; P, Maurovich-Hovart; M, Monaghan; J, Ribeiro; LE, Sade; M, Swaans; Bardeleben RS, Von; N, Wunderlich; JL, Zamorano; BA, Popescu; B, Cosyns; T, Edvardsen. The structural heart disease interventional imager rationale, skills and training: a position paper of the European Association of Cardiovascular Imaging Eur Heart J Cardiovasc Imaging 2021 471-479 Vol. 5

E, Riveland; TH, Larsen; T, Edvardsen; S, Saeed. Metastatic tumor of the interventricular septum mimicking myocardial calcification: The role of multimodality imaging Echocardiography 2021 774-776 Vol. 5

ET, Skjølsvik; Lie Ø, Haugen; M, Chivulescu; M, Ribe; AI, Castrini; K, Broch; AH, Pripp; T, Edvardsen; KH, Haugaa. Progression of cardiac disease in patients with lamin A/C mutations Eur Heart J Cardiovasc Imaging 2021 DOI: ehjci/jeab057

EW, Aabel; M, Chivulescu; LA, Dejgaard; M, Ribe; E, Gjertsen; E, Hopp; TE, Hunt; Ø H, Lie; KH, Haugaa. Tricuspid Annulus Disjunction: Novel Findings by Cardiac Magnetic Resonance in Patients With Mitral Annulus Disjunction JACC Cardiovasc Imaging 2021 1535- 1543

EW, Aabel and KH Haugaa. The Authors' Reply. *JACC Cardiovasc Imaging*. 2021; 14:1684-1685

F, Crea; H, Thiele; D, Sibbing; O, Barthélémy; J, Bauersachs; DL, Bhatt; P, Dendale; M, Dorobantu; T, Edvardsen; T, Folliguet; CP, Gale; M, Gilard; A, Jobs; P, Jüni; E, Lambrinou; BS, Lewis; J, Mehilli; E, Meliga; B, Merkely; C, Mueller; M, Roffi; FH, Rutten; GCM, Siontis; E, BarbatoS, James. Debate: Prasugrel rather than ticagrelor is the preferred treatment for NSTE-ACS patients who proceed to PCI and pretreatment should not be performed in patients planned for an early invasive strategy Eur Heart J 2021 2973- 2985 Vol. 31

FP, Kirkels; Ø H, Lie; MJ, Cramer; M, Chivulescu; C, Rootwelt-Norberg; FW, Asselbergs; AJ, Teske; KH, Haugaa. Right Ventricular Functional Abnormalities in Arrhythmogenic Cardiomyopathy: Association With Life-Threatening Ventricular Arrhythmias JACC Cardiovascular imaging 2021 900-910

G, Balaban; BP, Halliday; D, Hammersley; CA, Rinaldi; SK, Prasad; MJ, Bishop; P, Lamata. Left ventricular shape predicts arrhythmic risk in fibrotic dilated cardiomyopathy. EP Europace. 2021 Dec 15.

I, Stankovic; D, Muraru; K, Fox; GD, Salvo; NE, Hasselberg; OA, Breithardt; TB, Hansen; AN, Neskovic; L, Gargani; B, Cosyns; T. Stankovic I, Edvardsen; D, Muraru; K, Fox; GD, Salvo; NE, Hasselberg; OA, Breithardt; TB, Hansen; AN, Neskovic; L, Gargani; B, Cosyns; T, Edvardsen. Level 1 of Entrustable Professional Activities in adult echocardiography: a position statement from the EACVI regarding the training and competence requirements for selecting and interpreting echocardiographic examinations Eur Heart J Cardiovasc Imaging 2021 1091- 1097 Vol. 10

I, Stankovic; MR, Dweck; NA, Marsan; J, Bergler-Klein; E, Holte; R, Manka; J, Schulz-Menger; M, Sitges and KH, Haugaa. The EACVI survey on cardiac imaging in cardio-oncology. *European heart journal cardiovascular Imaging*. 2021; 22:367-371

IM, Salte; A, Østvik; E, Smistad; D, Melichova; TM, Nguyen; S, Karlsen; H, Brunvand; KH, Haugaa; T, Edvardsen; L, Lovstakken; B, Grenne. Artificial Intelligence for Automatic Measurement of Left Ventricular Strain in Echocardiography JACC Cardiovasc Imaging 2021 1918- 1928 Vol. 10

J, Cadrin-Tourigny; LP, Bosman; W, Wang; R, Tadros; A, Bhonsale; M, Bourfiss; ØH, Lie; AM, Saguner; A, Svensson; A, Andorin; C, Tichnell; B, Murray; K, Zeppenfeld; den Berg MP, van; FW, Asselbergs; AAM, Wilde; AD, Krahn; M, Talajic; L, Rivard; S, Chelko; SL, Zimmerman; IR, Kamel; JE, Crosson; DP, JudgeCA, James. Sudden Cardiac Death Prediction in Arrhythmogenic Right Ventricular Cardiomyopathy: A Multinational Collaboration Circ Arrhythm Electrophysiol 2021

J, Tangen; P, Aukrust; A, Barratt-Due; H, Skulstad; T, Edvardsen. Reduced cardiac function by echocardiography in a minority of COVID-19 patients three months after hospitalization Letter to the editor JASE 2021

JE, Otterstad; IB, Norum; V, Ruddox; ACM, Le; B, Bendz; J, Munkhaugen; O, Klungsøyr; T, Edvardsen. Prognostic impact of non-improvement of global longitudinal strain in patients with revascularized acute myocardial infarction Int J Cardiovasc Imaging 2021 DOI: 10.1007/s10554-021- 02349-2

JP, Collet; H, Thiele; E, Barbato; O, Barthélémy; J, Bauersachs; DL, Bhatt; P, Dendale; M, Dorobantu; T, Edvardsen; T, Folliguet; CP, Gale; M, Gilard; A, Jobs; P, Jüni; E, Lambrinou; BS, Lewis; J, Mehilli; E, Meliga; B, Merkely; C, Mueller; M, Roffi; FH, Rutten; D, Sibbing; GCM, Siontis; ESC Scientific Document Group 2020 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation Rev Esp Cardiol (Engl Ed) 2021 Vol. 6

KH, Haugaa. Improving the imaging diagnosis of mitral annular disjunction Heart (British Cardiac Society) 2021 4-5

KH, Haugaa and C, Rootwelt-Norberg. Cardiac desmosomal reserve: another piece of the exercise-induced arrhythmogenic cardiomyopathy puzzle? *European heart journal*. 2021

KH, Haugaa; EW, Aabel. Mitral Annulus Disjunction: Arrhythmic But Not Deadly? JACC Cardiovasc Imaging 2021 2088- 2090

M, Albatat; H, Arevalo; J, Bergsland; V, Strøm; I, Balasingham; HH, Odland. Optimal pacing sites in cardiac resynchronization by left ventricular activation front analysis Computers in Biology and Medicine 2021 Vol. 128

M, Bjørkavoll-Bergseth; CB, Erevik; Ø, Kleiven; TMH, Eijsvogels; Ø, Skadberg; V, Frøysa; T, Wiktorski; B, Auestad; T, Edvardsen; Aakre K, Moberg; S, Ørn. Determinants of Interindividual Variation in Exercise-Induced Cardiac Troponin I Levels J Am Heart Assoc 2021 Vol. 17

M, Chivulescu; E, Aabel; L, Dejgaard; T, Steen; O, Dunlop and KH, Haugaa. Cardiac Arrest in a Patient With Arrhythmic Mitral Valve Prolapse Syndrome: Multiple Possible Etiologies. *JACC Case Rep*. 2021; 3:1769-1773

M, Chivulescu; K, Krohg-Sørensen; E, Scheirlynck; BR, Lindberg; LA, Dejgaard; ØH, Lie; T, Helle-Valle; ET, Skjølsvik; ME, Estensen; T, Edvardsen; PS, Lingaas; KH, Haugaa. Mitral annulus disjunction is associated with adverse outcome in Marfan and Loeys-Dietz syndromes Eur Heart J Cardiovasc Imaging 2021 1035- 1044 Vol. 9

M, Rogstadkjernet; SZ, Zha; LG, Klaeboe; CK, Larsen; JM, Aalen; E, Scheirlynck; S, Droogmans; B, Cosyns; OA, Smiseth; KH, Haugaa; T, Edvardsen; E, Samset; PH, Brekke. Automated echocardiographic left ventricular strain measurements using deep learning European Heart Journal - Cardiovascular Imaging 2021 ehjci/ jeaa356.178 Vol. 22

M, Sitges; Marsan N, Ajmone; M, Cameli; A, D'Andrea; RF, Carvalho; E, Holte; B, Michalski; T, Podlesnikar; BA, Popescu; J, Schulz-Menger; I, Stankovic; KH, Haugaa; MR, Dweck. EACVI survey on the evaluation of left ventricular diastolic function European heart journal cardiovascular Imaging 2021 1098- 1105

M, Vagos; H, Arevalo; J, Heijman; U, Schotten; J, Sundnes. A computational study of the effects of tachycardia-induced remodelling on calcium wave propagation in rabbit atrial myocytes Frontiers in Physiology 2021

MK, Stokke; AI, Castrini; M, Aneq; HK, Jensen; T, Madsen; J, Hansen; H, Bundgaard; T, Gilljam; PG, Platonov; JH, Svendsen; T, Edvardsen; KH, Haugaa Reply to: TFC ECG in arrhythmogenic cardiomyopathy: Inadequate mixture of criteria? International journal of cardiology 2021

MM Maleckar; Myklebust, L; Uv, J; Florvaag, PM; Strøm, V; Glinge, C; Jabbari, R; Vejlstrup, N; Engstrøm, T; Ahtarovski, K; Jespersen, T; Tfelt-Hansen, J; Naumova, V; Arevalo, H. Combined In-silico and Machine Learning Approaches Toward Predicting Arrhythmic Risk in Post-infarction Patients Front. Physiol. 2021 DOI: 10.3389/fphys.2021.745349

N, van Osta; FP, Kirkels; T, van Loon; T, Koopsen; A, Lyon; R, Meiburg; W, Huberts; MJ, Cramer; T, Delhaas; KH, Haugaa; AJ, Teske; J, Lumens. Uncertainty Quantification of Regional Cardiac Tissue Properties in Arrhythmogenic Cardiomyopathy Using Adaptive Multiple Importance Sampling Frontiers in physiology 2021

OA, Smiseth (Chair); DA, Morris; N, Cardim; M, Cikes; V, Delgado; E, Donal; FA, Flachskampf; M, Galderisi; BL, Gerber; A, Gimelli; AL, Klein; J, Knuuti; P, Lancellotti; J, Mascherbauer; D, Milicic; P, Seferovic; S, Solomon; T, Edvardsen; Co-Chair BA, Popescu. Multimodality imaging in patients with heart failure and preserved ejection fraction: an expert consensus document of the European Association of Cardiovascular Imaging Eur Heart J Cardiovasc Imaging 2021 DOI: ehjci/jeab154

PJ, Schwartz; C, Moreno; MC, Kotta; M, Pedrazzini; L, Crotti; F, Dagradi; S, Castelletti; KH, Haugaa; I, Denjoy; MA, Shkolnikova; PA, Brink; MJ, Heradien; SRM, Seyen; R, Spätjens; C, Spazzolini; PGA, Volders. Mutation location and IKs regulation in the arrhythmic risk of long QT syndrome type 1: the importance of the KCNQ1 S6 region European heart journal 2021

R, Senior; JR, Lindner; T, Edvardsen; B, Cosyns. Ultrasound contrast agent hypersensitivity in patients allergic to polyethylene glycol: position statement by the European Association of Cardiovascular Imaging Eur Heart J Cardiovasc Imaging 2021 959-960 Vol. 9

S, Saeed; T, Edvardsen. Basal septal hypertrophy in hypertension; about time to introduce an objective and reproducible quantification J Hypertens 2021 1316-1318 Vol. 7

SA, Hicks; JL, Isaksen; V, Thambawita; J, Ghouse; G, Ahlberg; A, Linneberg; N, Grarup; I, Strümke; C, Ellervik; MS, Olesen; T, Hansen; C, Graff; N-H, Holstein-Rathlou; P, Halvorsen; MM, Maleckar; MA, Riegler; JK, Kanters. Explaining deep neural networks for knowledge discovery in electrocardiogram analysis Scientific reports 2021 Vol. 11

SM, Shavik; S, Wall; J, Sundnes; JM, Guccione; P, Sengupta; SD, Solomon; D, Burkhoff; LC, Lee. Computational modeling studies of the roles of left ventricular geometry, afterload, and muscle contractility on myocardial strains in heart failure with preserved ejection fraction Journal of cardiovascular translational research, Vol. 14, issue 6 2021

T, Edvardsen; E, Donal; NA, Marsan; P, Maurovich-Horvat; MR, Dweck; G, Maurer; SE, Petersen; B, Cosyns. The year 2020 in the European Heart Journal - Cardiovascular Imaging: part I Eur Heart J Cardiovasc Imaging 2021 1219- 1227 Vol. 11

T, Podlesnikar; N, Cardim; N, Ajmone Marsan; A, D'Andrea; M, Cameli; BA, Popescu; J, Schulz-Menger; I, Stankovic; J, Toplisek; G, Maurer; KH, Haugaa and MR, Dweck. EACVI survey on hypertrophic cardiomyopathy. European heart journal cardiovascular Imaging. 2021

VL, Thambawita; JL, Isaksen ; S, Hicks; J Ghouse; G, Ahlberg; A, Linneberg; N, Grarup; C, Ellervik; MS, Olesen; T, Hansen; C, Graff; N-H, Holstein-Rathlou; I, Strümke; HL, Hammer; MM, Maleckar; P, Halvorsen; MA, Riegler; JK, Kanters. DeepFake electrocardiograms: the key for open science for artificial intelligence in medicine Scientific Reports 2021

W, Budts; O, Miller; SV, Babu-Narayan; W, Li; Buechel E, Valsangiacomo; A, Frigiola; den Bosch A, van; B, Bonello; L, Mertens; T, Hussain; V, Parish; G, Habib; T, Edvardsen; T, Geva; JW, Roos-Hesselink; K, Hanseus; Subira L, Dos; H, Baumgartner; M, Gatzoulis; Salvo G, Di. Imaging the adult with simple shunt lesions: position paper from the EACVI and the ESC WG on ACHD. Endorsed by AEPC (Association for European Paediatric and Congenital Cardiology) Eur Heart J Cardiovasc Imaging 2021 58-70 Vol. 6

W, Mullens; A, Auricchio; P, Martens; K, Witte; MR, Cowie; V, Delgado; K, Dickstein; C, Linde; K, Vernooy; F, Leyva; J, Bauersachs; CW, Israel; L, Lund; E, Donal; G, Boriani; T, Jaarsma; A, Berruezo; V, Traykov; Z, Yousef; Z, Kalarus; Nielsen J, Cosedis; J, Steffel; P, Vardas; A, CoatsC, Leclercq. Optimized Implementation of cardiac resynchronization therapy - a call for action for referral and optimization of care Europace 2021 DOI: europace/euab035

ØH, Lie; M, Chivulescu; C, Rootwelt-Norberg; M, Ribe; MP, Bogsrud; E, Lyseggen; JO, Beitnes; V, Almaas; KH, Haugaa. Left Ventricular Dysfunction in Arrhythmogenic Cardiomyopathy: Association With Exercise Exposure, Genetic Basis, and Prognosis Journal of the American Heart Association 2021

ØH, Lie; LG, Klaboe; LA, Dejgaard; ET, Skjølsvik; J, Grimsmo; G, Bosse; E, Hopp; T, Edvards. Cardiac Phenotypes and Markers of Adverse Outcome in Elite Athletes With Ventricular Arrhythmias JACC Cardiovasc Imaging 2021 148-158 Vol. 1

Dissemination activities

B-J, Singstad. Comparing Binary Cross-entropy and F1-loss in Multi-label ECG classification Nordic AI Meeting 2021

B-J, Singstad. Multi-label ECG classification using Convolutional Neural Networks in a Classifier Chain Computing in Cardiology 2021

C, Rootwelt-Norberg. How to pitch a business idea ProCardio Fall meeting 2021

C, Rootwelt-Norberg. Young Investigator Award Session EuroEcho 2021 2021

C, Rootwelt-Norberg. Female arrhythmogenic cardiomyopathy patients have similar arrhythmic risk as males after adjusting for exercise habits 19th Annual Oslo Symposium on Heart Research 2021

E, Samset. Wearables, telemedicine and AI in arrhythmias ESC Cardiovascular RoundTable 2021

EW, Aabel. Moderator, Kasustikksesjonen Kardiologist høstmøte 2021

EW, Aabel et al. Tricuspid annulus disjunction is a common finding in patients with mitral annulus disjunction 19th Annual Oslo Symposium on Heart Research 2021

EW, Aabel et al. Tricuspid annulus disjunction frequently coexist with mitral annulus disjunction Kardiologist høstmøte 2021

EW, Aabel et al. Mitral and tricuspid annulus disjunction frequently coexists ESC Congress 2021

G, Balaban. Machine Learning Fundamentals Summer School in Computational Physiology 2021

J, Sundnes. Modelling electrical conduction in cardiac tissue, Summer School in Computational Physiology, Simula Research Laboratory, Norway 23.06.2021

J, Sundnes. Fundamentals of cardiac mechanics, Summer School in Computational Physiology, Simula Research Laboratory, Norway 01.07.2021

J, Tangen. Cardiac function is normal in most patients recovered from COVID-19 ESC Congress 2021 2021

K, Andresen. No signs of diffuse myocardial fibrosis by T1 mapping in male elite endurance athletes EuroEcho 2021

KH, Haugaa. Imaging in the arrhythmic mitral valve syndrome Myocardial Velocity and Deformation Imaging. Leuven meeting 2021

KH, Haugaa. 33 Year Old Female With MAD and Syncope. What Is the Workup?
American college of cardiology, USA 2021

KH, Haugaa. The Oslo ARVC Program
2021 ARVC meeting, Trolleholm, Sweden 2021

KH, Haugaa. Arrhythmogenic cardiomyopathy and exercise. Romanian annual conference on inherited heart disease 2021

KH, Haugaa. The influence of gender on arrhythmic risk in monogenic cardiac disease. European council for cardiovascular genomics webinar 2021

KH, Haugaa. What is the optimal treatment of asymptomatic patients with primary electrical syndromes? European society of cardiology 2021

KH, Haugaa. Genetics and cardiology.
lunch meeting Haukeland university hospital 2021

KH, Haugaa. Pregnancy in ARVC. Patient seminar Johns Hopkins annual ARVC meeting 2021

KH, Haugaa. Gender differences in arrhythmic syndromes- are men different? Annual conference cardiology, Israel 2021

KH, Haugaa. Cardiogenetics: What a cardiologist needs to know. Swedish association for cardiologists 2021

KH, Haugaa. Idrottskardiologiskt symposium: Genetiska hjärtsjukdomar. Karolinska universitetssjukhuset 2021

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KH, Haugaa. The role of echo in the diagnosis of ARVC. Lucerne course on echocardiography 2021

KH, Haugaa. Genetisk testing ved hjertesvikt og kardiomyopatier - nye norske anbefalinger. Norwegian association of Cardiology, annual fall meeting 2021

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T, Edvardsen. Beyond LVEF : Strain. Canadian Soc Echocardiography CSE 2021 Virtual meeting 2021

T, Edvardsen. Myocardial function in post COVID-19 patients Myocardial Velocity and Deformation Imaging. Leuven meeting 2021

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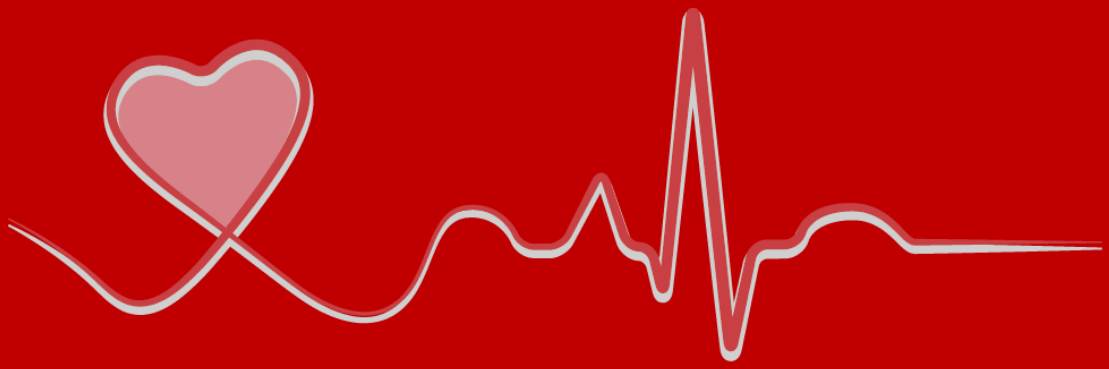

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