Annual report 2020
Operating Room of the Future

St. Olavs hospital FOR – NorMIT Infrastructure

Operating Room of the Future

ST. OLAVS HOSPITAL
TRONDHEIM UNIVERSITY HOSPITAL

NTNU

ST. OLAVS HOSPITAL
UNIVERSITETSSYKEHUSET I TRONDHEIM

NTNU | Norwegian University of Science and Technology

Frontpage photo: Gabriel Kiss, FOR

Preface

The year 2020 was a special and different year. We were all affected by the virus and the pandemic in different ways. "The Operating Room of the Future, FOR" has maintained its activity throughout this period. In January, a FOR seminar was held as planned in Røros. This time also with great participation and an exciting professional program.
During the year, we followed up and arranged for six master's students and eight bachelor's students who all completed their assignments using FOR infrastructure. Unfortunately, two planned disputations were postponed as a result of the Covid-19 pandemic.

Other projects that are researcher-initiated or industry-initiated have also been completed during the year.
In 2020, Unimed Inovation AS was wound up and officially transferred to St. Olavs Hospital and placed under FOR, and is now named" St. Olav's Hospital FOR – Research and Contracts". There is a clear political desire that hospitals in general should increase contact with business and industry, this includes both traditional testing of drugs in collaboration with the pharmacological industry, but also collaboration with larger and smaller companies that develop medical technical equipment, software and other products for the health sector. During 2020, a new structure and systems are in place, so that we are now able to meet tomorrow's demand.

As a result of the pandemic, most of all course activity, lectures and participation in conferences were cancelled. Most of the meeting activity took place on digital platforms.
In this edition of the annual report, we will show what FOR and NorMIT infrastructure consist of and at the same time give you an insight into our activity during 2020.

And we hope that you will enjoy our annual report of 2020!

Jan Gunnar Skogås
Head of department
Managing director
Photo: St. Olavs Hospital

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St. Olavs Hospital HF

St. Olavs Hospital HF, University Hospital of Trondheim, is integrated with NTNU and owned by Central-Norway Regional Health Authority RH. Treatment of patients, teaching of patients and their relatives as well as research and teaching of health care personnel, are the main tasks of the hospital as defined in the specialist health care act. The hospital covers psychiatry as well as somatic health care.

St. Olavs Hospital is running centers several places in Sør-Trøndelag County. In addition to the institutions in the center of Trondheim, hospital activity is taking place at:

- Orkdal hospital
- Røros hospital, Røros
- Departments of psychiatry at Østmarka and Brøset in Trondheim
- Three district centers for psychiatry; Orkdal DPS in Orkdal, Nidaros DPS and Tiller DPS in Trondheim
- Several psychiatry outpatient clinics for children and young patients in Sør-Trøndelag
- Department of psychiatry for children and youth at Lian
- Habilitation unit for adult patiens at Brøset, Trondheim
- Several outpatient clinics for psychiatry in Sør-Trøndelag

St.Olavs Hospital is the university clinic of Central Norway for a population of 731 931 inhabitants, and local hospital for a population of 325 375 per 01.01.20.

Our core values are integrity, equality, respect and co-determination, forming the background for our clinical activity and our students, colleagues and collaborators. St. Olavs Hospital is integrated with the Norwegian University of Science and Technology, NTNU, and students, teachers and scientists are representing natural parts of the hospitals` activity. Within teaching and research we are collaborating closely with several other institutions in central Norway.

In addition to the scientific activity, The University Hospital is responsible for the training of medical students and other health care professions. It is also responsible for the training of medical specialists in central Norway.

In 2020 we had:

- 10 621 employees
- 43 operating rooms at St. Olavs Hospital, Trondheim. In addition 5 operating rooms at Orkdal Hospital and 3 operating rooms at Røros hospital
- A total of 433 605 somatic outpatient consultations
- 1014 beds (somatic)

St. Olavs Hospital
Photo: Archive

Accelerating health care innovation when needed

The pandemic situation has accelerated the need for development of new vaccines as well as other health innovations. In this pandemic year, there have been important activities at NorMIT,- Norwegian centre for Minimally invasive Image guided Therapy and medical technologies. NorMIT responds to the need for new knowledge and innovation based on interdisciplinary collaboration. Being a safe and secure infrastructure for research and development within health technology, the facilities have also been used by students, researchers, business and health workers jointly during the pandemic year.

The revision of the white paper *"Long term plan for research and higher education"* is upcoming. In the years to come, the university sector will be more important than ever, because of the need for life long competence development for employees in all sectors as well as the need for new knowledge from research and innovation. This also stands for the healthcare services. The *"integrated university hospital"* at St. Olavs university hospital and NTNU is accordingly more important than ever because of the short way transforming research into innovation improving treatment of the patients and better efficiency in health care. Better healthcare for all citizens is also an important goal for the new upcoming Horizon Europe program. Norway is now in the moment of fulfilling our strategy for participation in this important program for research and innovation. We need better and more powerful tools, infrastructures and incentives to build more competence and capacity and to integrate research and innovation as an important part of the professional environments in various sectors. Digitalization and data analysis will be a premise is almost every task for optimizing therapy of the individual patient. The use of artificial intelligence algorithms and various information and communication technologies will be important to be able to give the best possible treatment of patients. Therefore, Norway´s participation also in Digital Europe Program will be important, including the establishment of *"digital innovation hubs"* in Norway. Norwegian healthcare including NorMIT will benefit from these digital innovation hubs for future digitalization in healthcare.

The conditions and time for working with transforming research into innovation must be strengthened and further developed both in the *"Long term plan for research and higher education"* as well as in the Norwegian strategy for participation in Horizon Europe and Digital Europe Program. Implementing good strategies will give new health industries in Norway as well as better healthcare for our patients.

Toril Nagelhus Hernes
Pro-rector for innovation, NTNU
Professor of medical technology
Photo: NTNU

Operating Room of the Future

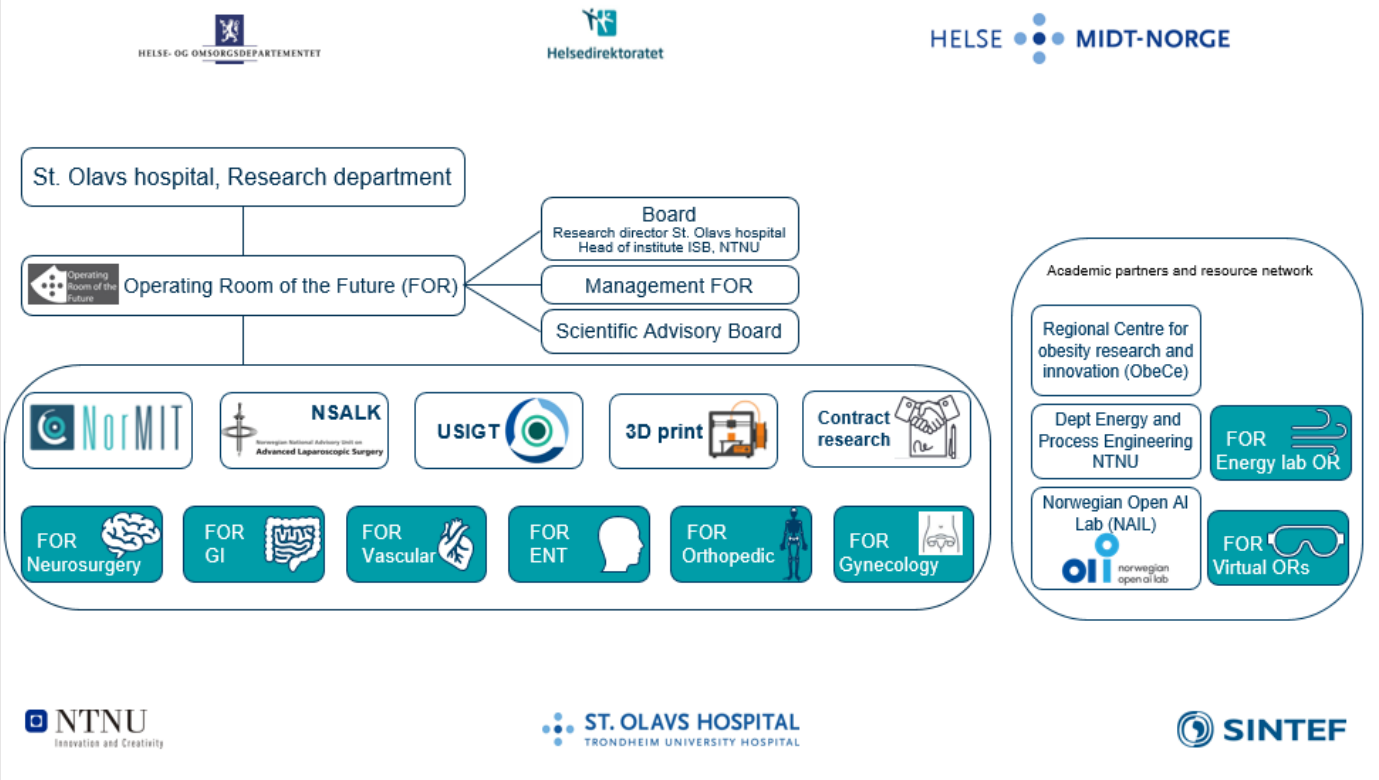
The Operation Room of the Future – FOR - contributes greatly to the continuous development of treatment and research at St. Olavs Hospital and the Faculty of Medicine and Health Sciences at NTNU. Better and more functional surgical treatment and other services such treatment at distance where the patient cannot or should not come to the hospital are in focus. The competence in treatment at distance has been especially valuable during the Covid- 19 pandemic in 2020. Together with researchers, innovators and industry; high-resolution visualization, holograms, robotics, artificial intelligence, and 3D printing has been adapted. FOR is a gateway to develop and test new technological solutions both in treatment of patients and in training of health professionals.

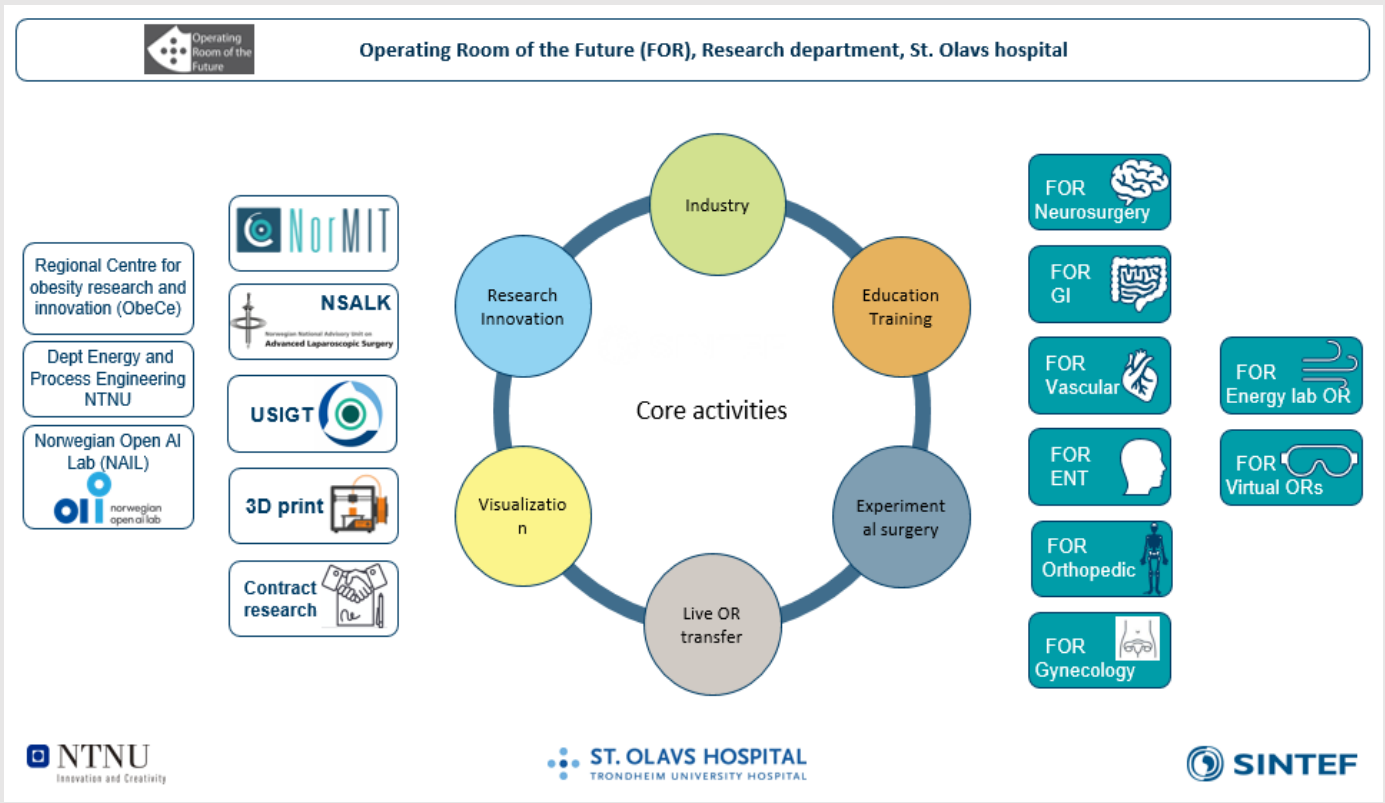
The ability to integrate advanced medical environment at St. Olavs Hospital with NTNU, SINTEF, the Innovation Center at OUS and commercial industrial partners is an important strength.

For St. Olavs Hospital and the Faculty of Medicine and Health Sciences, FOR is a key instrument for establishing business activities in cooperation with the private sector.

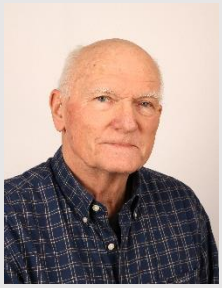
Gunnar Morken
Director of Research, Innovation and Education
St. Olavs Hospital and
Faculty of Medicine and Health Sciences, NTNU
Photo: St. Olavs Hospital

Organization of the Operating Room of the Future





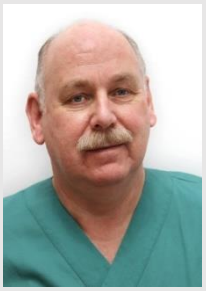
Staff



Hans Olav Myhre
Emeritus professor
of surgery

Jan Gunnar Skogås
Managing Director

Ivar Rossvoll
Associate Professor



Ronald Mårvik
Associate Professor

Frode Manstad-Hulaas
Associate Professor

Liv-Inger Stenstad
R&D coordinator

Jan- Magne Gjerde
R&D coordinator

Gabriel Kiss
Scientist, R&D coordinator

Ingrid Granbo
R&D coordinator

Marianne Haugvold
Advisor R&D

Vigdis Schnell Husby
R&D coordinator

Guangyu Cao
Professor NTNU

Thomas Langø
Researcher

Gunnar Gjeldnes
R&D coordinator

Maria Erlandsen Lynghaug
Economic adviser

Photo: St. Olavs Hospital

Scientific advisory board

An important task for FOR is to improve the quality and quantity of clinical research. Therefore the scientific advisory board is going through all research protocols, giving advice to those who are doing projects under the direction of FOR. FOR has special guidelines for projects, including the tasks of the scientific advisory board as well as a description how to make research protocols (Professor Per Farup). These documents are forming the basis for the collaboration between FOR and those who are conducting research projects there. In addition we are making separate agreements between FOR and the project leaders.
FOR additionally contributes a great deal to students at the research line at The faculty of Medicine (NTNU), an offer for medical students who are interested in research and a possible future research career possibly parallel to clinical activities.

The scientific advisory board has the following members:

Associate Professor Ivar Rossvoll (leader)

Emeritus professor Hans Olav Myhre

Professor Per Farup

Professor Olav Haraldseth

Professor Ståle Nordgård

Associate Professor Frode Manstad-Hulaas

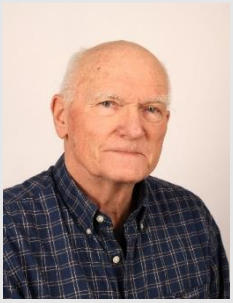
Associate Professor Knut Haakon Stensæth

Research director Thomas Langø

Associate Professor Wenche Moe Thorstensen

Specialist in clinical pharmacy Trond Oskar Aamo

Ivar Rossvoll
Scientific adviser
Associate professor



Hans Olav Myhre
Emeritus professor
in surgery

Per G. Farup
Professor

Olav Haraldseth
Professor

Wenche Moe
Thorstensen
Associate Professor

Ståle Nordgård
Professor

Frode Manstad-Hulaas
Associate Professor

Knut Haakon Stensæt
Assistant professor

Thomas Langø
Research director

Trond Oskar Aamo
Specialist in clinical
pharmacology

Photos: St. Olavs Hospital, NTNU, SINTEF and private

Highlights of 2020

St. Olavs Hospital FOR - Research and Contracts

From 30th of June 2020, Unimed Innovation AS changed its name to St. Olavs Hospital FOR - Research and Contracts.
Unimed's role and tasks have already been taken over by FOR in practice and will be continued under the auspices of St. Olavs Hospital with a clearer focus on contract research, drug studies and medical technology. Ongoing and new studies are continued in the usual way by St. Olavs Hospital FOR - Research and Contracts.

The political desire for the hospitals is to strengthen, and increase, the scope of drug studies and studies of medical technology in contact with business and private industry. The FOR research infrastructure has extensive experience with studies related to medical technology, and has a wide range of collaborating industry and hospital partners throughout the world.

From left:
Marianne Haugvold, Ingrid Granbo and
Jan Gunnar Skogås
Photo: St. Olavs Hospital

St. Olavs Hospital FOR-Research and Contracts is very happy to assist you as before with the following tasks:

- Link between company and project manager / hospital
- Assessment of legal content in a contract with a company, as well as budget based on the study protocol and associated resource needs for completion of the study
- Contact with service departments at St. Olavs Hospital - obtaining price quotes
- Contract and budget negotiations with a company
- Conclusion of agreements
- Financial follow-up; invoicing, reporting, final settlement
- Archiving of study material (15 years according to GCP)

R&D coordinators Ingrid Granbo and Marianne Haugvold are running St. Olavs Hospital FOR-Research and Contracts.
Feel free to get in touch, we will assist you!

New employee at The Operating room of the Future

Gunnar has recently been hired as a research coordinator at the Operating Room of the Future. He is a trained nurse and has worked at the cardiology department at the former Regional Hospital in Trondheim. He also has extensive experience from various positions in the pharmaceutical industry, health technology (Norwegian Health Informatics) and the equipment industry (orthopedic implants and flexible endoscopy). In FOR, Gunnar will mainly work with projects associated with NorMIT.

We are happy that Gunnar has come to FOR and look forward to the continuation - Wish him luck with new challenges in FOR!

Gunnar Gjeldnes
Photo: St. Olavs Hospital

The Annual FOR seminar 2020

The Annual FOR seminar was traditionally held in Røros. Two days of exciting and varied academic program were completed. Around 70 participants attended the seminar.

Photo: Google

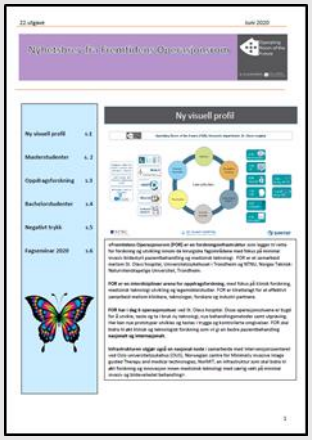
The program for this year's FOR Seminar was varied. We covered current topics within hospital infections and patient safety, robotics within surgery and R&D at the OUS Intervention Center and NorMIT. Thank you to all the speakers for great and inspiring lectures.

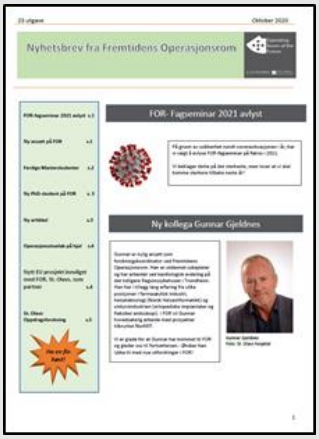
We hope that those of you you who participated had an educational and enjoyable seminar in Røros. Such a gathering means a lot to the environments and it is nice to be able to meet in a different arena than you do on a daily basis. This creates new ideas and strengthens the research infrastructure.

Newsletters from FOR

In October 2014 the first newsletter from FOR was available. So far the newsletters have been a great success. Three-four newsletters are distributed annually. They are focusing on the activity at the FOR infrastructure and are including visits at FOR, meetings, courses and information about scientific projects. We think this is a useful way of informing about FOR and hope you will enjoy it

If you would like to read the newsletters please visit this link: https://stolav.no/fag-og-forskning/kompetansetjenester-og-sentre/for





Activity at the FOR operating Rooms

Surgical Clinic

Operative activity FOR operating room AH- 1F Department of Surgery 2020	
TAVI	112
EVAR	78
Various vascular operations	56
Thoraco-abdominal stent-grafts w/ side branches	11
Combined procedures (open operation +PTA/stent)	69
Various endovascular procedures (coiling etc.)	9
Removal of infected pacemaker wires	8
Total	**343**

Birger H. Endreseth
Head of Surgical Clinic
Photo: St. Olavs Hospital

Operative activity, FOR operating room 4 Department of surgery 2020	
Upper gastro	54
Middle gastro	107
Lower gastro	322
Total	**483**

Department of Radiology and Nuclear Medicine

Edmund Søvik
Chief Attending Physician
Clinic for Medical Imaging
Photo: St. Olavs Hospital

Activity that the Clinic for Medical Imaging has participated in at the FOR operating room at AHL 2020	
Stent grafts in the abdominal aorta	61
Stent grafts in the thoracic aorta	17
Thoraco-abdominal stent-grafts w/ side branches	11
Combined intervention in the pelvis and lower extremities	69
Other	7
Total	**165**

Department of Women`s Diseases

Kjell Åsmund Salvesen
Head of Clinic of Women's diseases
Photo: St. Olavs Hospital

Operative activity FOR operating room 7 Department of Women and Children's diseases 2020	
Maternity unit	11
Gyn Cancer	
Gyn General	14
Total	**25**

Department of Neurosurgery

Tomm Brostrup Müller
Head of the Department of Neurosurgery
Photo: Aleris

Operative activity at FOR operating room 3 Department of Neurosurgery 2020	
Craniotomies/intracranial operations, vascular lesions and head trauma	173
Shunt operations	25
Operations on the spinal canal, spinal cord	101
Other operations: • Nerve root • Pain or dysfunksjon	49
Total	**348**

Clinic for Orthopedic-, Rheumatology and Skin Diseases

Vigleik Jessen
Head of Clinic for Orthopedic,
Rheumatologic and Skin Diseases
Photo: St. Olavs Hospital

Operative activity FOR operating room 8 Clinic of Orthopedic Surgery 2020	
Hip prostheses	90
Knee prostheses	238
Other operations	43
Total	**371**

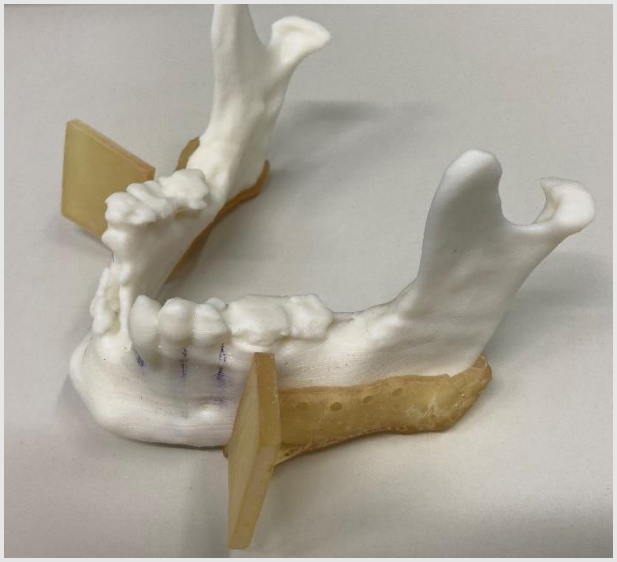
Clinic of Ear-Nose-Throat, Eye- and Maxillofacial Surgery

Marit Fagerli
Head of Clinic
Department of ENT, Maxillofacial and Eye diseases
Photo: Privat

Operative activity at the FOR operating room 1 Department of ENT, Maxillofacial and Eye diseases in 2020	
Arthroscopy	12
Conchotomy	5
FESS - Functional endoscopic sinus surgery	123
Multi-guide injections	2
Septal plasty	12
Sialoscopy	23
Dental procedures and other interventions	504
Total	**681**

FOR – NorMIT 3D-printlab

2020 has been another busy year for FOR-NorMIT 3D-print lab. Despite reduced clinical activity at St.Olavs Hospital for several months as a result of the Covid- situation, the lab has received almost twice as many orders as in 2019.



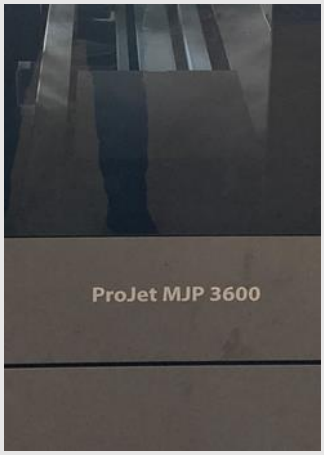
The Cranio-Maxillofacial department has implemented the use of 3D-planning and 3D-printing as standard treatment for bi-maxillary orthognathic surgery (patients in need of surgical repositioning of both the upper and lower jaw in order to obtain a functional occlusion). The department also utilizes 3D-printed patient specific anatomical models for planning of reconstructions and temporo-mandibular joint arthroplasty.

Photos: Jan Magne Gjerde, FOR

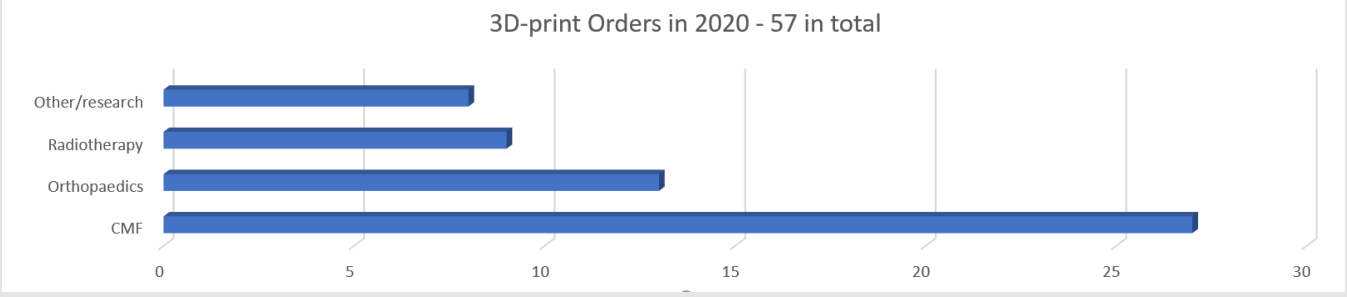
The Orthopedic department also utilizes 3D-printed patient specific anatomical models for planning and pre-bending of plates for both corrective osteotomies as well as complex fractures. Improved understanding of the anatomy gained by 3D-printed models has successfully enabled treatment of cases that initially were considered too complex for surgery.

The use of 3D-boluses for radio-therapy treatment is also increasing. 3D-boluses can help to obtain the optimal amount of radiation for the area of interest and minimizing the radiation for the surrounding area.

To meet the increasing demand the printer-park has been re-enforced with three new printers in 2020. The addition of 2 new Prusa FDM-printers have increased the capacity and reduced delivery time for large print-jobs. A new Multi-Jet printer will also improve the capabilities for printing delicate bone-structures and dental splints. We expect a lot from this new printer from 3D-Systems that will be installed early 2021.



In addition to clinical cases the Lab is also involved in several research project. The labs involvement in “Oral Health – Clinical Academic Group” and collaboration with SINTEF will ensure that the research activity within the lab will increase in the years to come.



Activity at St. Olavs Hospital FOR - Research and Contracts

It is a clear political desire that Norwegian hospitals should improve the contact with commercial industry including private business. This cooperation should include traditional testing of pharmacological treatment in cooperation with relevant industry, and collaboration with companies developing medical technology, software and other products relevant to the health care sector.

Department of Research and Development at St. Olavs Hospital and Operating Room of the Future (FOR) at St. Olavs Hospital have special competence and long experience in collaboration with commercial industry including technological companies. In November 2019 it was decided that the tasks that so far have been carried out by Unimed Innovation AS on behalf of St. Olavs Hospital will be taken care of FOR under a unit called "St. Olavs Hospital FOR - Research and Contracts" - with a more distinct focus on contract research, drug trials and medical technology.

It is interesting to observe that an action plan for clinical studies in Norway has been drawn up for for the first time – See link: Handlingsplan for kliniske studier
https://www.regjeringen.no/contentassets/59ffc7b38a4f46fbb062aecae50e272d/207035_kliniske_studier_k6_b.pdf

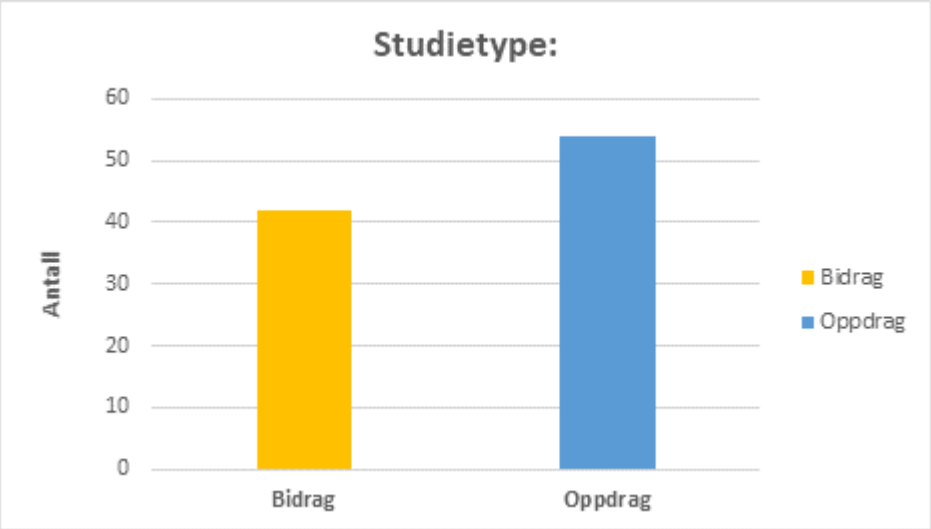
What is a clinical trial?

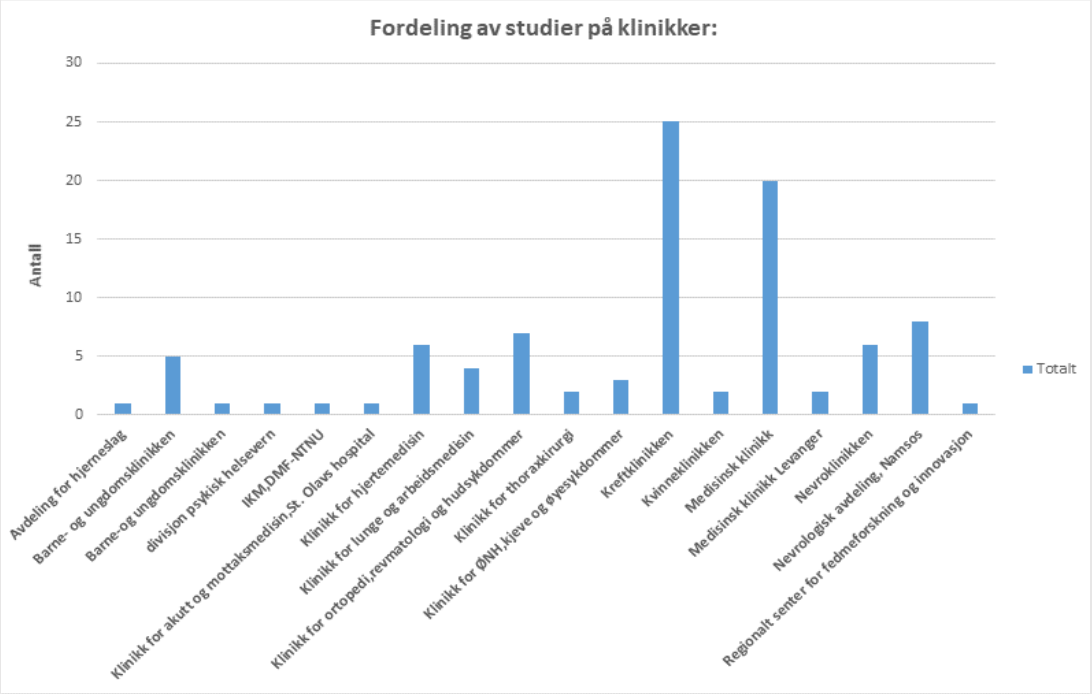
Clinical trials are scientific investigations exploring whether a medical strategy, treatment or device is safe and effective for human use. These studies may also show which medical approaches work best for various diseases. Clinical trials produce evidence that helps patients and their health-care providers to make better health-related decisions (evidence based medicine).

Participants in a clinical trial contribute to medical science by providing valuable knowledge about potential treatment modalities and methods of prevention. Participants with an illness or disease have the possibility to receive the most up to date treatment, getting care and attention from the clinical trial staff, while at the same time helping other patients.

Studies are divided into two main categories based on their funding:

- Funded studies - The Clinical study is initiated by an external party covering all study costs, also called Industry Sponsored Studies. The external party is the sponsor (responsible for the study and owner of the data).
- Partly funded studies - Investigator initiated clinical studies which receive financial contribution covering parts of the study costs. The investigator/hospital is the sponsor (responsible for the study and owner of the data)





Our role in clinical trials

After the preparation with the contract and budget process, we follow the clinical trial from the contract is signed until the study is finished. During the whole study we represent the link between the company and the project manager/hospital.

We handle:

- Contract and financial negotiations with the company, based on the study protocol and associated resource requirements for implementation of the study
- Contact with the various service departments, such as laboratory and radiology service, collecting price estimates and setting up the study budget
- Finalizing and signing of main contract together with the external company
- Sub-contracts with internal departments at the hospital
- Financial control and follow-up during the study; including invoicing, project accounting and reporting
- Filing essential documents for completed studies (15 years according to GCP)

From left: Marianne Haugvold and Ingrid Granbo
Photo: St. Olavs Hospital

If you have any questions, please feel free to contact us:

Research Coordinator Ingrid Granbo: ingrid.granbo@stolav.no
Research Coordinator Marianne Haugvold: marianne.haugvold@stolav.no

Medical Technology and Information Technology FOR-NorMIT

FOR is featured in the National ICT Strategy Plan for 2013-2020, and the Government's ICT research and development strategy is defining areas for ICT research and development in the future and signals how the government wishes to prioritize public resources allocated for research and development in ICT.
Link to National Strategy - ICT - Research and Development.
http://www.regjeringen.no/nb/dep/fad/dok/rapporter_planer/planer/2013/strategi-ikt-forskning.html?id=734430

The pace of digitalisation is challenging us massively. Technology companies and developers identify the healthcare sector as a major focus area for innovation. Society's expectations that the health sector will become more modern and technology-based will be strengthened in the years to come. Users and employees expect that the health service will be at the forefront of the development of using new therapies and technology. The proportion of people who collect and share information both at work and in their free time from their networks will increase every year. Society will therefore become more network-based by 2035. Both employees and patients will expect that necessary information and answers are "always" available. This requires that we change the way we are organized and work.

Medical technology and information technology give us new opportunities to improve our knowledge base through an explosive growth in available data. Future analysis platforms will provide integrated patient data, including data from MTU, and will provide a better and more accessible basis for own research. With the help of Big Data, strategies can be developed to prevent disease and to provide better treatment. Developments in technology and medicine will provide a good basis for research with available and integrated data. It is important to ensure that research results and new innovative solutions are implemented and that they form the basis for a knowledge-based and future-oriented health service.

FOR-NORMIT, with its unique relationship to technical competence environments of, for example, NTNU, SINTEF and international research and industrial environments, has a unique opportunity to utilize clinic-initiated development to a greater extent as the technology develops. There will be a standardization and coordinated development / innovation throughout the health service. In this work, patient needs and requirements, as well as clinically initiated innovation, should be assessed and new measures evaluated through research.

FOR-NorMIT is an established research infrastructure at the University Hospital in collaboration with NTNU. Under the auspices of FOR-NorMIT, various professional environments can try out new technology in a safe way. The NorMIT initiative emphasizes that FOR is a research infrastructure that will benefit the entire health region - and beyond, nationally and internationallyThere will be a lot of new technology that requires testing in clinical practice. It is also likely that it will be a rationale in the future for some heavy technological investments to be concentrated in order to get the most out of the resources.
Through collaboration with environments and forums where development in the future is a theme, FOR-NORMIT can capture trends / new technologies at an early stage.
Several conditions that previously had to be treated at larger clinics can eventually be taken care of at the local hospital level. There will be more technological equipment in the operating rooms. The operation of this requires considerable training. Engineers are given a more important role. There will be a centralization of the most complicated interventions. Other conditions that do not require extensive interdisciplinary collaboration, including several different specialists, can be done at the local hospital level. Analysis and interaction technology can provide very good opportunities for comprehensive innovation in mental health care.

The trend towards 2035 will be more personalized medicine, technology that enables even more decentralized treatment, as well as better utilization of health data from various sources. Consequences of this may be that with more available research data, the time interval from research to results will be shortened and clinical practice may become even more adaptable.

Advanced digital image processing and great computing power provide new ways of visualization and image production with higher information value with ever better resolution and shorter recording time. Developments in equipment and software increase diagnostic precision combined with lower amounts of ionizing radiation. Other non-ionizing diagnostic equipment gets new applications. Both 3D printing and holography provide better opportunities for modeling and simulation. Large amounts of diagnostics and data processing for new image presentations are available in

commercial software. Therefore, it is important that such systems are integrated so that documentation is included in the patient's diagram directly.

Navigation with electromagnetic tracking system in the vascular system is under development. The effect reduces the use of radiation and is time-saving. You depend on good visualization in the treatment situation. Developments in MRI spectroscopy can replace the need for a biopsy in many situations. Interventional radiology enhances and uses several imaging modalities and combinations of them to increase precision with many treatment technologies, such as thermal, radio frequency, microwave and laser. Future focus will be even more use of high-resolution camera systems and visualization equipment combined with 3D ultrasound and radar technology will use holograms and in hybrid operating rooms.

Medical robots are already in use, and medical personnel and robots are expected to work even closer together in the near future. Medical robots can improve surgical precision, medicine production, laboratory analysis, logistics and cleaning tasks, including disinfection of hospital rooms and surgical rooms. Properly used, the most important effect is the release of healthcare personnel time spent on routine tasks. Robotization will also be able to streamline administrative and technical tasks in the health services. Many claim that everything that can be robotized if the labor costs exceed the investment and operating costs with the robotization.
Robot parts attached to the body can speed up the rehabilitation of injured patients or let people with paralysis go again. Robots come in all sizes and shapes, today's miniature robots are in millimeters. These robots can be swallowed and allow less invasive surgical procedures and targeted drug delivery. However, it is expected that nano-sized robots will be developed, and these can be placed in the blood. They can be used to repair damaged cells or to help the body fight infections. Human contact will nevertheless be the core of good patient care. The development plans will include how medical personnel and robots can work together, and how patients can best adapt to the presence of a robot in the health sector.

Artificial intelligence (AI). The data produced daily in the clinic and stored digitally in PACS systems is doubled every two years. The large amount of information makes it impossible for healthcare professionals to keep track of everything that is stored or to use this information in daily practice. However, artificial intelligence-based (AI) tools can help keep track of and retrieve relevant information from the database and adapt it to the particular situation they face. AI in medical education will improve the learning process and enable students to have a much broader experience than they encounter during the traditional period at the clinic. It is expected that AI will have a beneficial effect in all areas of the health sector. Patient logistics, treatment planning, medical development or surgical procedures can all benefit from using AI, using intelligent medical information systems and devices. Access to big data will allow more accurate decision making and targeted medication. The decision on treatment and medication will be tailored to each patient and based on the outcome of those with a similar medical history. AI will make it possible to establish a link between a disease and genetic information, medical records or DNA mutations. This new development will also require the audience to be informed and used to AI. Furthermore, a new set of ethical standards must be developed to update existing guidelines and ensure that AI is used correctly in the health sector.

FOR-NorMIT infrastructure

In 2020, the NorMIT infrastructure was used to a large extent by 198 users in Trondheim and Oslo, with 119 different projects benefiting from the NorMIT infrastructure. In Trondheim, 12 PhDs are in progress. 6 Master's candidates and 8 Bachelor students were involved in research collaboration with FOR-NorMIT. A total of 9 articles, 4 national presentations and 2 international presentations were based on NorMIT-related work.

An overview of all equipment that can be ordered from FOR-NorMIT is available at www.normit.no

Our partners have used NorMIT equipment park extensively. In the next two sides we will present some of the technical development projects that have used NorMIT equipment.

Department of Circulation and Imaging (ISB)
The ultrasound laboratory At NTNU, Department of Circulation and Medical Imaging hosts two Verasonics Vantage systems which are used in various projects related to cardiovascular imaging, contrast agent development and imaging, and for the development and use of dual-frequency ultrasound transducers, used for instance to enhance image quality and cancer treatment. Several groups are using the systems, including the ultrasound research group at ISB, Dept. of Physics and Prof. Catharina Davies, SINTEF Digital, and SURF imaging, a spin-off company from ISB led by Prof. Bjørn Angelsen.

At ISB we develop high frame rate imaging applications, such as vector-Doppler imaging which may shed new light on the development of plaques in the carotid artery, as well as new high frame rate cardiac imaging setups to improve quantification of cardiac function. These efforts uses extensive imaging setup enabled by the powerful Verasonics systems in NorMIT, and has resulted in several fruitful international collaborations and 3 journal papers in 2020. In addition, several conference contributions included the use of Verasonics, as listed below.

Peer-reviewed journal papers using Verasonics (2020):

1. "Translation of Simultaneous Vessel Wall Motion and Vectorial Blood Flow Imaging in Healthy and Diseased Carotids to the Clinic: a Pilot Study", IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, Aug. 2020: https://ieeexplore.ieee.org/document/9163079
2. "Tapered vector Doppler for improved quantification of low velocity blood flow", IK Ekroll, V Perrot, H Liebgott, J Avdal, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, Oct. 2020: https://ieeexplore.ieee.org/document/9214487
3. “High-Frame-Rate Color Doppler Echocardiography: A Quantitative Comparison of Different Approaches”, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, 2020: https://ieeexplore.ieee.org/abstract/document/8926539

Conference contributions using Verasonics:

1. Intraventricular Pressure Gradients – Vector Flow Imaging versus Color M-Mode, Solveig Fadnes, Kristian Sørensen, Siri Ann Nyrnes, Morten S. Wigen, Lasse Løvstakken, IEEE International Ultrasoncs Symposium 2020.
2. High-frame-rate imaging of cardiac tissue-flow interaction: Towards the origin of the atrial kick wave, Sebastien Salles, Solveig Fadnes, Siri Ann Nyrnes, Lasse Løvstakken

SINTEF and ISB
In a project funded by The Liaison Committee for Education, Research and Innovation in Central Norway, SINTEF is working in collaboration with ISB and pulmonologists at St. Olavs Hospital and Levanger Hospital to improve characterization of mediastinal lymph nodes in lung cancer patients. The Verasonics Vantage system is used for implementation of shear wave imaging applications with clinical linear transducers. Implementation for nonlinear tissue characterization with a dual frequency transducer is also ongoing. The dual frequency transducer is expected to be ready for use in Q2 2021.
In a project funded by The Liaison Committee for Education, Research and Innovation in Central Norway, NTNU is working together with St Olav’s Hospital and SINTEF to enhance tumor uptake of chemotherapeutics in patients with pancreatic cancer by therapeutic ultrasound and microbubbles. A custom-made, dual-frequency probe for combined imaging and therapy is integrated with the Verasonics Vantage system. Publications are expected.

SINTEF: Inst. for physics and ISB
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NorMIT has been very important in conducting both experimental, preclinical, and clinical investigations of new ultrasound methods for better detection of cancer in the early stages, and also ultrasound efficacy of cytotoxic drugs.

Development and testing of new ultrasound methods and transducers at SINTEF

The research infrastructure related to ultrasound imaging which is available through NorMIT is valuable for several research projects in SINTEF. The Verasonics Vantage system enables fast implementation of new imaging methods, and the possibility of using custom made ultrasound transducers, which are not compatible with clinically approved systems. In addition, the Onda AIMS III water tank system gives the opportunity to do acoustic transducer characterization and safety measurements, which are important in the process towards clinical testing of new methods and transducers.

An example is the ERA-Net project "XploreCAD - Mechanisms of early atherosclerosis and/or plaque instability in Coronary Artery Disease", where a new dual frequency transducer with a Verasonics connector has been developed and produced in collaboration with the French company Vermon SA. The transducer has separate high and low frequency elements with center frequencies of 18 MHz and 4 MHz respectively, and is mounted as a linear array side-looker on a catheter with a diameter of 2.3 mm. The goal of the project is to image and characterize atherosclerotic plaques in a pre-clinical rabbit model. The research ultrasound scanner Verasonics Vantage 256 from NorMIT is used to implement imaging schemes for B-mode and contrast enhanced imaging, and the Onda AIMS III water tank system with 3D robotic stage has been used to characterize the pressure field at various voltages and frequencies.

SURF and ISB:

A clinical study using the Verasonics system and a novel dual-frequency transducer to increase the permeability of cancer drugs has been started:

«*Ultrasound-enhanced Uptake of Chemotherapy in Patients With Inoperable Pancreatic Ductal adenocarcinoma»,* https://clinicaltrials.gov/ct2/show/NCT04146441,
Cytotoxic drugs are combined with microbubbles and ultrasound to increase the transport of cytotoxic drugs to the tumor in patients with pancreatic cancer

Funding was acquired to develop dual-frequency transducers and imaging setups for tissue characterization:

«*MUNIN - Ultrasound detection, characterization, and treatment of (prostate) cancer»*,https://prosjektbanken.forskningsradet.no/#/project/NFR/313778
Two-frequency ultrasound is used for tissue characterization by estimating non-linear bulk elasticity

Users of the infrastructure	**2020**
Total number of users	198
Total number of internal users (Users employed by the host institutions	93
Total number of external users (Users not employed by the host institutions	105
Number of students (Master, Bachelor)	30
Number of PhD students	66
Number of scientists (permanent employment, post doc etc.)	79
Number of users from industry	24
Type of projects (funding) where the infrastructure has been used	**2020**
Total number of projects	119
Number of projects with international funding (EU, Nordic, etc.)	14
Number of projects with external national funding	74
Number of projects funded by the host institution (e.g. via the basic budget)	10
Number of projects funded by the industry	21

Courses arranged by FOR

Electro-medical equipment (EMU) - courses arranged in 2020:

10th of January: EMU-course for Departement of orthopedic surgery

- High energy equipment
- Endoscopy
- Irradiation protection and use of C-arm for fluoroscopy

Courses in the use of electro-medical equipment
On behalf of the operating clinics FOR is conducting compulsory courses in the use of electro-medical equipment. In 1999 a new regulation regarding "Use and maintenance of electro-medical equipment" was passed. This regulation has its background in law on medical equipment from 1995. According to § 13 training and instruction in the application of such equipment is necessary because:

- *Personnel who are going to use electro-medical equipment must have training and instruction in the application of such equipment.*
- *They should know potential side-effects connected to the application of electro-medical instruments and know how to prevent them.*
- *The training program must be systematic and include documentation.*

The Systematic training program must include:

- *Training when new equipment is introduced.*
- *Training of new employees.*
- *Maintenance of the knowledge achieved during this training program.*

At present the training program including the documentation is well established at all operating clinics at St. Olavs Hospital. All surgeons, including surgeons in training as well as staff surgeons, are getting invitation to the courses as part of the continuing medical education.

Competence portal
All courses in the use of electromechanical equipment and infection protection are now assigned to the individual doctor and LIS in the competence portal.

Everyone can now see which courses are valid and what courses need to be renewed. When you click on the course in the competence portal, you will automatically come to the course in the learning portal, if it is an e-learning course.
Initially, this applies to the courses in infection protection. High-energy devices and endoscopy, as well as the use of C-arm are still based on classroom teaching.

Staff
Medical personnel affiliated to FOR is going through annual certification in compliance with national regulations regarding use and maintenance of electro-medical equipment. All surgeons at St. Olavs Hospital are also going through courses on an annual basis regarding the use and maintenance of electro-medical equipment. The personnel at FOR is including so-called super-users having special focus on modern, advanced medical technology. They need to go through refreshing courses on a regular basis.

The personnel at FOR is contributing to training of personnel from other departments at St. Olavs Hospital as well as personnel from institutions focusing on clinical procedures, research and application of medical technology.
FOR has through visits and visitors from other hospitals in Norway helped to provide important information and training on new technologies, methods and integration of laparoscopic / endoscopic surgery. Organization and design of operating rooms has also been the subject. At the simulator course organized by the National Center for Advanced Laparoscopic Surgery (NSALK), FOR has been used as a venue for transmission of operating procedures and information on the integration of new equipment.

Experimental surgery

All FOR operating rooms are authorized for experimental surgery including animal research. Such experimental procedures can be ordered at FOR who will then organize them. This arrangement is well established among clinicians and scientists. We have a “package” where FOR is organizing and planning the animal experiments in collaboration with Department of Comparative Medicine (AKM). FOR has trained and authorized personnel assisting during the whole process. Personnel who is planning or taking part in animal experiments must go through courses in animal experiments approved by the Norwegian Food Safety Authority. An important part of this course is to understand laws and regulations connected with the use of animals in medical experiments. The regulation regarding animal experiments assumes that all persons planning or performing such experiments should have passed the courses and be registered in the electronic system (FOTS) of the board for animal research. Both the responsible scientist and his co-workers involved in the practical performance of the experiments, including those who are taking care of the animals, should be included in the registration and have documentation that they have passed the course in animal experiments, category C.

Research Collaborations - National and international partners

Together with the Intervention Center (IVS) at Oslo University Hospital, FOR has established the national research infrastructure, NorMIT; Norwegian center for minimally invasive Image-guided Therapy and medical technology, where infrastructure is in place both in Oslo and in Trondheim, with several ongoing projects.
The NorMIT infrastructure is available both nationally and internationally. In 2020, we have run some projects in collaboration with partners in our own health region; Central Norway Regional Health Authority, the health register HUNT and Møre og Romsdal. The FOR-NorMIT infrastructure is available for research projects.
SINTEF is one of FOR's most important partners. The collaboration is, among other things, built around the "National competence center for ultrasound and image-guided therapy". FOR also has a very good collaboration with NTNU through the MH faculty, at the Department of Circulation and Medical Imaging, the Department of Energy and Process Engineering, the Department of Design, the Department of Mathematical Sciences, the Department of Electronic Systems and the Department of Technical Cybernetics and the AI laboratory .
The students at the Faculty of Health Sciences at NTNU use the FOR infrastructure for projects related to the bachelor's and master's degree in collaboration with FOR. Various competence centers such as the "National Competence Center for Ultrasound and Imaging Therapy" and the "National Center for Advanced Laparoscopic Surgery", NTNU Technology Transfer (TTO), Center for Interdisciplinary Research in Space (CIRiS) are important partners, and it is important to maintain the synergy effect of this collaboration.
Furthermore, FOR has a good collaboration with a number of industrial partners such as: Sony, Medtronic, Brainlab, Intuitive, Siemens, Stryker, Karl Storz, IBM, Apple, ConocoPhillips, Total, Aker BP, Olympus, Ortomedic, Smith & Nephew. This is to name a few. Good practice and guidelines for collaboration with industry partners have been developed together with experts in this area.

FOR has established joint research projects with several international partners such as Vanderbilt University Medical Center in Nashville, TN, USA. Together, we investigate the effect of new treatment methods on technological solutions and decisions made in the operating room. We also want to collaborate on the efficient use of ICT in the operating rooms to optimize workflow and patient flow. There is also collaboration with Albert Einstein Hospital in Sao Paulo and the UFF Universidade Federal Fluminense in Brazil, mainly focusing on telemedicine and "decentralization of specialized health services".

Cooperation with several other international partners has been established over the years. Examles are research collaboration with Massachusetts General Hospital in Boston, Operation Room of the Future in Tübringen and research groups at Krakow University Hospital in Poland. A collaboration with Yonsei University Health System, Seoul, Korea, where handling the growing number of elderly patients is a topic. The intelligent hospital and the transfer of high-quality medical information are some of the projects that have been initiated, and which we want to focus on in the coming years. FOR also collaborates with organizations such as the European Association for Endoscopic Surgery (EAES), the Society for Minimally Invasive Therapy (SMIT) and Technoport in Trondheim.

Research and development in cooperation with SINTEF and USIGT

USIGT - Norwegian national advisory unit for ultrasound and image guide therapy

The Operating Room of the Future (FOR) is the arena and infrastructure provider for several ongoing research projects, including many of the projects at the national advisory unit for ultrasound and image-guided therapy (www.USIGT.org). SINTEF is a key research partner in USIGT and in FOR. Thomas Langø at SINTEF has a coordinator position at St. Olavs Hospital related to USIGT. One of the most important activities in 2020 was linked to the projects within the national advisory unit, which is appointed by the Ministry of Health and Care Services. USIGT carries out many projects in FOR, i.e., using it as an arena for a number of clinical and technological research, development and innovation projects, ranging from technology development, prototyping and clinical trials / studies of new solutions to improve patient care. In 2020 there were 12 PhD projects in progress, 3 of them finishing successful in 2020, and 3 ongoing Postdoc research projects, both clinical and technological. About half of these have a workplace at SINTEF, having a shared position between SINTEF and NTNU. Often, a technologist and a clinician are working together on PhD projects related to the same clinical application, illuminating the problem from both a clinical and a technological perspective. There were published about 20 scientific papers with peer review at USIGT in 2020, some from projects conducted at FOR, St. Olavs Hospital.

Through several user-driven projects supported by the Research Council and EU, the USIGT advisory unit has been an important competence environment for innovation and industrial cooperation. The center has a broad national and international network and extensive activity related to the development and dissemination of expertise and knowledge, one of the core tasks of the center. Through participation in several EU projects like the previous (finished) VECTOR, IIIOS, FUSIMO, MISTELA, RASIMAS, TRANS-FUSIMO, and currently on-going projects like IDEAR, HiPerNav, MIREIA, and the MEDITATE EID (European Industrial Doctorate), important expertise from international academic environments has been “imported”, while at the same time generating and contributing to the spread of local expertise both nationally and internationally. SINTEF and St. Olavs Hospital applied for 4 EU projects in 2020 (AI-STOR, ImFuse, SiFlex, ORConnect), which did not receive funding, but the experience from these proposal developments are crucial to network development and future possibilities for the group in Trondheim.

The advisory unit USIGT focuses on ultrasound and image-guided minimally invasive therapy with areas of interest related to vascular surgery, endovascular treatment, neurosurgery, laparoscopic and flexible endoscopic surgery, pulmonary medicine and radiology/urology. In addition to the use of ultrasound, navigation, visualization, image analysis using deep learning techniques (artificial intelligence) and decision support are also important fields of research in USIGT. A software research platform, CustusX, developed and maintained by SINTEF, is available as an open-source software package (www.CustusX.org) to the research community in the field of research where USIGT operates. Through collaboration in NorMIT with the Interventional Centre at the National hospital in Oslo, we are expanding this intraoperative navigation platform with planning tools (www.normit.no). The purpose is to make the diagnosis better and the treatment safer and more targeted. These platforms are disseminated nationally through the NorMIT infrastructure and internationally as open-source software in the form of customized versions for clinical applications. An example of the latter is Fraxinus (based on CustusX), a project that will create and distribute a free software package for bronchoscopy guidance (particularly planning) and thus making the diagnosis of lung lesions more robust with the ambition of a higher success rate in sampling suspicious lesions in the peripheral parts of the lungs.

The activity of the national advisory unit is a good example of how the future operating space can support research, development and testing of new technology and methods, while strengthening national and international cooperation. In addition, FOR contributes with expertise related to courses and publishing popular science articles in close cooperation with SINTEF. SINTEF also brings considerable expertise into the collaboration and utilizes its basic funding for strategic efforts to develop new technology for minimally invasive surgery / therapy.

Thomas Langø
Head of Research, Department of Medical Technology, SINTEF
Photo: SINTEF

Scientific production

Master degrees - finished in 2020

Henriette Holstad Urke and Janne Rong Haga
Photo: Private

Henriette Holstad Urke and Janne Rong Haga have this spring worked on a Master's thesis dealing with remote management in health trusts. This study is a research contribution that examines challenges related to remote management in hospitals, with the following problem: *"What challenges exist for remote management in health trusts?".* By studying a case company and conducting 11 interviews with employees and managers at different levels, they observedthat one of the biggest challenges for remote managers is to contribute to increased integration and interaction between the locations. Findings were also made that indicate that it is extra challenging for a remote manager to build relationships and trust across locations. Set against the desire for integration, this creates challenges for the remote conductor.

Thomas Hardbattle Hybertsen
Photo: Private

Thomas Hardbattle Hybertsen
The master thesis describes the connection between the heat loss of a patient undergoing surgery and the indoor climate in the operating room. It describes a correlation between the air humidity and air enthalpy and the core temperature of the patient during the surgery. Why the air enthalpy and air humidity impacts the patient is described through a mathematical model created by literature review and laboratory work.The thesisalso highlights several other important factors to heat loss, and describes why the enthalpy and humidity may impact the patients' core temperature.

Ida Sandsbraaten
Photo: Private

Ida Sandsbraaten, thesis entitled *"Tissue Deformation Estimation with Deep Learning on Ultrasound Data."* Investigated the feasibility of tracking anatomic landmarks in the kidney and myocardium of the heart with a deep learning model. By using a frame-to-frame displacement estimation, points in the tissue were tracked. The displacements were estimated by a convolutional neural network (CNN), inspired by previous work in the field of image registration.

Kristoffer Røise
Photo: Private

Kristoffer Røise, worked on "*Deep Learning Based Ultrasound Volume Registration for Interventional Applications*". His thesis aims to contribute towards fully automated monomodal ultrasound image registration of perioperative echocardiographic recordings by investigating the feasibility of fast, automatic image registration in TEE images using unsupervised deep learning methods. A registration pipeline is proposed, composed of a deep neural network to do local registration on patches, and a Procrustes method that takes the patch predictions and transforms them to a global alignment and introduces a rigidity constraint that is applied to the full volume.

Thea Amalie Solberg Hatten
Photo: Private

Thea Amalie Solberg Hatten
Title: *"CFD Simulation of Thermal Comfort Level of Patients and Surgical Staff in an Operating Room with Mixing Ventilation".*
The thesis investigated how the thermal comfort level of the surgical staff and patient in an operating room changes when the supplied air temperature and relative humidity in the room are changed. The results were obtained by using Computational Fluid Dynamics (CFD). The simulation model was modelled as FOR operating room 1. By using CFD, specific values for the environmental parameters are obtained for the surgical environment. The personal parameters are found from literature. In order to determine the thermal comfort level, the Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) are calculated by using the steady state equation of Fanger. Five scenarios were created in order to determine the thermal comfort level in different environments. Supplied air temperature was 20°C, 23°C and26°C, while the relative humidity was 20%, 40% and 60%. The supplied air velocity was constant.
Supervisor: Prof. Guangyu Cao.

Bachelor degrees – completed in 2020

Faculty of Medicine and health sciences, NTNU

Bachelor`s degree program Radiography

Kim Sæther and Mathias Åsheim Figenschau
Photo: Private

«Measurement of radiation doses with a ring dosimeter on surgeons during orthopedic operations at St. Olavs Hospital»

Bachelor`s degree program Nursing

Hanne-Maren Amalie Bergholt Jakobsen

Malin Malum

«Nursing care for patients who are sexually abused» (Hanne-Maren and Malin)

Bettina Nygaard Wroldsen

Iver Vammervold

Thea Ersdal Hansen

Kine Halgunset

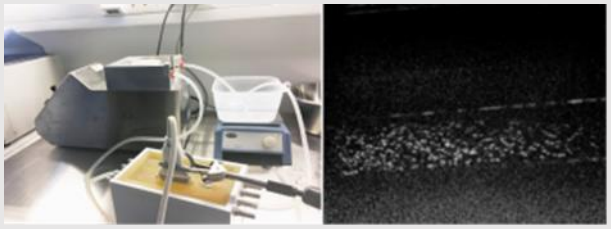
«Health professionals' meeting with women seeking provoked abortion» (Kine, Bettina, Thea and Iver)

All Photos: Private

Postdoctoral staff affiliated with FOR

Sigrid Berg (SINTEF) and Rune Hansen (NTNU / SINTEF)
Project title: Imaging of ultrasound contrast bubbles at high frequencies.

Microbubbles, consisting of thin lipid shell and gas core, are used in the clinic to provide better images of microcirculation in echocardiography and cancer diagnostics. With clinically available ultrasonic machines, bubbles can be depicted at relatively low frequencies (2-5 MHz) and low pressure (MI = 0.1). At high frequencies, one must typically use higher pressures to activate bubbles, and thus it will no longer be possible to suppress the signal from the tissue in a satisfactory manner. We have been working on implementing a new method for depicting bubbles at high frequencies on the research scanner Verasonics (NorMIT). By combining high frequency imaging pulses with low-frequency manipulation pulses, we achieve both a high signal from the bubbles and a good suppression of the tissue. The method is patented and has been implemented on linear transducers with frequencies from 5 to 25 MHz, this includes transducers from Verasonics, GE and Visualsonics. When methods for imaging bubbles are developed, it is important to have validated information about the pressures and frequencies of the transducer transmits. To characterize transducers, we have used NorMIT's Onda AIMS III system.



Left photo: Lab setup for optimization of imaging methods of microbubbles. The bubbles are pumped from a plastic tank and through one flow channel in a tissue-smoothing material. Right image: Example of ultrasound recording from flow model, where you can see strong signal from bubbles flowing through the channel and weak signal from the material around.

Sigrid Berg
Photo: NTNU

Rune Hansen
Photo: SINTEF

Erik Smistad, Postdoc ISB, NTNU / Researcher SINTEF

Erik Smistad
Photo: NTNU

Erik Smistad is working mostly with automatic image analysis of ultrasound, MR and CT images.
Finding structures such as blood vessels, nerves and tumors in images automatically in real-time can be useful in many applications such as diagnosis, pre-operative planning and ultrasound and intra-operative guidance. His main research interests includes: image segmentation, machine learning and neural networks, parallel and GPU processing and ultrasound.

PhD degrees – Ongoing

Geir Arne Tangen
Photo: SINTEF

Geir Arne Tangen
”Enhanced Minimally Invasive Therapy”. Technological PhD candidate.
The purpose of the project is development and testing of methods for integration of navigation technology in endovascular procedures. This involves accurate match between image information presented to the operator and catheter/guidewire movements inside patient vascular anatomy.

Supervisors: Petter Aadahl, Toril A. Nagelhus Hernes and Frode Manstad-Hulaas

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Kent Are Jamtøy
Photo: NTNU

Kent Are Jamtøy
Project title: Botulinum toxin type A blocked by sphenopalatin ganglion in chronic pain and inflammatory conditions of the craniofacial region.

Innomet is a research group based at St. Olavs hospital and the Norwegian University of Science and Technology (NTNU) in Trondheim. A new method of blocking ganglion sphenopalatinum (SPG) with botulinum toxin type A (BTA) has been developed. This is done using a navigation-based instrument (MultiGuide) to ensure accurate deposition of BTA. The method has been usedin 10 patients with headache pains using transnasal access under the anesthesia.Endoscopic block of the sphenpalatine ganglion is investigated in intractable cluster headache. A pilot study on chronic migraine has also been published, where the injection is done with lateral access (through the cheek). This study also shows acceptable side effects and good potential for effect. In addition, there is also a pilot study on the injection of botulinum toxin against SPG by trigeminus neuralgia. In this PhD project, Jamtøy will inject botulinum toxin against SPG from chronic rhinosinusitis with nasal polyps and atypical facial pain. Jamtøy plans to complete his research with a 50% position over 6 years

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Javier Pérez de Frutos
Photo: SINTEF

Javier Pérez de Frutos, PhD candidate SINTEF/NTNU

Javier is working on a PhD project with title: “Intraoperative registration techniques for improved ultrasound-based navigation in laparoscopic soft tissue surgery.” It is a technological PhD linked to the HiPerNav EU project (an ITN project under the MSCA program). Oslo University Hospital is coordinating the project and among the partners are SINTEF and NTNU. In Trondheim the project overlaps and is linked to the USIGT Laparoscopy project at St. Olavs hospital where he is using one of the Future ORs. Javier plans to finish his PhD and defend it in 2021.

Rita Elmkvist-Nilsen

Rita Elmkvist-Nilsen
Photo: NTNU

"Mapping Brain Plasticity"
Rita Elmkvist-Nilsen's PhD project examines the formative role of newer imaging technologies playing as knowledge-producing, diagnostic and therapeutic tools in neuroscience research practice. The project addresses newer approaches in cognitive neuroscience that considers the brain as an adaptive and dynamic body of plastic potential and, through diffractive reading, actualizes recent human-scientific perspectives on human perception and cognition as bodily rooted, relational, situational, action-oriented and shaped by technological medias.
Supervisors: Aud Sissel Hoel and Anne Beaulieu

Yang Bi

Yang Bi
Photo: Private

"Energy efficient airflow distribution methods for surgical microenvironment control in operating rooms".

The design of indoor air distribution system of operating rooms (OR) is a complex task due to the strict requirements of indoor environment parameters on which there is no global consensus.The purpose of this PhD project is to explore energy efficient indoor environment control and airflow distribution methods enabling safe surgical microenvironment in ORs.

To achieve this goal, many tasks should be accomplished. Firstly, an evaluation system should be established to help designers directly evaluate the comprehensive effect of air distribution systems in ORs. Secondly, a well-performed air distribution system in ORs should be developed, optimized, and validated. Finally, a new model/tool of virtual reality should be developed to visualize the indoor environment together with St. Olavs Hospital.

The main method of the research is the combination of simulation and experiments. The experiments will be carried out in the laboratory of NTNU and a real OR of St Olavs Hospital. CFD simulations will be performed to validation and optimization of the air distribution system.

The results of this study will provide a solid scientific basis for ventilation design in ORs. Visualization tools will help designers better analyze CFD results.
Supervisor: Prof. Guangyu Cao

Erik Nypan

Erik Nypan
Photo: Private

Three-Dimensional Visualization and Navigation in Endovascular Procedures
Abdominal aortic aneurysm (AAA) can be treated minimally invasive by stent graft insertion endovascularly. Endovascular treatment is not possible for all aneurysms depending on anatomy, but more advanced stent grafts allowing fenestrations or branches through the graft is becoming increasingly prevalent. Image fusion, which allows high-definition pre-operative imaging to be used intraoperatively, is introduced in the last years. The aim of this project is to facilitate better and easier endovascular navigation in endovascular aortic procedures, potentially leading to more patients being treated by endovascular methods as well as a reduction in x-ray radiation and use of contrast media, which can be toxic to the kidney. The project has several sub studies, and consists of studies conducted on phantoms, animal models and in patients. An integral part of the project is to study the feasibility of combining preoperative imaging to the patient on the operating table. With the help of position sensors integrated into instruments, it is possible to record position data inside the patient. The position data may then be registered to the preoperative imaging and can be used for navigation. Together with medical student Håvard Ulsaker and with help from FOR, we have in 2020 utilized 3D printed models to try to correct for tissue deformation that occur during the procedure.
Main supervisor: Frode Manstad-Hulaas
Assistant supervisor: Reidar Brekken

Andreas Østvik

Andreas Østvik
Photo: Private

Project title: Automatic analysis of medical ultrasound using machine learning
The goal of the PhD project is to utilize and further develop machine learning methods to improve state-of-the-art solutions in the field of ultrasound image analysis and visualization. More specifically, research is conducted on automating pipelines for clinical measurements in echocardiography, with motivation of improving robustness and workflow. This involves classification of images, quality assurance, semantic segmentation and landmark extraction, as well as integrating these components for quantitative measurements. Supervisor: Thomas Langø

Arne Kildahl- Andersen

Arne Kildahl-Andersen
Photo: Private

PET and advanced ultrasound in navigated bronchoscopy
The project is part of the activity in the research group LUNA –Lung Navigation (part of the National Competence Center for ultrasound and image-guided treatment) which is a collaboration between SINTEF, NTNU and St. Olav's hospital. The group has long track record with electromagnetic navigation integrated in the bronchoscope. Together with the project group, Arne will continue to work on ultrasound bronchoscopy integrated with electromagnetic navigation and PET-CT. A clinical trial of Fraxinus, a navigation software for virtual bronchoscopy will be performed. In addition, Arne will explore the possibilities for improved diagnostics of peripheral lung tumors by combining ultrasound and navigation. Additionally, Arne has been involved in testing Hololens based visualization during bronchoscopic procedures. Both phantom tests as well as a pilot study on one patient have been carried out.
Main supervisor: Håkon Olav Leira

Jakub Wladyslax Dziedzic
Photo: NTNU

Jakub Wladyslaw Dziedzic
As a PhD Candidate of the Department of Energy and Process Engineering, I have developed a methodology to motion capture occupant indoor activities. The development scope was to track energy-related activities, but due to robustness of the proposed method, it was possible to implement it in different fields of research.
We have managed to conduct series of experiments in surgical rooms with mixed and laminar ventilation. The goal of the research was to investigate the influence of surgeons and nurses on a spread of bacterial contamination. Conducting this investigation required usage of the motion capture technique and passive CFU sampling. The developed methodology was responsible for capturing the surgical staff spatial displacement and their activity. The preliminary results of research have highlighted critical issues influencing the contamination rate of surgical rooms with mixed ventilation. Supervisor: Prof. Guangyu Cao

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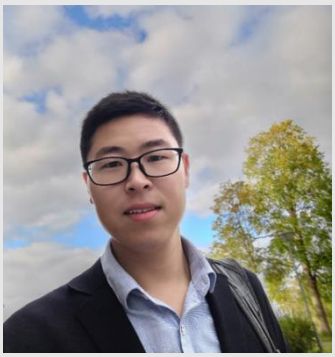
Masab Khalid Annaqeeb
Photo: NTNU

Masab Khalid Annaqeeb
Simulation of Energy/related Occupant Behavior in Buildings
The focus of the doctoral research work is on developing occupant behavior (OB) models, to be used in building simulation. In order to improve the understanding of OB, its drivers and influencing factors, the models will be developed in different domains, taking into account the multidisciplinary aspect of OB. To achieve that, the work includes collection of behavioral data with regards to the occupant's surrounding layouts, movement, social influences, and energy-use habits. The collected data is being used to develop databases, and agent-based models to simulate OB in buildings.
Supervisor: Prof. Guangyu Cao



Kai Xue
Photo: Private

Kai Xue
Predict the Hospital Energy Use Based on Machine Learning
The doctoral research work focused on the prediction of energy consumption and indoor environment through machine learning methods (ML), based on the historical weather data and monitored energy use data from Hospital. Through selecting the convenient predict tools, building a comprehensive framework in predict model and choosing a reasonable evaluation index, the research achieves a much more accurate and quick prediction by with the mature machine learning methods.
Supervisor: Prof. Guangyu Cao

Medical Student`s Research Program, Faculty of Medicine and Health Sciences, NTNU

At the Faculty of Medicine and Health Sciences, NTNU, a separate research programme has been established around the ordinary curriculum of medicine. The research programme involves two additional semesters devoted only to research, and that research is organized in parallel with the medical curriculum.
The research programme is an offer for medical students interested in research and a possible future research career, possibly in parallel with clinical activities.
Admission to the research programme takes place after two or three years of medicine studies at NTNU. From the autumn of 2002, the research programme was established at all four medical faculties in Norway, based on a wish to recruit more medical students to research, improving the organization of research education, and promoting scientific attitude for the practise of medicine.

Henrik Alexander Runde
The effect of altered hip biomechanics on physical function, quality of life and pain after hip fracture surgery.

Adequate restoration of preoperative femoral offset (FO) is critical for successful outcome in patients with osteoarthritis receiving total hip arthroplasty, but the literature is scarce concerning its influence on outcome following hip fractures. Reduction of the FO after fixation with dynamic osteosynthesis decreases the moment arm for the abductor muscles of the hip. Leg-length discrepancy (LLD) may also be readily perceived after surgery and may affect clinical outcomes and patient satisfaction. Although the mechanical physics in the joint apply in the same way, hip fracture patients represent a noticeably different patient group. Specifically, other factors may play a greater role, such as frailty, comorbidity and dementia. To what extent biomechanical factors determine the functional outcome following hip fracture treatment in a representative cohort is still not clear in the literature of orthopaedic trauma. The aim of the project was to investigate the relationship between specific joint biomechanical parameters and 1 year functional outcome scores in a general cohort of patients with hip fracture.

He conducted an observational cohort study in a consecutive series of 117 patients that underwent surgery for hip fracture. Patients were contacted and invited to a follow-up clinical investigation involving pelvic radiographs. A total of 54 patients participated at the 1-year follow-up and were completely analysed. We measured alternation in FO and LLD on the plain anteroposterior pelvic radiographs. Outcome were assessed by Trendelenburg test, Harris Hip Score (HHS), Short Physical Performance Battery (SPPB), EuroQol 5-dimension 5-level (EQ-5D), EQ-VAS (visual analogue scale measure of quality of life) and numeric rating scale (NRS) for pain in the affected hip. Relationships between patient characteristics, radiographic measures and functional outcomes were investigated.

Our study could not demonstrate any effect of change in FO on physical function, quality of life or pain. Subtle benefits may not have been revealed due to limited sample size. Further research is required to see if our findings apply to other patient samples. Femoral offset alteration and leg-length discrepancy is common following treatment for a hip fracture, especially after internal fixation. More knowledge on the subject is clinically relevant and might be used to improve the physical function and quality of life of this vitally important group of patients.

Henrik defended his Medical Student Research Thesis in October 2020. He is now finishing his medical studies and is applying for grants to continue his project with regards to the relationship between body-worn accelerometer-based measures of physical activity and altered biomechanics in a larger patient sample.

Main supervisor: Lars Gunnar Johnsen
Assistant supervisor: Trude Basso

Henrik A. Runde
Photo: Privat

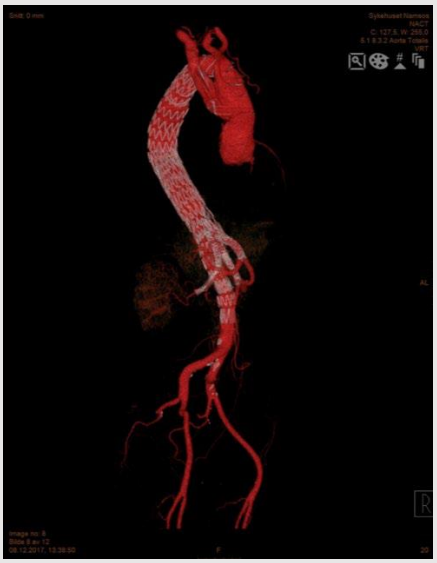
Håvard Ulsaker

In the first part of the project, we performed a national multicenter study to assess patients that are treated with endovascular aortic repair (EVAR) for thoracoabdominal aortic aneurysms (TAAA). Open surgery for TAAAs are comprehensive operations, and mortality rates have been reported as high as 20% in small volume centers. Many patients are deemed too high risk to undergo open surgery. Recent years' advancement in endovascular techniques has made it possible to treat TAAAs with an endovascular approach. In the study we assess the short and medium term outcomes in patients treated with branched EVAR (t-Branch, Cook Medical) at the Norwegian centers. Patients from all four university hospitals in Norway are included. Mortality, complications and comorbid data are compared with that of open repair patients.

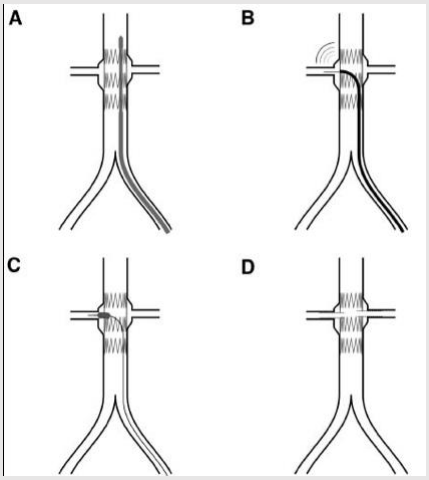
In the second part of the student research thesis, we assess whether in situ fenestration is a feasible technique for revascularization of the four main visceral arteries. In situ fenestration is a technique where a standard, non-fenestrated stent graft is implanted in the abdominal aorta so that it covers the ostia of the visceral arteries. Subsequently, the stent graft is perforated at the artery ostia to revascularize the visceral organs. We will use an electromagnetic navigation system, which is not based on traditional fluoroscopy technology, to visualize the surgical instruments. An important research question is whether the electromagnetic navigational system is sufficiently accurate to localize the ostia of the visceral arteries. Two other major questions are how fast the superior mesenteric artery can be revascularized, and whether or not we can restore blood flow to at least one kidney within 30 minutes.

Main supervisor: Frode Manstad-Hulaas
Assistant supervisors: Reidar Brekken and Arne Seternes

Håvard Ulsaker
Photo: Private



T-Branched stent graft implanted in thoracoabdominal aorta



Other projects

An important part of the mandate of The Operating Room of the Future is to develop and promote research and development projects in the intersection between scientists, health care personnel and industry. The aim is to create new and original knowledge with new solutions which are useful for the patients. We are in the intersection between science and innovation – between creation of new knowledge and new solutions and their application in daily clinical practice. The collaboration with various clinical disciplines is important to make sure those new solutions, methods, processes and new knowledge is introduced in clinical routine. We have our own infrastructure for the testing of new medical technology and new treatment modalities to create and maintain the bridge between new knowledge and well known routine. FOR has an extensive collaboration with national and international industry through research and development projects.

Prophylactic treatment with negative pressure at closed surgical incisions – Development project

In recent years there have been technological innovations and product innovations in wound healing treatment with negative pressure (Negative Pressure Wound Therapy, NPWT).
This is a qualitative project with the purpose of a systematic evaluation of patient satisfaction and user-friendliness/ease of use where NPWT is used - based on questionnaire and patient interviews. The project took place in a safe and controlled environment at the Operating Room of the Future, St. Olavs Hospital, University hospital in Trondheim, Norway. Two motivated test sites were selected for the implementation of the project.
Project Manager: Marianne Haugvold, The Operating Room of the Future, St. Olavs Hospital.
A final report is available - please contact the project manager if you would like to read the report.
Marianne.haugvold@stolav.no

The effects of tourniquet on muscle strength and function in patients operated with total knee arthroplasty and a multicenter prospective cohort study on Persona total knee system

About 5000 total knee arthroplasties (TKA) are performed annually in Norway. Pain and reduced physical function are present in patients operated with TKA up to a year after surgery and about one of five patients are not satisfied with the outcome from TKA surgery. The use of tourniquet during surgery to minimize hemorrhage, may have impact on pain and physical function. Whether TKA surgery should be performed with or without the use of tourniquet, is a much-debated issue in orthopedic surgery today, and there is still no consensus in this field. The overall aim of this project is to improve knowledge about the effects of tourniquet vs. no tourniquet on pain, muscle strength and function and thereby improve patient satisfaction. The results from the project might have implications for rehabilitation and the outcome after TKA surgery. This project will investigate early muscle strength and power recovery, neuromuscular recordings, neuronal changes and patient reported outcome measures. 80 patients will be included in this randomized controlled study. The patients are also invited to participate in a multicenter study which evaluates patient- reported outcome measures and ssurvival after TKA using the Persona total knee system. All patients have been included in the study.
The study is initiated by Zimmer Biomet.

Indoor climate and working environment in the operating room

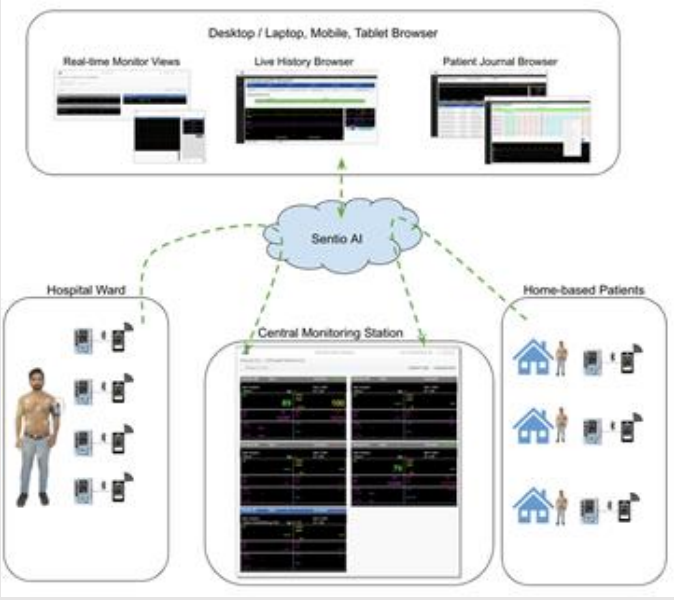
Both surgical staff and surgical patients require strict indoor environment quality, which influence both surgeons performance and patient safety. However, recent studies show that surgical staff suffered high temperature working environment due to the fact that surgical patients need extra heating to avoid hypothermia. Unfortunately, nowadays solutions are not able to satisfy both surgical staff, who needs cooling, and surgical patients, who need heating, at the same time. This project aims to develop and test a new indoor environment service which provides desired indoor environment for both surgical staff and patients in ORs ensuring patient safety. Experimental measurements have been performed in this project to reduce the use of hot air duvets as a heat source and to explore better alternatives. The novelty of this project will be to take existing technology and develop a device in a new way to create a better working environment which in turn leads to better patient safety. The new device will then will generate a good and comfortable working environment for the surgical team, and at the same time having an optimal temperature for the patient.

Innovation project «Clinical insight and evaluation of intelligent telemedicine and virtual cardiologist»

The Norwegian company Infiniwell has developed software for advanced interpretation of biometric data using artificial intelligence. With FOR as a partner, innovation funds were granted in 2019 from Health Central Norway for the development of a decision support tool with ECG recording and real-time remote monitoring based on this platform.
The project will potentially be able to provide benefits by streamlining current practice and expanding the offer of diagnosing heart problems in the districts, within its own health trust, as well as by broadening to other health trusts and the rest of the country if desired.
With a functioning telemedicine solution, it will be possible to offer specialist health services to the population, regardless of geographical location. Based on the solution developed in this project, neither a specialist nor a patient needs to be present in a hospital. Such a solution will also simplify the diagnosis and monitoring of patients in the districts, as they do not necessarily have to travel far to see a cardiologist, but could have a full consultation in their own municipality.

In the autumn of 2020, a collaboration was established with cardiologist Jan Pål Loennechen at St. Olav's Hospital and FOR, with coding of data sets and validation / sensitivity / specificity analyzis of the AI model's interpretations. The project is now ready for testing of the technical communication solution, which will take place in late winter / spring 2021.

World's smallest portableICU grade patient monitor with wireless connection to a central monitoring station or a cloud-enabled remote monitoring. This portable monitor enables the patient to move freely both within a hospital area as well as at home or anywhere in between. With a full set of vital sign parameters (ECG, SpO2, NiBP, IBP, Temp., Respiration and EtCO2) as well as waveforms, this fully functional patient monitor introduces a new level of mobile monitoring.



The solution,schematic
Photos: Infiniwell

Scientific articles 2020

Cao, Guangyu; Kvammen, Ingeborg; Hatten, Thea Amalie Solberg; Zhang, Yixian; Stenstad, Liv-Inger; Kiss, Gabriel; Skogås, Jan Gunnar.
Experimental measurements of surgical microenvironments in two operating rooms with laminar airflow and mixing ventilation systems. Energy and Built Environment 2020. Volume 2, Issue 2, April 2021, Pages 149-156. NTNU STO

Xue, Kai; Ding, Yiyu; Yang, Zhirong; Nord, Natasa; Barillec, Mael Roger Albert; Mathisen, Hans Martin; Liu, Meng; Giske, Tor Emil; Stenstad, Liv-Inger; Cao, Guangyu.
A Simple and Novel Method to Predict the Hospital Energy Use Based on Machine Learning: A Case Study in Norway. *Communications in Computer and Information Science* 2020 ;Volum 1332. s. 11-22. NTNU STO

Ignacio Oropesa, David Gutiérrez, Magdalena K. Chmarra, Luisa F. Sánchez- Peralta, Cecilie Våpenstad, Patricia Sánchez-González, José B. Pagador, Ana González-Segura, Thomas Langø, Francisco M. Sánchez-Margallo, Jenny Dankelman & Enrique J. Gómez (2020). Can effective pedagogy be ensured in minimally invasive surgery e-learning?, Minimally Invasive Therapy & Allied Technologies, DOI: 10.1080/13645706.2020.1777165. PMID: 32543248

Fagertun H, Våpenstad C, Brekken R, Dahl T. Bruk av ultralyd i lommeformat i karkirurgi. Tidsskr Nor Legeforen 2020 doi: 10.4045/tidsskr.19.0260

Våpenstad C, Lamøy SM, Aasgaard F, Manstad-Hulaas F, Aadahl P, Søvik E, Stensæth KH. Influence of patient-specific rehearsal on operative metrics and technical success for endovascular aneurysm repair. Minim Invasive Ther Allied Technol. 2020 Feb 14:1-7. PMID: 32057277

D. Bouget, A. Pedersen, S.A.M. Hosainey, J. Vanel, O. Solheim, I Reinertsen. Fast meningioma segmentation in T1-weighted MRI volumes using a lightweight 3D deep learning architecture, arXiv preprint arXiv:2010.07002, 2020

Teatini A, Perez de Frutos J, Eigl B, Pelanis E, Aghayan DL, Lai M, Kumar RP, Palomar R, Edwin B, Elle OJ. Influence of sampling accuracy on augmented reality for laparoscopic image-guided surgery, Minimally Invasive Therapy & Allied Technologies, 2020. DOI: 10.1080/13645706.2020.1727524. PMID: 32134342

Individual lectures / presentations at conferences

1. Skogås JG. FOR og NorMIT som forskningsinfrastruktur, en mulighet for tverrfaglighet innen medisinsk teknologi. Næringshagen 2020. 13. januar, 2020
2. Skogås JG. Basalkurs laparoskopisk kirurgi NSALK: Laparoskopi og elektrokirurgi. 15. januar, 2020
3. Haugvold M. FOR Fagseminar 2020: «Profylaktisk behandling med negativ trykk ved kirurgiske snitt», Røros, 30. januar, 2020
4. Skogås JG. FOR-NorMIT som forskningsinfrastruktur for kirurgisk forskning og utvikling. Ledersamling, Lerkendal Trondheim. 05. februar, 2020

5. Berg, E A R, Kiss, G, et al. Automated per-operative monitoring of left ventricular function based on deep learning. Meeting on myocardial function imagin. Leuven, 6.-7. februar 2020

6. Skogås JG. Hva er medisinskteknisk utstyr, forventninger, krav til standarder og hvordan komme dit. Lover og forskrifter, Nasjonal Sensordag, 27. februar, 2020

7. Skogås JG. Helsedatasenter, morgendagens kirurgi og behovet for dataflyt basert på lagrede data og sann-tidsdata. Navigasjon, AI, AR og helsedata. Styringsgruppe Helsdata Midt-Norge. 14. mai 2020

8. Skogås JG. Basalkurs laparoskopisk kirurgi NSALK: Laparoskopi og elektrokirurgi. 2. september, 2020

9. Haugvold M. & Granbo I. St. Olavs hospital FOR-Oppdragsforskning, Strategisamling, Oppdal, 15. september, 2020

10. Gjerde JM. 3D-printing – utvidelse av aktiviteten – nye printere, Strategisamling, Oppdal, 16.september, 2020

11. Skogås JG. Basalkurs laparoskopisk kirurgi NSALK: Laparoskopi og elektrokirurgi. 23. september, 2020

12. Skogås JG. NTNU, Fakultet for informasjonsteknologi og elektroteknikk Institutt for elektroniske systemer, ELSYS. FOR og NorMIT som forskningsinfrastruktur, en mulighet for din Masteroppgave. Tverrfaglighet i utviklingen og prosjektene. ELSYS-studenter, gjesteforelesning 8. oktober, 2020

13. Langø T. Robotassistert/navigert minimal invasiv kirurgi – fremtiden? Foredrag under kurs 'Laparoskopi for viderekomne' ved Nasjonalt Senter for Avansert Laparoskopisk Kirurgi, Trondheim, 6. november, 2020

14. Skogås JG. Spesialsykepleierutdanningen NTNU: Teknologiske og kliniske aspekter ved endoskopi og elektrokirurgi. 1. oktober 2020, hel dag

15. Kiss, G: AR in education: state of the art and future possibilities, Game Technology for Health (GT4H) seminar, NTNU, 23. November, 2020

16. Reinertsen I. Keynote: Multi-modal imaging in medicine, CIUS fall conference, Trondheim, November 2020

17. Bouget D. and Haram M. Treatment of liver metastasis, clinical experience from St. Olavs Hospital. CIUS fall conference, Trondheim, November 2020

18. Smistad E. Innlegg om AI og medisinske bilder for Rådet og ledelsen i Helseplattformens utvalg om AI

19. Langø T. Ultrasound and image-guided interventions. KeyNote Lecture at the annual iSMIT (International Society for Medical Innovation and Technology) congress, online, Chicago, December 3, 4, 5, 9, and 10, 2020

20. Nypan E. Aortic deformation during endovascular procedures in 3D printed models of abdominal aortic aneurysms. iSMIT (International Society for Medical Innovation and Technology) congress, online, Chicago, December 3, 4, 5, 9, and 10, 2020

FOR-related lectures

Lectures and posters at conferences with summaries (peer review), other lectures for health professionals, popular scientific publications, visits to the service where there are lectures, and invited lectures dynamics provide in diagnostics and treatment

Langø T. Robotassistert/navigert minimal invasiv kirurgi – fremtiden? Foredrag under kurs 'Laparoskopi for viderekomne' ved Nasjonalt Senter for Avansert Laparoskopisk Kirurgi, Trondheim, 6. november, 2020.

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Live streaming and high-resolution recording in the operating room

NorMIT has built expertise and technology related to recording, broadcasting and live transmissions from the operating room. This means that today we are able to perform high quality live streaming from all operating rooms at St. Olavs Hospital in a cost-effective way without the need for a permanent installation. The production systems we use are mobile solutions that are easily rigged in the operating room and in the conference auditorium. With access to high-speed internet, live surgery and other medical procedures can be shared rapidly with colleagues internally as well as globally. Cost effective transfers and recordings of all forms of medical procedures are now possible, regardless of surgical specialty. We transfer both images and support two-way sound from the operating room to the lecture hall. We also perform recording of the live transfer so that it can be reviewed afterwards.

In 2020, a 3 day course organized by Andrea Irene Hildegard Egey and Augun Blindheim, clinicians at the urology department was live streamed to the participants that were prevented from participating physically due to restrictions imposed as a result of the Covid-19 situation. FOR-NorMIT technology was used to film 8 surgeries over 3 days with technical support from Jan Magne Gjerde and Gabriel Hanssen Kiss. In collaboration with the regional education center RegUt (Peter Hatlen), this was combined with an online platform (Whereby). As such course participants situated at various remote locations could join online and actively participate in the course. Interactive Q&A sessions with the operating surgeon were possible, via a moderator as a 2 way audio connection with the OR was also established.

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