

Department of Clinical Physiology, Nuclear Medicine & PET

Annual Report 2014





Rigshospitalet

King Frederik V founded Rigshospitalet in 1757. Today, it has 1,200 beds, 8,300 employees and an annual budget of 7 billion DKK. Research at Rigshospitalet is published in more than 2,000 peer review papers per year, including higher academic theses (PhD and Doctor of Medical Science). Rigshospitalet is part of The Capital Region of Denmark and is a Copenhagen University Hospital.

University of Copenhagen

The University of Copenhagen was founded in 1479. The Faculty of Health and Medical Sciences has 8,000 students, including medicine and bioengineering in collaboration with The Technical University of Denmark, DTU. The University of Copenhagen is member of IARU, The International Alliance of Research Universities. www.ku.dk

Contents

Preface.....	2
Mission and objectives	5
Organisation and Staff 2014.....	6
Highlights 2014.....	10
Radium-223: A new alpha-particle radionuclide treatment directed to bone metastases.....	12
Pediatric nuclear medicine	16
PET / MR	18
SpinLab MR Hyperpolarizer	20
HyperPET	23
Nuclear Medicine.....	24
Cyclotron Unit	26
Radiochemistry.....	30
PET / CT in oncology, infection and inflammation.....	34
PET / CT scanning in radiation therapy	37
Cardiac PET.....	38
PET scanning of the brain	40
Collaboration with Landssygehuset, Faroe Islands.....	42
Academic and other activities	44
Studies 2014.....	46
Finance.....	48
Publications 2014.....	49
Equipment 2014.....	54
Research.....	56
Cluster for Molecular Imaging.....	60
Global Excellence Prize	63
Danish Chinese Scientific Collaboration	65
Danish Indian Scientific Collaboration.....	66
Young Investigator Prizes	68
Anniversaries.....	69
CIMBI.....	70
Education 2014	72
Nuclear medicine technologists, radiographers and lab technicians.....	74
MSc in Medicine and Technology.....	78
PET and PET hybrid systems	80
Danish National Research Foundation	82
Accreditation.....	84

Preface

The Department of Clinical Physiology, Nuclear Medicine & PET had yet another record year in 2014 with 95,195 patient studies, again showing a significant increase in productivity in comparison to previous years. We would like to express our genuine thanks to the entire staff for this major achievement.

This year has been the second with special challenges due to problems with the ICT. The PACS system (Picture Archiving & Communication System) is out of date, and until the new system will be installed in 2015, it continues to be a challenge to complete clinical services for our patients. It has required many extra hours and effort, and we owe the entire department our most sincere "Thank you for a great job done".

In spite of the trouble with the PACS system, the research programmes have performed on the most exceptional level. Thank you to Professor Andreas Kjær and the whole department for this impressive effort.

This year the research program resulted in 125 peer review publications, 3 theses and 2 patents. These strong papers are pushing the boundaries of nuclear medicine,

and we are collaborating with our colleagues worldwide through attendance at important meetings and in numerous publications. It is the aim of our department that all patients receive the best and most appropriate research based investigations, and that our patients are treated in a dignified and professional atmosphere. We continue to strive to accomplish this aim.

Thank you to our directors at the Centre of Diagnostics, Rigshospitalet: Centre Director Bettina Lundgren, MD, DMSc and Vicedirector Lene Ørnstrup and their team for important, positive and helpful collaboration. Thank you to Chief Medical Officer, Jannik Hilsted and Chief Nursing Officer, Helen Bernt Andersen, for their assistance throughout the year.

Thank you to the Department of Radiology, Head of Department Ilse Vejborg and Chief Radiographer Johnny Madelung for positive collaboration on patients and research.

The highlight of 2014 was the opening of our new SpinLab for the PET/MR scanner, the first of its kind worldwide. It will be used for research to secure a more



optimal multimodality characterization of cancer: cancer pathophysiology, diagnosis, treatment evaluation and planning of radiotherapy.

In 2014 we started treatment with Radium-223 as the first and at present only place in Denmark. Radium-223 is used to treat patients with prostate cancer with severe pain from bone metastases. It is a laborious and time consuming procedure, specially due to strict regulations from the National Institute of Radiation Protection, more strict in Denmark than other places in the world regarding this patient treatment. However it is very good for patients, who report already after the first treatments, that this alleviate their pain, and that message back to a hospital department is the best reward anyone can get.

Our aim is to deliver the best patient treatment and the best research and education

Without all your great effort it would not have been possible

Thank you to all staff, collaborators and international colleagues

Liselotte Højgaard
Professor, Head of Department

Linda M. Kragh
Chief Techonologist



Mission and objectives

The mission of Rigshospitalet is to be the leading hospital in Denmark for patients in need of highly specialized treatment.

The general objectives of Rigshospitalet are:

- » to be at the forefront of highly specialized diagnostic treatment and nursing
- » to carry out research and development at an advanced international level
- » to educate staff in the health services to a highly specialized level
- » to contribute with professional advice and exchange of knowledge and expertise to the wider healthcare community
- » to be characterized by openness and human respect

The objectives of the Department of Clinical Physiology, Nuclear Medicine & PET are:

- » to provide optimal clinical physiology and nuclear medicine for patient investigations and patient treatment with radiopharmaceutical
- » to carry out research at the highest international level in clinical physiology and nuclear medicine with special emphasis on molecular imaging, isotopes and radiopharmaceuticals
- » to deliver undergraduate and postgraduate education for all relevant professionals nationally and internationally
- » to provide a good patient experience and ensure the wellbeing of patients, relatives and staff

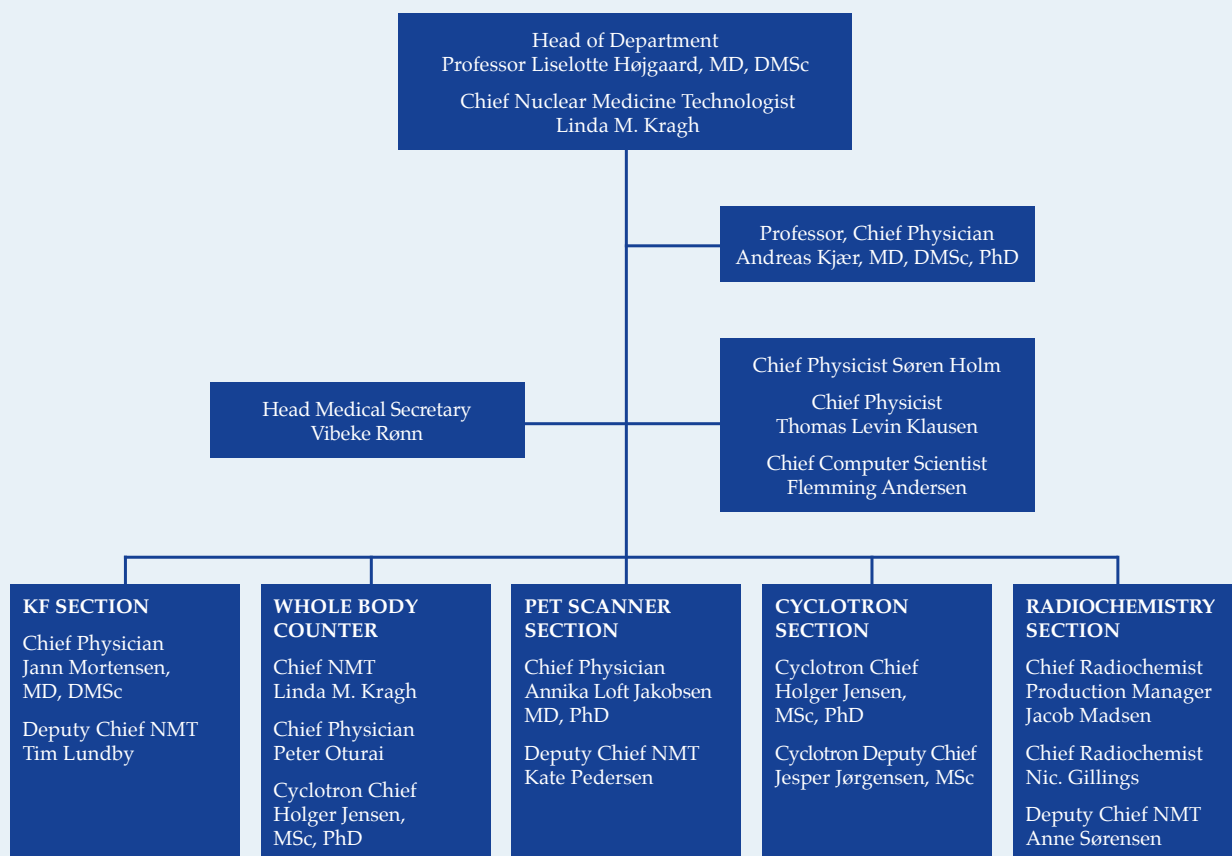
We aim high – we strive to be one of the five best departments of this kind world wide before 2020.

The staff participates in many congresses, symposias, meetings and workshops with invited lectures, oral presentations, abstracts and posters. We have a comprehensive program for all staff members at the department, and frequent visits from Danish and international research groups.

In 2014 more than 250 groups and individuals visited the department.

Organisation and Staff 2014

Abrahamsson, Elisabeth, Radiographer.
Agner, Elissaveta Castella, Radiographer.
Albers, Mia C. Hjorth, Teaching NMT.
Albrecht-Beste, Elisabeth, MD, Chief Physician.
Alslev, Louise, MD, Staff Specialist.
Amtoft, Annemarie Gjelstrup, MD, Chief Physician.
Anderberg, Lasse, Student.
Andersen, Anne Sofie Bech, Student.
Andersen, Flemming, MSc, PhD, Chief Computer Scientist.
Andersen, Julie Bjerglund, MD, PhD Student.
Andersen, Kim Francis, MD, Staff Specialist.
Azizi, Nadia, Radiographer.
Bender, Thomas, Student.
Benjaminsen, Claus, MSc Engineer.
Benoit, Didier, Physicist, Post Doc.
Benzon, Eric von, MD, Chief Physician.
Berg, Ronan Martin Griffin, MD, Registrar.
Berthelsen, Anne Kiil, MD, Chief Physician.
Binderup, Tina, MSc Human Biology, PhD, Post Doc.
Birk, Kirsten Junker, NMT.
Bojesen, Christina, Teaching NMT.
Borgwardt, Henrik Gutte, MD, PhD, Post Doc.
Borgwardt, Lise, MD, PhD, Chief Physician.
Blomberg, Anne Louise, Student.
Brandt-Larsen, Malene, MSc, PhD, Chemist.
Buhelt, Sophie, Student.
Børresen, Betina, DVM, PhD Student.
Cappelen, Katrine Louise, Engineer.
Christensen, Anders, MD, PhD Student.
Christensen, Camilla, Chemist and NMT.
Christensen, Camilla, NMT.
Christensen, Charlotte Birk, MD, Staff Specialist.
Christensen, Helle, NMT and Nurse.
Christensen, Jan Damgaard, Cyclotron Technician.
Christensen, Kirstine Kjær, Student.
Christensen, Thomas Emil, MD, PhD Student.
Christensen, Tine Nøhr, MD, PhD Student.
Clausen, Malene Martini, MD, PhD.
Clemmensen, Andreas Ettrup, MSc Med.Tech, PhD Student.
Cortsen, Annette, NMT.
Costa, Junia, MD, Staff Specialist.
Dahan, Daniel, Cyclotron Technician.
Dall, Bente, NMT.
Damgaard, David, Student.
Danielsen, Maria, Student.
de Nijs, Robin, Medical Physicist, MSc, PDEng, PhD.
Dejanovic, Danijela, Staff Specialist.
Denholt, Charlotte Lund, MSc, PhD, Chemist.
Drachmann, Anders Paaske, Student.
Dunbar, Douglas, NMT.
Durmus, Sevil, Medical Secretary.
Dähnhardt, Andreas, Computer Assistant.
El-Ali, Henrik, Physicist, PhD, Ass. Prof.
Elkington, Sakeena, NMT.
Ellebæk, Sofie, MSc, PhD Student.
Ellegaard, Andreas Høyby, Student.
Elsgaard, Maria Stenvig, Secretary.
Enevoldsen, Lotte Hahn, MD, Staff Specialist.
Engberg, Astrid, Student.
Erlandsson, Maria, MSc, PhD, Chemist.
Federspiel, Marianne, NMT.
Fischer, Barbara Malene, MD, DMSc, PhD, Chief Physician.
Fliedner, Frederikke Petrine, Student.
Fosbøl, Marie Øbro, MD, Senior Registrar.
Frederiksen, Mette, NMT.
Ghotbi, Adam Ali, MD, PhD Student.
Gillings, Nicholas, MSc, PhD, Chief Radiochemist.
Girkov, Mia Seremet, Scholarship.
Gutt, Lars Emil, Student.
Hag, Anne Mette Fisker, MSc Human Biology, PhD, Post Doc.
Hansen, Adam Espe, Physicist.
Hansen, Anders Elias, DVM, PhD, Post Doc.
Hansen, Anja Vallin, NMT, Clinical Instructor.
Hansen, Camilla Josephine Teglgård, NMT.
Hansen, Casper, Student.
Hansen, Christian, Student.
Hansen, Ingeborg, Student.
Hansen, Lasse, NMT, Clinical Instructor.
Hansen, Michele Zaugg, Student.
Hansen, Nini, NMT.
Hansen, Rie Beck, Student.
Harder, Fie Barbara, NMT.
Hasbak, Philip, MD, Chief Physician.
Hasler, Signe Walther, Student.
Hassan, Mariam, NMT.
Hassing, Christina, Student.
Henning, William Sebastian, Engineer.
Henriksen, Martin Romme, Student.
Henriksen, Otto Mølby, MD, PhD, Chief Physician.
Hesse, Birger, MD, DMSc, Chief Physician.
Hildebrand, Sanne, Secretary.
Holm, Stine, NMT.
Holm, Søren, MSc, PhD, Chief Physicist.
Holtz, Simon Herken, MSc, QA Academic.
Højgaard, Liselotte, MD, DMSc, Professor, Head of Department.
Ilett, Emma Elizabeth, Scholarship.
Iljazovska, Cejlan Zulfovaska, NMT.
Jakobsen, Annika Loft, MD, PhD, Chief Physician.
Jensen, Holger, MSc, PhD, Chief Cyclotron Physicist.
Jensen, Julie Milbak, Student.
Jensen, Line Due, Radiographer.
Jensen, Martin Juul Ravn, NMT.
Jensen, Mathilde Dyrholm, Student.
Jensen, Mette Munk, MSc Human Biology, PhD, Post Doc.
Jensen, Rasmus Ramsbøl, MSc Engineer, PhD.
Jensen, Tina Gade, QA Assistant.



Jeppesen, Troels Elmer, Chemist, PhD Student.
 Johannesen, Helle Hjorth, MD, Chief Physician.
 Johnbeck, Camilla Bardram, MD, PhD Student.
 Juhl, Karina, MSc Human Biology, PhD Student.
 Jørgensen, Jesper, MSc, Cyclotron Physicist.
 Jørgensen, Jesper T., MSc Human Biology, PhD, Post Doc.
 Jørgensen, Mette Møller, NMT.
 Kaijer, Michelle Nymann, Technologist.
 Keller, Sune Høgild, MSc, PhD, Computer Scientist.
 Kjær, Andreas, MD, DMSc, PhD, MBA, Chief Phys., Professor.
 Klausen, Thomas Levin, MSc, Chief Physicist.
 Kleczewski, Karina, Medical Secretary.
 Klyver, Cecilia, Student.
 Knudsen, Camilla Sloth, NMT, Clinical Instructor.
 Knudsen, Jesper Andreas, MD, PhD Student.
 Korsholm, Kirsten, MD, Registrar.
 Kragh, Linda M., Chief NMT.
 Kristensen, Lotte K, MSc Human Biology, Research Assistant.
 Kronvall, Johanna, NMT.
 Ladefoged, Claes Nøhr, Computer Scientist.
 Langer, Natasha Hemicke, Scholarship.
 Larsen, Camilla, Student.
 Larsen, Laura Højland, MSc Human Biology, Research Assistant.
 Larsen, Trine Bjørnbo, MSc Pharm Tech, PhD Student.
 Lass, Jakob, Student.
 Lassen, Martin Lyngby, Engineer.
 Law, Ian, MD, PhD, Chief Physician, Professor.

Lehel, Szabolcs, MSc, PhD, Chemist.
 Li, Fan, MSc Med Tech, PhD Student.
 Lindell, Elin, NMT.
 Linnet, Solveig, NMT.
 Ljunggren, Anna, NMT.
 Lundby, Tim Mølgaard, Deputy Chief NMT.
 Lærke, Sonja Pedersen, Technician.
 Löfgren, Johan, MD, Chief Physician.
 Madsen, Casper Lillegård, Student.
 Madsen, Jacob, MSc, PhD, Chemist, Chief Production Manager.
 Madsen, Lasse Ahlbech, Student.
 Magnusson, Linda Helena Margaretha, Technologist.
 Malmberg, Catarina Anna Evelina, Scholarship.
 Mark, Peter Dall, Student.
 Marnier, Lisbeth, MD, DMSc, PhD, Senior Registrar.
 Mikkelsen, Mathias, Student.
 Mistry, Jacqueline Møller, Student.
 Mohebi, Ali, Student.
 Mortensen, Jann, MD, DMSc, Chief Physician, Ass. Professor.
 Mose, Camilla, NMT.
 Munkholm-Larsen, Mathias, Student.
 Myltoft, Mette Gylling, Medical Secretary.
 Myschetzky, Rebecca, NMT.
 Mørk, Mette Louise, MD, Registrar.
 Nedergaard, Mette Kjølhede, MD, PhD Student.
 Nehme, Ghina, NMT.
 Nielsen, Anders Bo, Student.



Nielsen, Carsten Haagen, Med.Tech, Phd Student.
 Nielsen, Dorthe Baunbjerg, NMT.
 Nielsen, Mariane, Service Assistant.
 Nielsen, Tina Vikmann, Medical Secretary.
 Nyrnberg, David Enslev, Student.
 Nørgaard, Martin, Student.
 Olesen, Oline Vinter, MSc Engineer, PhD.
 Olsen, Ingrid Holst, MD, PhD Student.
 Omanovic, Dzenita, Student.
 Oturai, Peter, MD, Chief Physician.
 Oxbøl, Jytte, Chief Technologist.
 Pedersen, Kate, Deputy Chief NMT.
 Pedersen, Maria Badir, Student.
 Pedersen, Sune Folke, MSc Human Biology, PhD, Post Doc.
 Pejtersen, Maria, NMT.
 Perez, Nicolas Palm, Student.
 Persson, Morten, MSc Pharm, PhD, Post Doc.
 Petersen, Lars Ringaard, MSc Bio.Med, PhD Student.
 Porojan, Monica, Technician.

Poulsen, Jákup Martin, Radiographer.
 Pourhassan, Houman, MSc Bio.Chem, PhD Student.
 Rahbek, Rikke Sofie, Student.
 Rahimi, Khalida, NMT.
 Rasmussen, Sine Hvid, Scholarship.
 Rasmussen, Thomas, Registrar.
 Ripa, Rasmus S, MD, DMSc, Staff Specialist.
 Røboe, Kristian Frostholm, Student.
 Rønbirk, Lilian, Medical Secretary.
 Rønn, Vibeke, Head Medical Secretary.
 Saxtoft, Eunice, NMT, Clinical Instructor.
 Schjøth-Eskesen, Christina, MSc Chem, PhD Student.
 Schou, Peter, Cyclotron Technician.
 Schulze, Christina, NMT.
 Semitoje, Gudrun, Medical Secretary.
 Setterberg, Victoria, NMT.
 Sinik, Elida, NMT.
 Skou, Katrine Bugge, Student.
 Skovgaard, Dorthe, MD, PhD, Post Doc.



Stahlfest, Marianne, Medical Secretary.
 Stahr, Karin, NMT.
 Strøm, Emil, Student.
 Svalling, Susanne, NMT.
 Sørensen, Anne, Deputy Chief NMT.
 Sørensen, Louise Sørup, NMT.
 Tolstrup, Britt Maria Jæger, Radiographer.
 Vensby, Philip Hvalsøe, Student.
 Weihrauch, Filip, Student.
 Weihrauch, Per, Cyclotron Technician.
 Weihrauch, Simone, Student.
 Westh, Louise, Medical Secretary.
 Wikke, Tina, NMT.
 Wittekind, Anne-Mette Nielsen, QA Pharmacist.
 Yerst, Joo, NMT.
 Zornhagen, Kamilla Westarp, DVM, PhD Student.
 Ørting, Silas, Student.
 Østergaard, Daniella Elisabet, Scholarship.



*In 2014 we lost Nuclear Medicine Technologist
 Anne Birgitte Sørensen, who died suddenly.*

*The department participated in the funeral and sends all
 the best regards to Anne Birgitte Sørensens family.
 She was a very respected and important member of the
 staff, and we will miss Anne Birgitte Sørensen and send
 her warm regards with many thanks for all the days she
 worked so well in the department.*

Highlights 2014



In summer 2014 the department initiated treatment with Radium-223 to patients with prostate cancer with bone metastases with severe bone pain. It was an immediate success, as patients already after the first treatment could report on pain alleviation and better every day life. The setup is rather laborious due to the radiation protection needs, and staff is measured in the whole body counter both before and after treatment as a special precaution chosen by the national authorities here in Denmark (in the other 17 countries internationally this has not been judged necessary).



Our Head of Department, Professor Liselotte Højgaard is Chair of the EU Horizon 2020 Advisory Group for the Health Research Programmes and the much acclaimed report advising for the funding in 2016/2017 was finalized August 2014. The annual budget is $\approx$ 1 billion €.

Our Head of Department Liselotte Højgaard was also acting Head of Department from October 2013 to June 2014 for the Department of Clinical Microbiology, Rigshospitalet, University of Copenhagen.



The old wings from 1910, when the hospital was moved from the centre of Copenhagen to here at Blegdamsvej, are now worn out, and a new beautiful hospital wing will open in 2018. It is a bit messy at present, but we are looking forward to the fine new buildings.



The annual Summer Symposium for the department was celebrated with an evening in Tivoli with a nice dinner for all of us.



The Department started in the 1960'es. The old archieve on paper with lots of historical material has been cleared. Important items have been kept, and the archieve is moved to another place outside Rigshospitalet. It was a huge task for the team behind the renovation.

In 2014 Rigshospitalet had a bicycle team again joining Team Rynkeby with the tour starting at Rigshospitalet and ending in Paris to collect funding to children with cancer. Diagnostic Center had this time a crucial function for the Team, and Centerdirector, MD DMSc, Bettina Lundgren, Chief Technologist Lene Ørnstrup and from our department Deputy Chief Nuclear Medicine Technologist, Tim Mølgaard Lundby participated in the service team for the Team Rynkeby Rigshospitalet. The team left Rigshospitalet in sunshine and good spirit, but it was a challenge both for the team and the service team, as the weather through Belgium and France was nasty with rainstorms and very cold weather. This Tour 2014 will be remembered as the toughest tour in the history of Team Rynkeby.



The department participates in the campaign commuting to work by bike

The department got one of the first PET/MR scanners some years ago, and in 2014 we opened the hyperpolarisator, so that we as the first in the world can produce PET/MR with hypoeerpolarization. We have named it hyperPET, and we can see in the litterature that it has been a good suggestion.



Radium-223: A new alpha-particle radionuclide treatment directed to bone metastases



Jann Mortensen and Søren Holm

The first treatment in Denmark with Radium-223 ($^{223}\text{RaCl}_2$, Xofigo, Bayer) was given on the 15th of May 2014 in our department. Through 2014 we have treated 29 patients with castration-resistant prostate cancer (CRPR) with 88 doses given on 14 treatment days. We treat with Ra-223 every other Tuesday and get referrals from all over the country (2/3 from the Capital Region H and Zealand, 1/3 from Jutland and Funen) since, at present, our department is the only one in Denmark having license to use Ra-223. On the 9th of December the first two patients finalized their planned series of six treatments and had experienced a good pain palliation with only modest side effects. In fact, the approval of Ra-223 treatment in the US and EU was based on results from a large randomized study (NEJM 2013), which showed that the patients can expect a longer survival, longer time to bone related complications, and improvement in biomarkers of bone metastases and quality of life especially due to pain reduction.

Ra-223 is given to outpatients as an intravenous injection over 1 min (typically 4 MBq in 4 ml, 50 kBq/kg). The injection is repeated every four weeks for a total of six planned series. Since Ra-223 is an alpha-emitter (and the first to enter routine clinical use) extra safety handling procedures are requested by the radiation safety authorities to protect

the staff (two technologists and one physicist) involved in the direct handling and administration of Ra-223 (see figures). In the introduction phase, this includes two measurements per person in our whole body counter before and after handling the Ra-223 – to document that no internal contamination has occurred even at Bq-level.

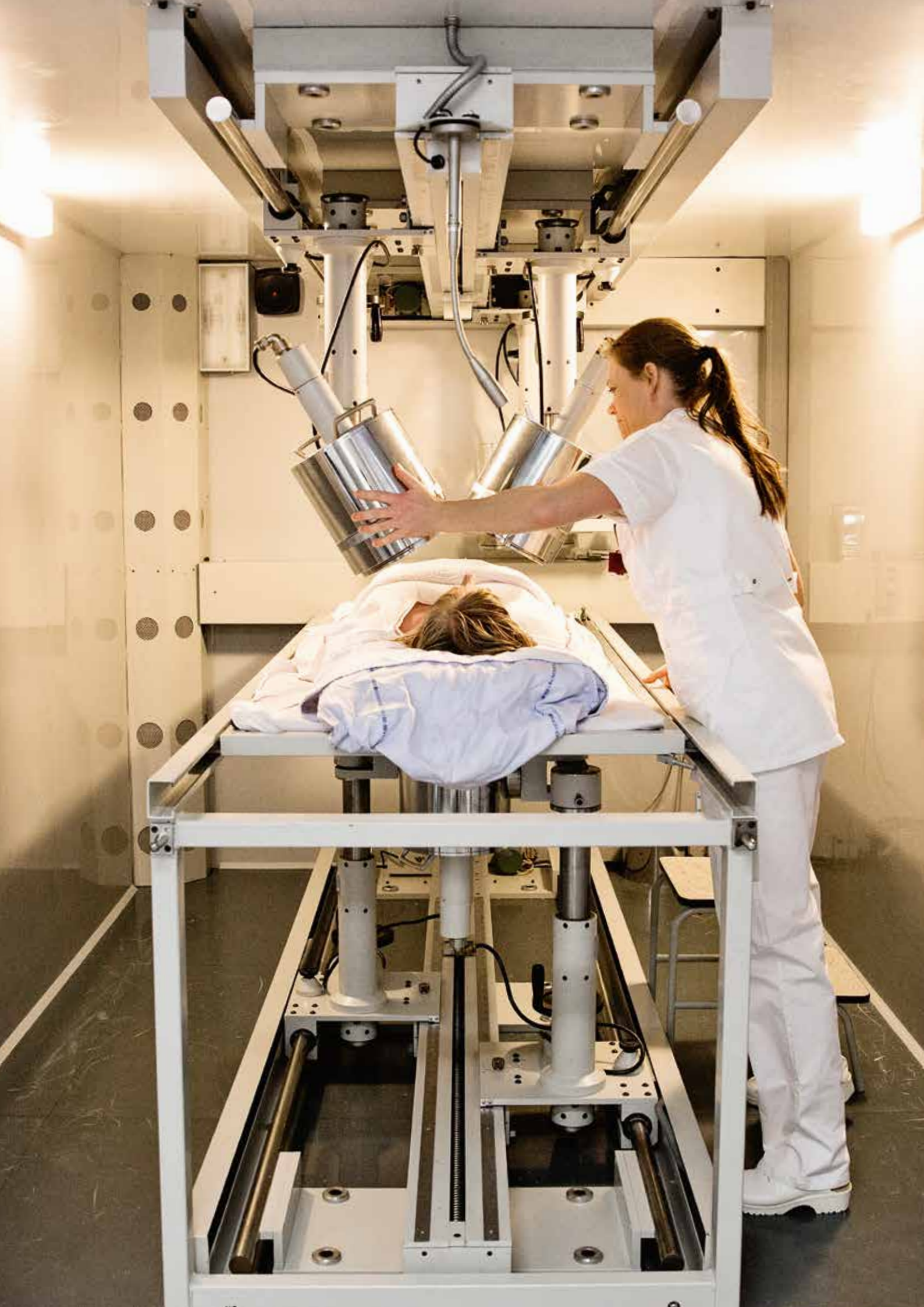
To inform the patients and referring doctors of this new treatment opportunity we have given various interviews to the Danish radio and newspapers, as well as written scientific papers and given lectures at scientific meetings.



A Tc-99m HDP bone scan showing metastases



A Ra-223 scan showing uptake in bone metastases (1 hour after injection)





Pediatric nuclear medicine



Lise Borgwardt

Each year we perform 1,700 pediatric nuclear medicine investigations, thereof 300 pediatric PET scans, mainly for the large pediatric departments at the hospital. It is a special focus area for our department to perform these investigations at the highest level of excellence, and at the same time make it a positive experience for both the child and the parents. The department is a member of the EANM Pediatric Committee and the Pediatric Imaging Harmonization SNM/EANM.

In our children section we have a children-friendly PET/128SliceCT, SPECT/CT, EDTA Clearance room and a renography room. In each scanner room, high quality projectors are showing movies at the ceiling to secure and entertain the child during the scan. In the waiting area the children have the opportunity to watch the animated decorations, use apps or watch movies at the tablets giving when entering the section or play in the toy corner. In March we started investigating all the pediatric PET studies at the children section, so children examinations are gathered here.

Once more we have successfully participated in Health Days at the Øksnehallen in Copenhagen, communicating our speciality to the public and especially for children.



Our multidisciplinary pediatric haematology and oncology conferences are presented as a web-based nuclear medical platform combined with videoconference including districts outside the capital. Our collaborators are very pleased with the possibilities and the advantages in the diagnostic evaluation of the children.

Research in pediatric nuclear medicine and PET is necessary, as we have an increasing amount of medical doctors, students and technicians involved in the field, and we conduct research protocols in children primarily with PET/MRI in order to develop this interesting area.

The work in the Pediatric Committee, EANM, this year has been very interesting and inspiring, and we are looking forward to next years work in the committee.



PET/MR



Johan Löfgren and Adam Espe Hansen

The integrated PET/MR scanner, donated by the John and Birthe Meyer Foundation, which allows simultaneous acquisition from both modalities, was installed at the end of 2011. The PET/MR scanner has, since it was installed, mainly been used in clinical, translational and basic research. In 2014 the modality has taken a big leap into clinical routine as a valuable tool in neurooncology and diagnosing dementia. In addition to being a convenient one stop shop for the patients it has also facilitated the work for our nuclear medicine physicians and their cooperation with neuroradiology (see the section on PET scanning of the brain).

After these first pioneering years we have now gained experience and confidence to implement this new and promising technic in other clinical settings. Especially pediatric patients, head and neck oncology patients and sarcoma patients have gained from this raising clinical use. PET/MR has in these cases often been used as a valuable supplement to whole body PET/CT.

In addition to growing clinical use there is a frenetic ongoing research activity with current research topics including oncology, inflammation, dementia, atherosclerosis, neurobiology and the new multi-modality functional molecular

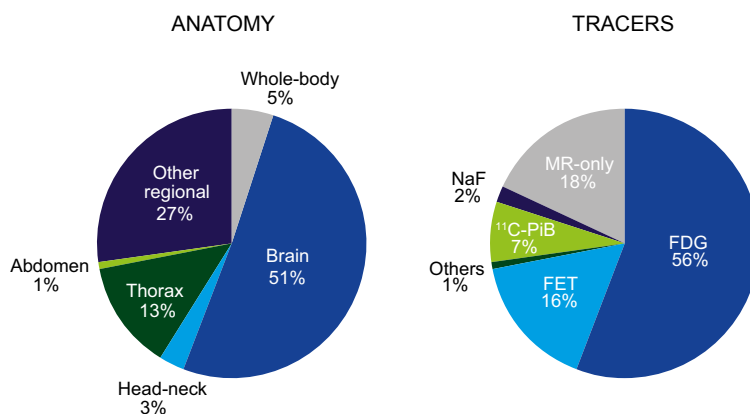
imaging based on the combination of PET and hyperpolarized MRI (see the sections on PET/MR research and hyperpolarized MRI).

PET/MR attenuation correction for neurological brain examination has been one very active physics research topic in 2014. Having characterizing the detrimental effect of neglecting bone attenuation, 2 new methods for a clinically feasible attenuation correction have been developed and are ready for large scale testing. In this context, the department together with Siemens hosted a workshop with participation of PET/MR researchers from Boston, London, St Louis, New York, Leuven, Leipzig and Vienna. The main outcome of the workshop was that the department will organize and perform a multi-center evaluation of MR attenuation correction methods suitable for clinical PET/MR brain examinations.



Figure 1 is an example of multiparametric imaging with a neuroendocrine tumor metastasis in the liver and an oncocytoma of the right kidney. 66 year old female, incidentally discovered with multiple liver metastases – unknown primary tumor. PET/MR images, from left, anatomic MRI (T2 HASTE), apparent diffusion coefficient (DWI-ADC), ^{64}Cu -Dotatate-PET and FDG-PET. A liver metastasis (hollow arrow) with reduced diffusion coefficient (ADC value) is ^{64}Cu -Dotatate avid but FDG negative while a benign oncocytoma in the right kidney with reduced diffusion is ^{64}Cu -Dotatate negative but FDG avid (solid arrow). Project leader Camilla Bardram Johnbeck, MD. Figure by Johan Löfgren.

Figure 2 is a PET/MR examination of sarcoma on the femur. 90 year old male. Images in sagittal orientation are, from left, anatomic MRI (T2 TSE with fat suppression), FDG-PET and fusion. The lesion has central necrosis as seen by the lack of FDG uptake and bright intensity on T2w MRI. Edges and a central structure are FDG avid. Project leader Kim Francis Andersen, MD. Figure by Adam Espe Hansen.



The distribution of PET/MR examinations in 2014, with a total of 577.

SpinLab MR Hyperpolarizer



Andreas Kjær and Adam Espe Hansen

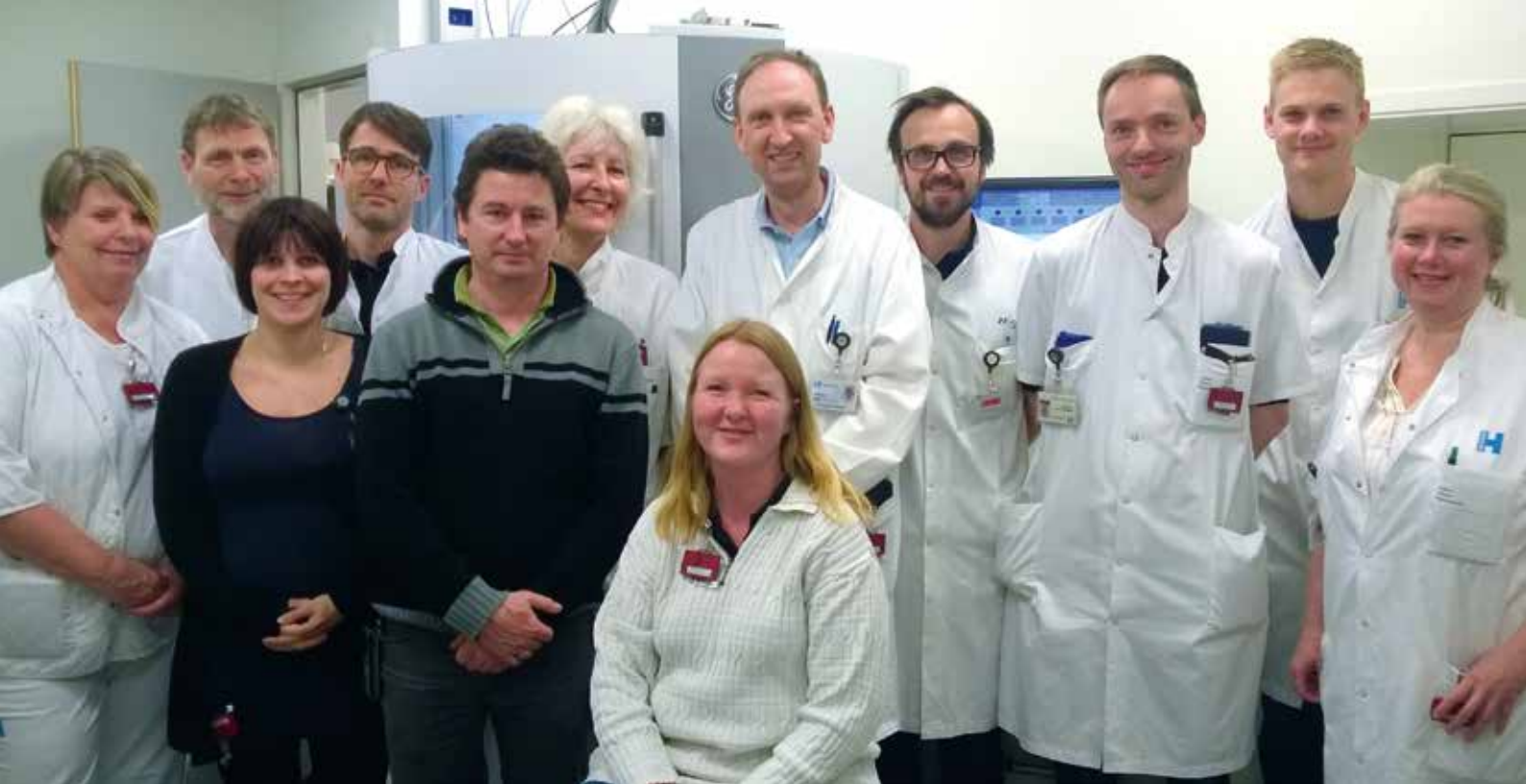
The SpinLab system from GE Healthcare was installed in the department of Clinical Physiology, Nuclear Medicine and PET, on the 25th of March 2014. The installation was the 8th worldwide; however, the combination with an integrated PET /MR scanner (installed at the department in 2011 as the 4th worldwide) is the first ever.

SpinLab enables Magnetic Resonance Spectroscopic Imaging (MRSI) of disease metabolism in real time. The underlying physical principle is hyperpolarization, by which the MR signal in a biological compound is increased 10,000 to 100,000 times. The hyperpolarization is achieved by a combination of low temperature (1 degree above absolute zero), high magnetic field (4 Tesla) and irradiation by micro waves. This hyperpolarization method is denoted Dynamic Nuclear Polarization (DNP). One of the inventors of DNP and the driving force behind the implementation is Danish, Professor Jan-Henrik Ardenkjær from GE Healthcare and the Technical University of Denmark.

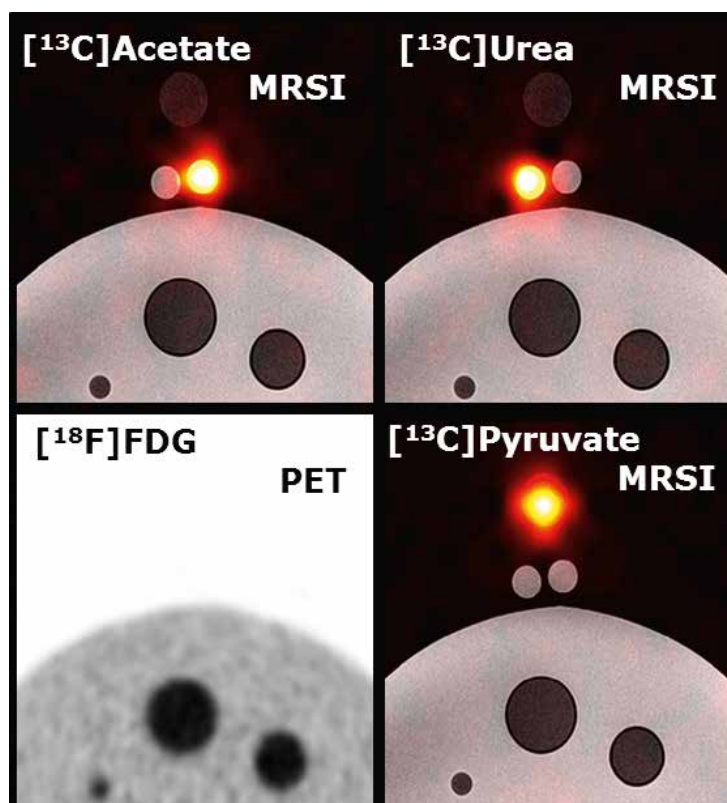
Once hyperpolarization has been achieved, the biological compound is injected in the subject. Imaging must be performed fast, as the lifetime of the hyperpolarization is short, typically below one minute. MRSI is based on Carbon-13, for which dedicated MR coils and software has been obtained.

The system is integrated with quality control and is able to hyperpolarize 4 samples at the same time. The system is operated by specially trained PET technologists at the department. Hence the system is prepared to be used in human studies.

Since installation, 16 animal studies have been performed in canines and rodents. The biological compound which has been used is Carbon-13 enriched Pyruvate. In all studies an MR signal from the injected Pyruvate has been detected, along with one or more metabolites generated in real time.



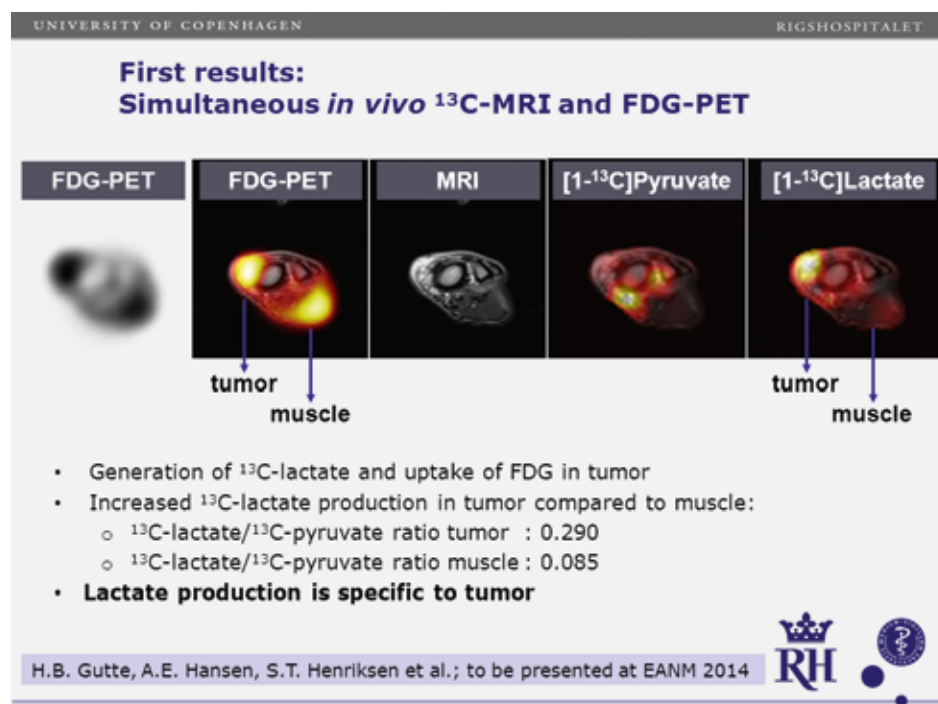
A happy hyperPET team at Rigshospitalet after SpinLab system installation



*Example of integrated Hyperpolarized Carbon-13 MRSI and PET in a phantom.
Left: FDG-PET. Right: Hyperpolarized Carbon-13 MRSI using Pyruvate
(color overlay on standard MRI)*



The labrador Fiola is being prepared for the premiere of hyperPET



HyperPET of Fiola clearly demonstrating that FDG uptake is non-specific to Warburg effect in tumors (positive both in tumor and muscle) whereas lactate generation specifically demonstrates the effect (positive in tumor but not in muscle)

HyperPET:

A new imaging concept combining hyperpolarized ^{13}C -Pyruvate MRSI and FDG-PET



Andreas Kjær and Adam Espe Hansen

On the 4th of April, 2014, the dog Fiola was the first mammal to be examined by simultaneous hyperpolarized ^{13}C -Pyruvate MRSI and ^{18}F -FDG-PET. Fiola had a spontaneous tumor, a liposarcoma, on the right forepaw, which showed FDG-uptake on PET and production of ^{13}C -Lactate on MRSI due to aerobic glycolysis (Warburg effect) in the tumor. In contrast to ^{18}F -FDG uptake, lactate production is a direct consequence of the Warburg effect. Accordingly, it was observed that whereas the muscle of the forepaw also had a high ^{18}F -FDG uptake due to use of the muscle during anesthesia this was not accompanied by a significant ^{13}C -Lactate production. This clearly demonstrates how the Warburg effect is specifically

shown by hyperpolarized ^{13}C -Pyruvate MRSI whereas ^{18}F -FDG was not capable of this. We have named this new methodology which was pioneered at our department hyperPET. The use of this technology was covered in the weekly medical newspaper Dagens Medicin. The scientific feasibility study was published online in AJNMMI 2014 (Gutte et al.). At present, we have performed hyperPET in more than 10 additional dogs with various spontaneous tumors.

Nuclear Medicine

Diagnostics and treatment



Jann Mortensen and Peter Oturai

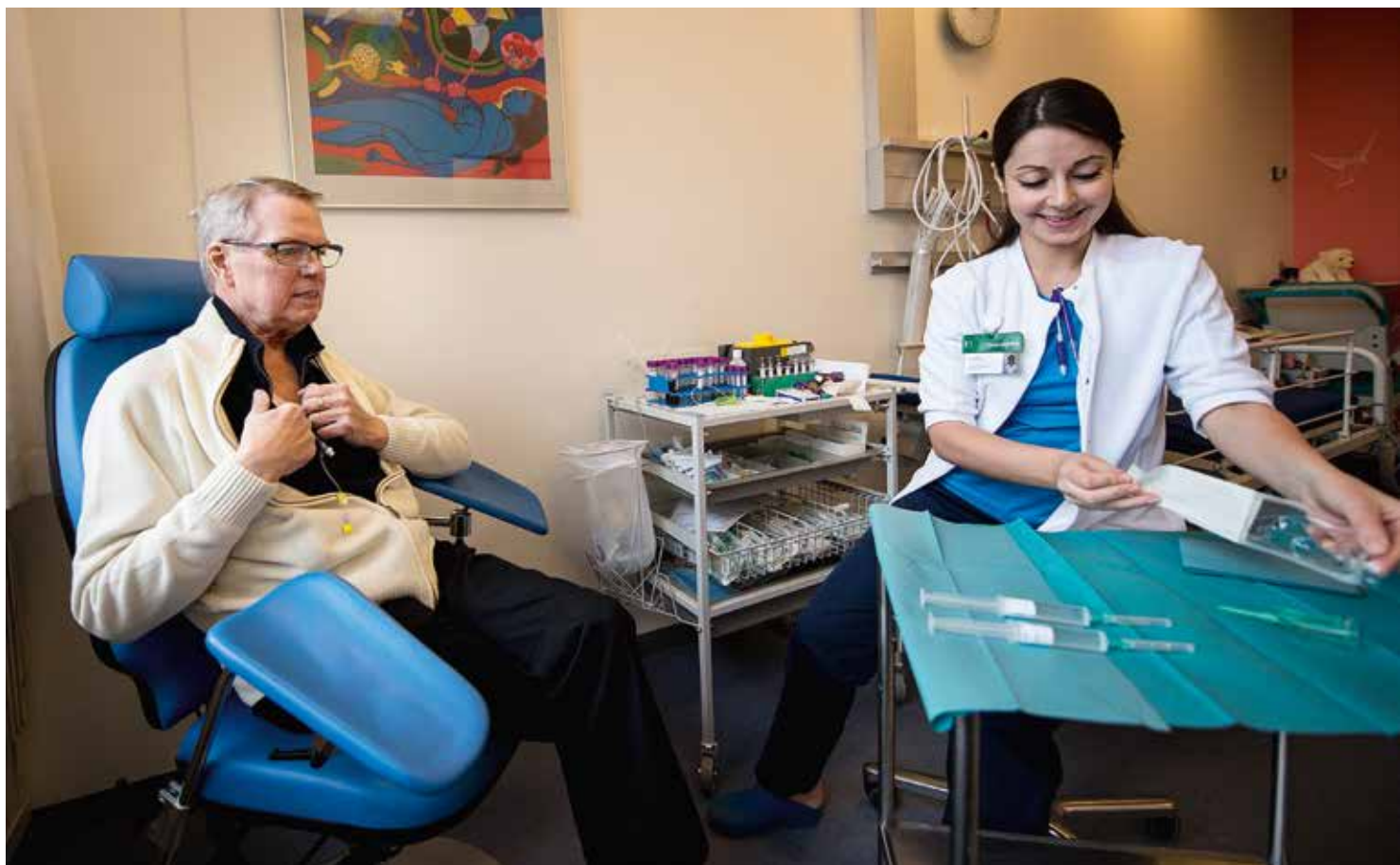
During 2014 our new PET/CT scanner has been extensively used for cardiac (^{82}Rb PET/CT), neuroendocrine (^{68}Ga DOTATOC PET/CT) and pediatric (^{18}F -FDG PET/CT) investigations in our section. This has resulted in higher diagnostic values, shorter examinations and referrals from abroad. We are currently analysing data from our comparison study investigating the diagnostic value of ^{18}F -PET/CT and ^{99}Tc -HDP SPECT/CT for malignant bone disease. The PET/CT scanner together with the gamma camera equipment for routine nuclear medicine imaging and research studies - three hybrid SPECT/CT cameras, one dual-head gamma camera and four single-head cameras - allow us to offer state-of-the-art nuclear medicine investigations to most clinical departments in the hospital. We receive requests for among others - sentinel node scintigraphy for oral cancer, breast cancer, malignant melanoma, penile and vulva cancer, ventilation/perfusion SPECT/CT for pulmonary embolism and pre and post operative assessment for lung surgery, bone SPECT/CT for malignant tumors and

benign disorders, SPECT/CT for various endocrine disorders, and radio-aerosol mucociliary clearance scintigraphy to diagnose primary ciliary dyskinesia. Furthermore, we are now again able to offer aprotinin scintigraphy for the diagnosis of amyloidosis.

For lung function testing we have two Jaeger body plethysmographs. Frequent indications for lung physiology measurements are pre- and postoperative evaluation of endobronchial stents in COPD, transplantation, lung cancer and control after chemotherapy.

Our DEXA-scanner has been extensively used for bone mineral density and whole body composition investigations - for both routine patients and research projects.

Diagnostic ultrasound is used as an adjunct to thyroid scintigraphy in patients having thyroid diseases or hyperparathyroidism.



The radionuclide therapy function in the section has been extended to comprise – as the first department in Denmark – ^{223}Ra treatment of patients with prostate cancer and bone metastases.

Treatment with ^{177}Lu -DOTATATE in Denmark to patients with neuroendocrine tumors has been performed in the department since May 2009. Until the end of 2014, 134 patients have been given a total of 436 treatments. Being one of the two highly specialised centers using this treatment modality in Denmark we work in close collaboration with the Departments of Gastro Surgery, Oncology, Radiology, Pathology and Endocrinology at Rigshospitalet. More patients from Odense University Hospital, Århus University Hospital and abroad (eg. the USA and Canada) are now referred to us. The NET-Center at Rigshospitalet has been accredited as *Center of Excellence* by the European Neuroendocrine Tumour Society (eNETS).

^{177}Lu -DOTATATE is synthesized and labelled at the Hevesy Laboratory at Risø, DTU and is administered in our dedicated facilities in the department. The radio labelled somatostatin analogue binds to neuroendocrine tumors expressing somatostatin receptors. Beta-particles from the ^{177}Lu -isotope destroy the tumor cells and the gamma photons are used for scintigraphic imaging and dosimetry.

For many years the department has successfully treated patients with benign thyroid diseases – goitre and hyperthyroidism – with ^{131}I -iodine.

In 2014 we have had weekly and monthly conferences dealing with neuroendocrine tumors, thyroid diseases, pediatric oncology, cardiology, and lung, adrenal and orthodontic diseases.

Cyclotron Unit



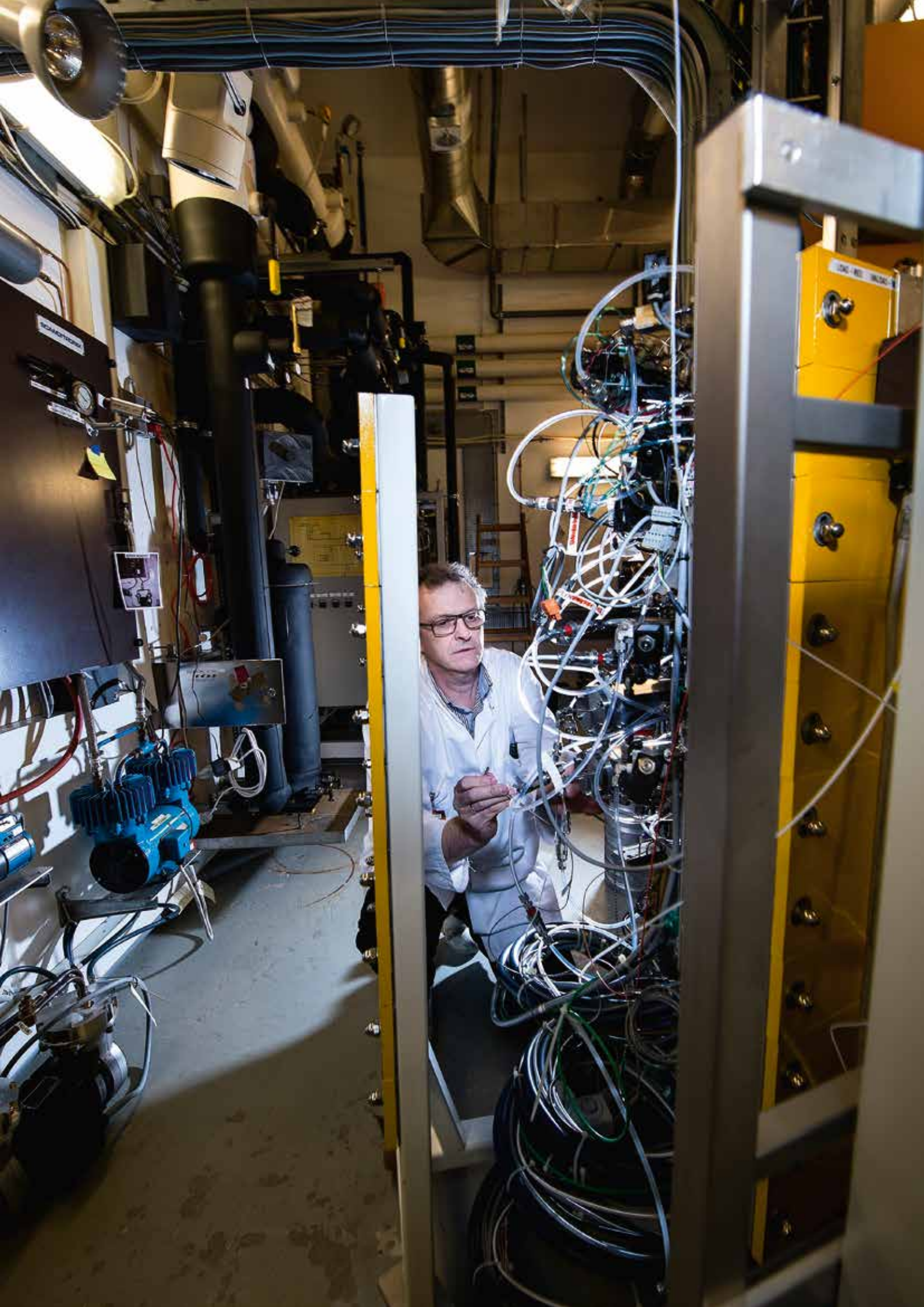
Holger J. Jensen

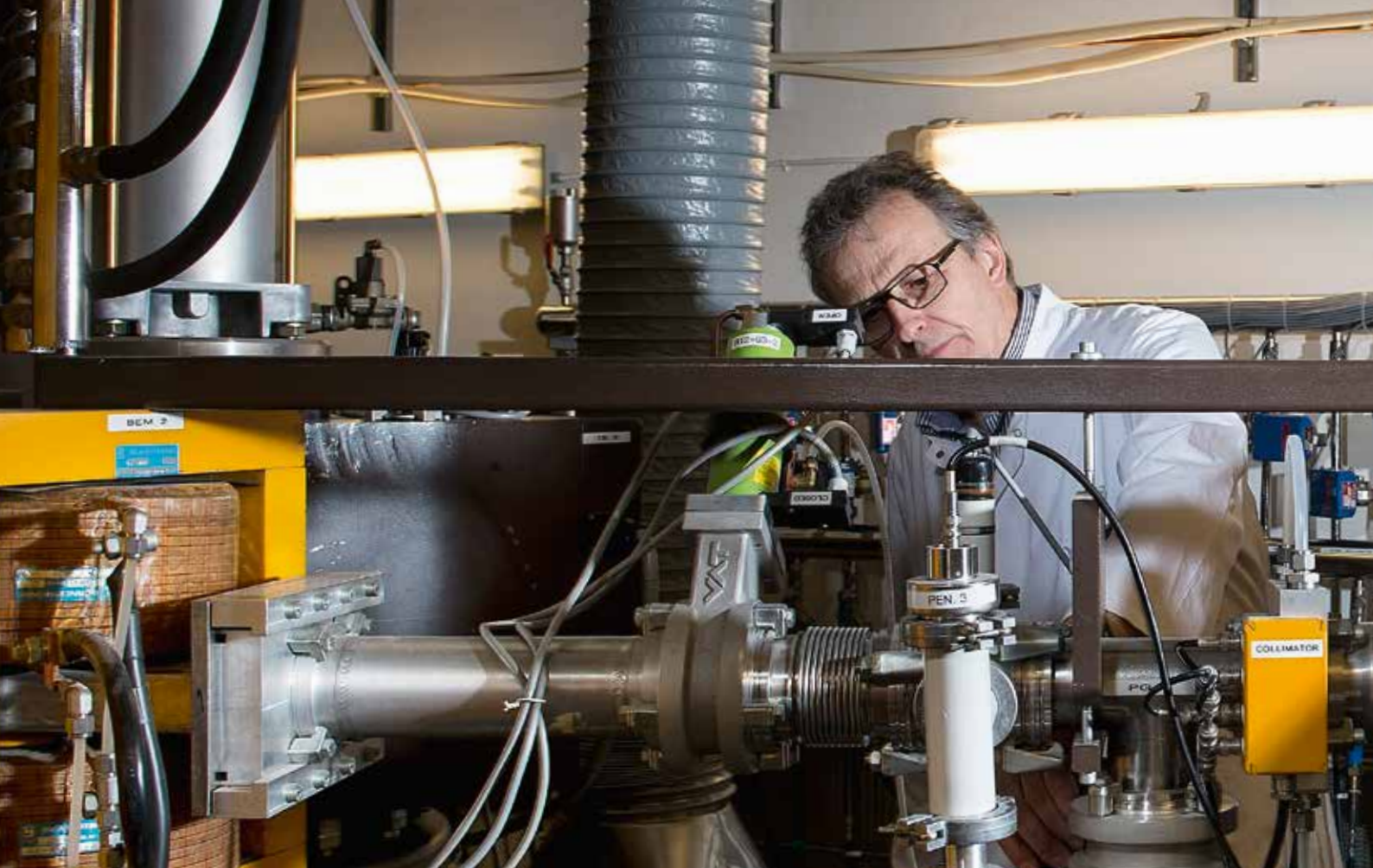
During the last 9 years we have experienced a steady increase in our total number of productions of 6,3% per year in average as seen in figure 1 (page 29). In 2014 we had in total 1,206 successful productions (613 and 593 for our Scanditronix MC32 and Siemens RDS Eclipse cyclotrons respectively) or 5,3% more than in 2013. As in the previous years we also managed to keep the average radiation dose to the employees in the Cyclotron- and Radiochemistry unit at a low level, see figure 2 (page 29).

In 2014 we experienced increasingly serious RF problems for the RDS Eclipse cyclotron, but due to the flexibility of running two cyclotrons we succeeded to have only one cancelled production in 2014 giving an average success rate of 99.5% since 2006. The problem was finally solved in December.

Several upgrade projects for our Scanditronix MC32 cyclotron were initiated in 2012 and continued in 2013 and 2014:

- A new ^{18}F target loading and unloading system has been designed and build together with our colleagues in Uppsala. The target system can serve two ^{18}F targets at the same time. The control system was integrated in our new S7 PLC cyclotron SCADA system in 2014 and makes the old IBA system obsolete. The new system gives us full control and flexibility on all details of the system. Hardware, coding and operation details can easily be copied to other targets that are planned to be renovated / upgraded in near future (^{13}N , ^{15}O and Rb/Kr).
- In order to improve the beam optics and performance for the first critical orbits in the central region and the vacuum, we started in 2012 a process of constructing new parts for the central region and for ion sources together with the company HRS. This work was continued in 2013 and 2014, and today we have full control of design and construction of all critical parts.
- As part of the project on improving the central region, we initiated in 2014 a collaboration with the School of Electronic and Electrical Engineering, Sung Kyun Kwan University, in the Republic of Korea on simulations of





electric and magnetic fields for our MC32 cyclotron, and calculations on beam tracking and optics.

- A new target for production of $^{62}\text{Zn}/^{62}\text{Cu}$ generators as a source of ^{62}Cu (97.4% β^+) for PET radiopharmaceuticals was build together with HRS last year. The short half-life of ^{62}Cu (9.74 min) makes the use of ^{62}Cu very limited, when produced directly in a cyclotron. But with the 9.13h half-life of ^{62}Zn the generator can be used for more than one day and can potentially at the same time be distributed to many hospitals in Denmark and Sweden. The nuclear fusion reaction used for producing ^{62}Zn requires beam energies of 30 MeV or higher. This is much higher than the available energies for typical medical cyclotrons and therefore ideal for our Scanditronix MC32 cyclotron. The final validation of the target is planned to be done in 2015.
- A replacement of the original Siemens Simatic S5 and CP521 based control system from 1992 with a new S7 and IGSS based SCADA system was started in 2012 and continued in 2013 and 2014. The work is still ongoing and in 2015 all I/O boards for the more than 1,000 digital and analog signals will be exchanged. The update gives us a modern software and hardware platform and an up to date system with modern features of easy handling of alarms and coding of new

logic, the possibility of logging parameters and making various reports and graphs. The upgrade plays an important part in our future plans for the MC32 cyclotron



- The last project to be mentioned here is the project on replacing major parts of the electronics in the RF system (RLC, RPM, RDRC and RDRA). The original system is more than 22 years old and it is getting more and more difficult to find spare parts for this sub-system. Consequently a new project were started in 2012, where we together with Axcon Aps carried out a detailed pre-investigation of the system in order to establish the necessary knowledge to design new electronic boards and to estimate the cost for a total replacement. In the new design 46 electronic boards are replaced with only 8 boards and all parts are replaced with modern and up to date technology. The project was finally funded in 2013 and in 2014 the new system was build, installed and validated.



The building of the new Nordfløj at Rigshospitalet has initiated another big project for our department. Already in 2010 it was realized that our existing chimney for release of radioactive gases produced in our growing radiopharmacy production, would not be sufficient to fulfill the requirement from the authorities (SIS) during and after the building of the new building. The requirements are that we by a risk analysis can guarantee that no one in the general publication will receive more than $100 \mu\text{Sv}/\text{y}$ from our activities (or approximately 30 times lower than the average background dose in Denmark). In 2011 we made a new risk analysis together with the Wind Energy Section at Risø for a new chimney 2 meter higher than the highest building at Rigshospitalet (as it is demanded in the legislation) and placed at the south-east corner of Central-komplekset. In 2012 the plans were accepted by SIS. The funding was finally approved in early 2014 and the building project was transferred to Byg og Teknik medio 2014. It is expected that the project will start beginning of 2015.

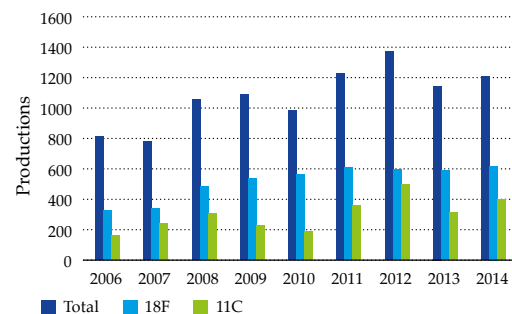


Figure 1 Development in total number of productions, ¹⁸F and ¹¹C productions since 2006.

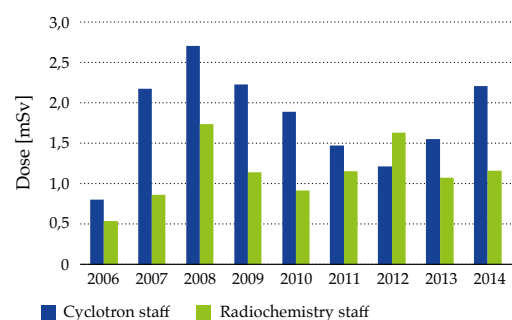


Figure 2 Average received doses for employees in the Cyclotron- and Radiochemistry Unit since 2006.

Radiochemistry



Nic Gillings and Jacob Madsen

Highlights

- In 2014 we produced in-house developed radiopharmaceutical, [^{64}Cu]DOTA-AE105, which shows great promise for uPAR imaging for a first-in-man clinical trial of 10 cancer patients.
- After considerable work validating our in-house produced radiolabelling kits, we finally received approval from The Danish Health and Medicines Authority for use of $^{99\text{m}}\text{Tc}$ -Aprotinin in humans. This radiopharmaceutical can now again be used for diagnostic imaging of amyloidosis patients.
- Productivity continues to increase year on year (see figure) and in 2014 there were more than 1,100 productions for human use or animal studies.
- In December 2014, Radiochemist Matthias Herth, who has been a postdoc researcher in our department for the last 5 years, was appointed as associate professor in radiopharmaceutical chemistry at the Department of Drug Design and Pharmacology, Faculty of Health and Medical Sciences, University of Copenhagen. Together with continuing his research activities, Matthias Herth will establish a radiopharmaceutical chemistry education program for masters students.

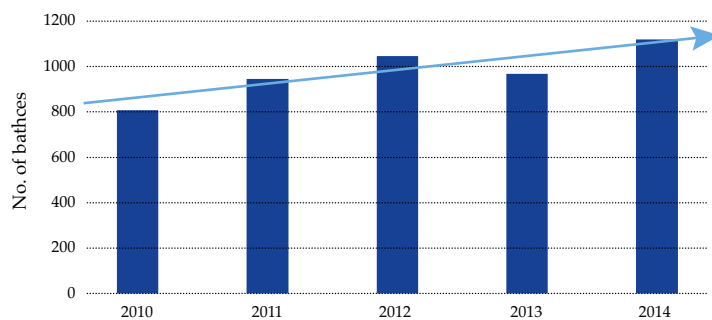
Production for clinical and research PET in humans

Production of [^{18}F]FDG and Krypton-81m generators along with [^{18}F]FET and [^{18}F]FLT was on a par with 2013, whilst production of [^{68}Ga]DOTATOC for neuroendocrine tumors again increased dramatically with almost twice as many production compared to 2013. The number of production of neuroreceptor tracers for humans was lower than in previous years due to a much increased focus on animal studies for development of new tracers. The production of the Alzheimer tracer, [^{11}C]PIB, was on a par with the last two years.

Radiopharmaceutical development

Oncology — Due to the limited availability of Copper-64 and fast pharmacokinetics, a Gallium-68 labelled uPAR imaging agent [^{68}Ga]NOTA-AE105, has been developed and validation for human use commenced at the end of 2014 and a clinical trial application for this tracer will be submitted in 2015. Development of various Fluorine-18 labelled analogues of AE105 was continued in 2014, although an optimal tracer has yet to be developed.

Various strategies for radiolabelling and purification of [^{64}Cu]Herceptin were developed in 2014 with a view to testing this as a HER2 imaging agent. Results from in vivo



Radiopharmaceutical productions 2010-2014

evaluation in animals were promising and further studies are planned in 2015.

For angiogenesis imaging [^{68}Ga]NODAGA-cRGDyK₂ has shown promise in animal studies and validation for human use will be undertaken in 2015.

For apoptosis imaging, synthesis of the small peptide, [^{18}F] ApoPep-1, via the copper(I)-catalyzed alkyne-azide cycloaddition (click reaction), was investigated. The radiochemical development and biological evaluation will continue in 2015.

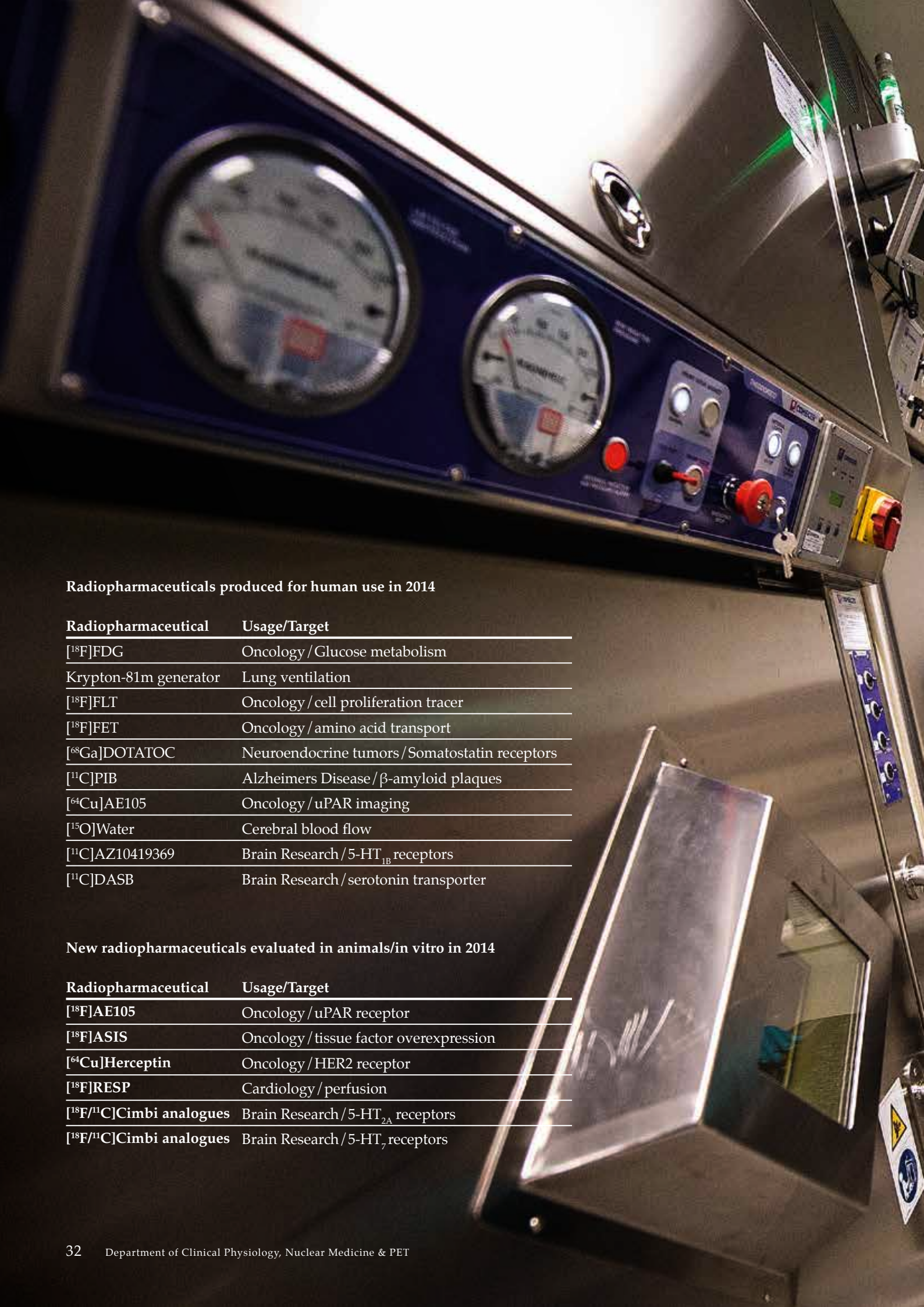
Several strategies for site-specific radiolabelling of ASIS (active site-inhibited factor VIIa) were investigated in an ongoing PhD project. For this purpose a new Fluorine-18 labelled synthon used for an oxime coupling was successfully developed. For radiolabelling with Copper-64, a NOTA chelator was introduced in a well-defined position using a copper-free click reaction.

Neurobiology — In collaboration with The Neurobiology Research Unit, Rigshospitalet and the Department of Drug Design and Pharmacology, Faculty of Health and Medical Sciences University of Copenhagen under CIMBI (Centre for Integrated Molecular Brain Imaging) there was consid-

erable activity with respect to new tracer development and evaluation. Activities focused mainly on 5-HT₇ antagonists and Fluorine-18 labelled analogues of Cimbi-36 (5-HT_{2a} agonist). There were 62 productions of new compounds in 2014 for evaluation in pigs which is twice as many as in previous years.

Amyloidosis — In 2014 we worked on radiolabelling of aprotinin with both Fluorine-18 and Gallium-68 and these tracers will be evaluated in an animal model of amyloidosis in 2015.

Radiochemistry — Work on selective [^{11}C]methylation of phenols in the presence of amines was undertaken in 2014 and this work has allowed us to develop of new labelling strategy for our 5-HT_{2A} ligand, [^{11}C]Cimbi-36. [^{11}C]Cimbi-36 will be labelled in a new position and a head-to-head comparison with the original tracers will be performed in pigs in order to investigate whether a now identified radioactive metabolite disturbs the quantification of the PET data. As part of her PhD. project, Christina Schjøth-Eskesen worked on optimisation of aziridine ring-opening reactions with [^{18}F]Fluoride and this work was published at the end of 2014. Christina Schjøth-Eskesen will defend her Ph.D. in March 2015.



Radiopharmaceuticals produced for human use in 2014

Radiopharmaceutical	Usage/Target
[¹⁸ F]FDG	Oncology / Glucose metabolism
Krypton-81m generator	Lung ventilation
[¹⁸ F]FLT	Oncology / cell proliferation tracer
[¹⁸ F]FET	Oncology / amino acid transport
[⁶⁸ Ga]DOTATOC	Neuroendocrine tumors / Somatostatin receptors
[¹¹ C]PIB	Alzheimers Disease / β -amyloid plaques
[⁶⁴ Cu]AE105	Oncology / uPAR imaging
[¹⁵ O]Water	Cerebral blood flow
[¹¹ C]AZ10419369	Brain Research / 5-HT _{1B} receptors
[¹¹ C]DASB	Brain Research / serotonin transporter

New radiopharmaceuticals evaluated in animals/in vitro in 2014

Radiopharmaceutical	Usage/Target
[¹⁸ F]AE105	Oncology / uPAR receptor
[¹⁸ F]ASIS	Oncology / tissue factor overexpression
[⁶⁴ Cu]Herceptin	Oncology / HER2 receptor
[¹⁸ F]RESP	Cardiology / perfusion
[¹⁸ F/ ¹¹ C]Cimbi analogues	Brain Research / 5-HT _{2A} receptors
[¹⁸ F/ ¹¹ C]Cimbi analogues	Brain Research / 5-HT ₇ receptors



PET/CT in oncology, infection and inflammation



Annika Loft Jakobsen and Anne Kiil Berthelsen

In oncology, indications for PET/CT are diagnosis, staging, therapy planning and monitoring besides detection of recurrent disease in patients with a variety of malignant diagnoses. PET/CT is a well integrated tool due to the high sensitivity and specificity and has in many workflows replaced other imaging modalities.

At Rigshospitalet the CT scans of our PET/CT 's are performed as high quality diagnostic scans with the use of oral and intravenous contrast media. The PET- and the CT scans are interpreted by an expert in nuclear medicine and an expert in radiology side-by-side reporting a final, combined conclusion taking both the PET and the CT examinations into account besides the fused images. This provides the clinician with a more precise PET result, a better CT result and also a more useful conclusion. To improve the diagnostic quality we have included a supplementary CT of the lungs with breath hold technique.

We participate in 17 weekly multidisciplinary team conferences, where our PET/CT scan results are discussed with the clinical experts. This teamwork is inspiring and crucial for improving the diagnostic quality of our PET/CT scan interpretation. The number of PET/CT scans is still increasing.

Approximately, 50% of our patients participate in various clinical research protocols. Our main topics are gynaecological cancers, malignant lymphoma, neuroendocrine tumors, head & neck cancer and lung cancer.

FDG is still the main tracer in oncology, but we also use ^{18}F -NaF, ^{18}F -FET, ^{18}F -FLT, ^{68}Ga -DOTATOC and ^{64}Cu -DOTATATE in clinical studies as well as in research protocols.

The use of PET/CT in infectious and inflammatory diseases is increasing for diagnostic purposes as well as in treatment monitoring. The idea of exchanging leucocyt scintigraphy with PET is quite obvious for the patient due to the time-saving procedure of the PET/CT, and the clinical results are promising but not yet confirmed in large randomized protocols.

Working with PET/CT is fascinating due to the great clinical impact of the method as well as the inspiring collaboration with the clinical departments and there is no doubt that PET/CT has found its place in the everyday clinical work. However, research and clinical trials are still necessary to verify the usefulness of the method, to refine the scanning protocols as well as to exploit new indications.

228130

VG930m

Fig 1. Sagittal view of patient with an esophageal cancer referred for PET/CT planned radiotherapy. This image reveals the primary tumor in the upper esophagus.

Fig 2. The PET/CT scan also revealed an unknown other primary tumor in the head and neck region.

Fig 3. Dose plan for radiotherapy for the esophageal cancer. The head and neck tumor was resected at surgery.



Fig 1.



Fig 2.

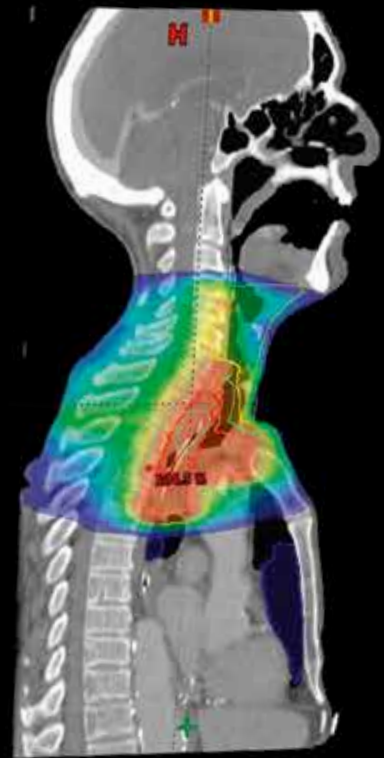
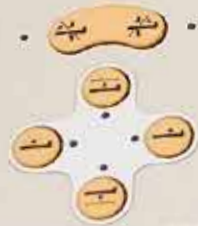


Fig 3.

ViewSonic

PHILIPS



WARNING: Do not use this monitor for medical purposes.





PET/CT scanning in radiation therapy



Annika Loft Jakobsen and Anne Kiil Berthelsen

Performing 800 PET/CT scans yearly for radiotherapy planning of cancer patients; it has become a daily routine procedure in our department for patients with brain, head & neck-, lung-, oesophageal-, cardia-, cervix- and vulva cancer as well as malignant lymphoma and sarcoma.

We are fortunate to have an excellent collaboration with the Department of Oncology, The Radiotherapy Section between all involved professional groups. The workflow is facilitated due to our location in the same building as well as the fact that some of our radiologists are employed in both departments.

The advantages of implementing PET/CT in the workflow are numerous: the anatomical localization and the metabolic activity of the tumor are defined, especially when the tumor density in CT images is difficult to differentiate from that of the surrounding normal tissue. The tissue heterogeneity can then be taken into account when choosing radiation technique and energy, and only one scan is necessary. All our PET/CT scanners have the possibility of performing PET/CT scans for radiotherapy planning. The nuclear medicine specialist delineates the viable tumors depicted by PET on the fused PET/CT images after interpretation together with

the radiologist. We rely on visual analysis more than fixed threshold levels.

We always perform our therapy scans as whole body examinations which in almost one fifth of the cases reveals unknown distant metastases or new primary tumors which changes the treatment plan for the patient.

Research in this field is necessary. Breathhold PET in mediastinal lymphoma is now implemented as a routine therapy scan procedure hereby reducing the radiation dose to the heart and lungs. We are involved in numerous research protocols, local as well as multicentre including the clinical impact of using PET/MR for radiotherapy planning.

Cardiac PET



Philip Hasbak

At Rigshospitalet there is a special need to provide cardiac PET every day, since a large proportion of our patients with ischemic heart disease need an acute or sub-acute work-up that requires quick decision making as to coronary revascularisation strategy. Patients with unstable angina or non-STEMI should be revascularised with percutaneous coronary intervention (PCI) within 3 days after admission or with coronary artery bypass graft surgery (CABG) within 5-7 days according to The Danish National Board of Health. Non-invasive assessment of myocardial function is an important domain of PET. Traditionally, cardiac PET images have been visually interpreted, using uptake as a measure of function. This approach, however, takes only a fraction of the full PET information into account. In contrast, the application of tracer kinetic modelling to dynamically measured data is able to extract objective measures of perfusion and /or metabolism, depending on the tracer. While such true cardiac quantification has been troublesome and time consuming in the past our new cardiac tool now makes this state-of-the-art technology readily available

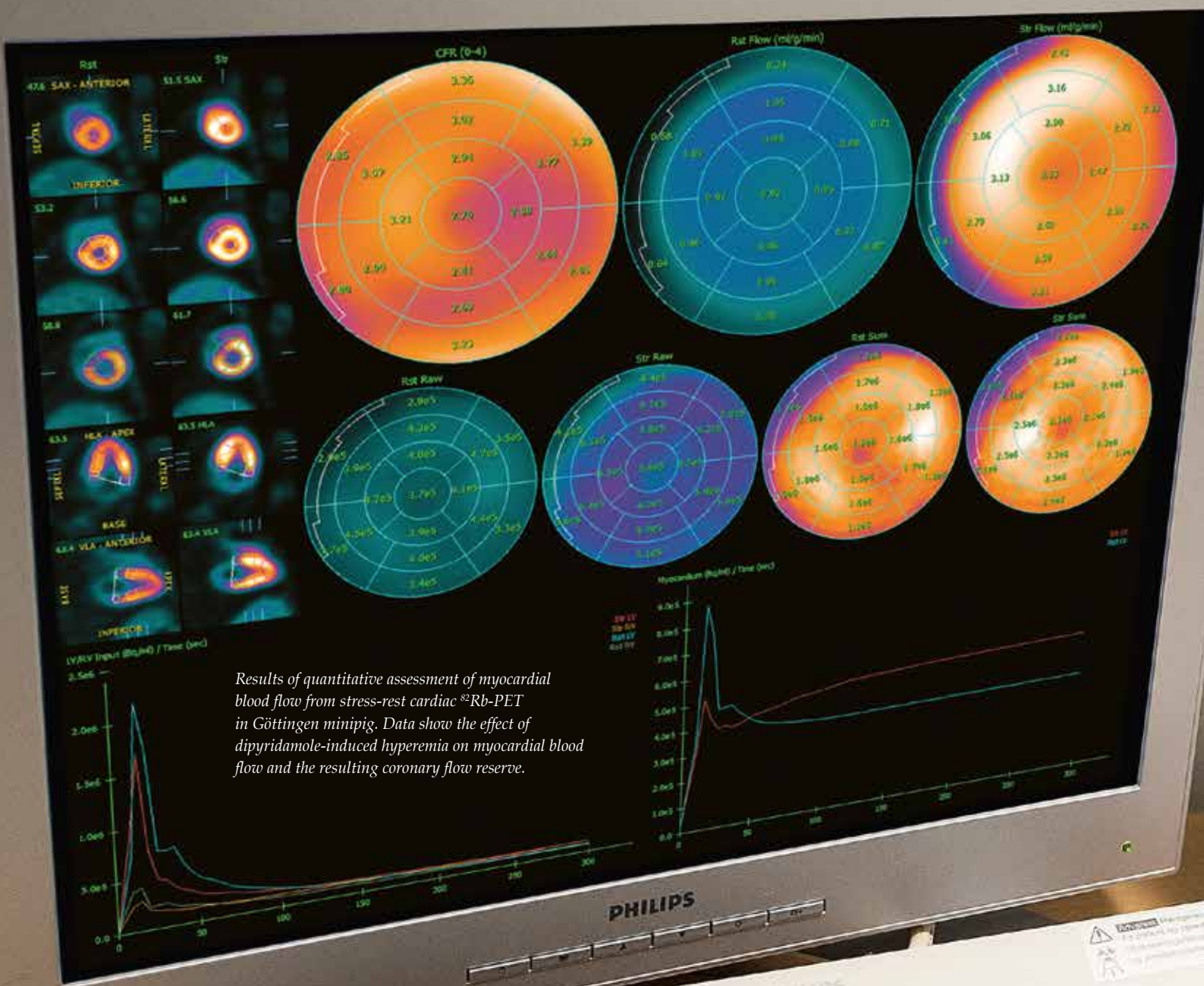
Research-wise we have a close and good cooperation with various clinical departments.

Certain ongoing projects should be emphasized:
In collaboration with

- Department of Cardiology: Molecular imaging in patients suspected of acute ST-elevation myocardial infarction (STEMI) with angiographically normal coronary arteries.
- Department of Oncology: Cardiac side effects in radiation therapy for breast cancer
- Department of Vascular Surgery and Department of Anesthesiology: Buttock ischemia after endovascular abdominal aortic aneurysm repair

Cardiac ¹²³I-MIBG

In 2010 we introduced cardiac ¹²³I-Metaiodobenzylguanidine (¹²³I-MIBG). Radiotracer analogs of the sympathetic mediator norepinephrine have been investigated extensively, and are at the brink of potential widespread clinical use, especially after the presentation of the ADVANCE-HF trial. The most widely studied SPECT tracer, ¹²³I-MIBG has consistently shown a strong, independent ability to risk stratify patients with advanced congestive heart failure. One ongoing project should be emphasized:
In collaboration with the Department of Cardiology: Cardiac sympathetic activity in patients suspected of Takotsubo-cardiomyopathy.



Results of quantitative assessment of myocardial blood flow from stress-rest cardiac ^{82}Rb -PET in Göttingen minipig. Data show the effect of dipyridamole-induced hyperemia on myocardial blood flow and the resulting coronary flow reserve.

PET scanning of the brain



Ian Law and Otto Mølby Henriksen

In 2014 we performed 1,400 clinical PET scans of the brain. The investigations cover the range from neurooncology over neurodegenerative disease, cerebrovascular disease, neuroinflammation and epilepsy. Our most important clinical neuro PET tracer is still [F18]Flouro-Deoxy-Glucose (FDG) that accounts for 2/3 of our investigations, and is a significant tool particularly in the evaluation of dementia. The brain utilizes approximately 20% for the body's glucose metabolism. Thus, the measurement of the regional glucose uptake using FDG PET is a very sensitive marker of neuronal dysfunction in dementia and other disorders even with apparently normal structures on CT or MRI imaging (Fig 1). FDG PET is an increasingly frequently used tool in the diagnostic evaluation of dementia.

The Siemens hybrid PET/MR scanner has been implemented into clinical routine investigations for dementia. A diagnostic package consisting of 5 standard MR sequences focused at localizing cerebral ischemia, infarcts, haemorrhages, tumors and normal pressure hydrocephalus have been combined with either FDG or the amyloid imaging agent - [C11]Pittsburgh compound B (PiB) in a short and very comprehensive one-stop imaging shop for dementia.

Our experience is that PET/MR can solve real life clinical diagnostic dilemmas and PET/MR is indeed a technique that can be used robustly in clinical practice. In a single session a patient may receive a thorough and comprehensive examination of outstanding image quality in a short duration and with little risk.

Amyloid uptake in the brain is considered an important risk factor in Alzheimer's disease, and can be used to differentiate between dementia types. We have introduced new standardized methods to measure and report amyloid binding in the brain that have been well received by our clinical partners.

PET imaging with the amino acid analogue [F18]Flouro-Ethyl-Tyrosine (FET) has an established role in the management of brain tumors, and has increasingly been evaluated using PET/MR e.g. in monitoring of therapy effects (Fig 2). We are in the process of developing FET PET/MR in pediatric neurooncology to reduce the stress of anesthesia and improve patient management in this sensitive population.

For radiotherapy planning and the evaluation of recurrent meningioma we are employing [Ga68]-DOTATOC using our high resolution, research tomograph (HRRT) PET scanner, as the growth pattern of meningioma, and the small margins of the stereotactic radiation therapy used make a 2 mm resolution desirable (Fig 3).

In 2014 we participated in 2 randomized clinical treatment trials for Alzheimers disease in collaboration with the Memory Disorders Research Group. These trials are given a high priority as they give access to a potential treatment for a serious progressive condition. Further they enable us to evaluate new tracer technology before they introduced nationally, e.g. alternative brain amyloid tracers.

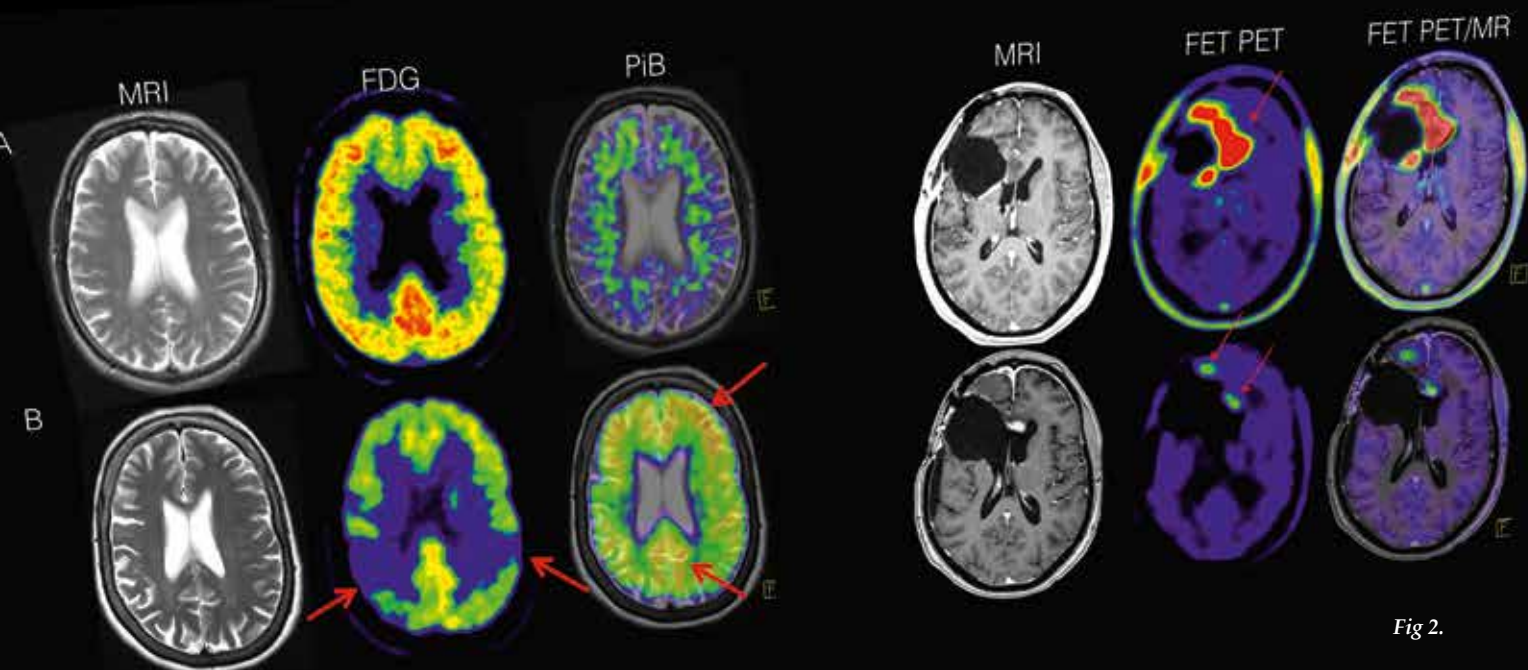


Fig 1.

Fig 2.

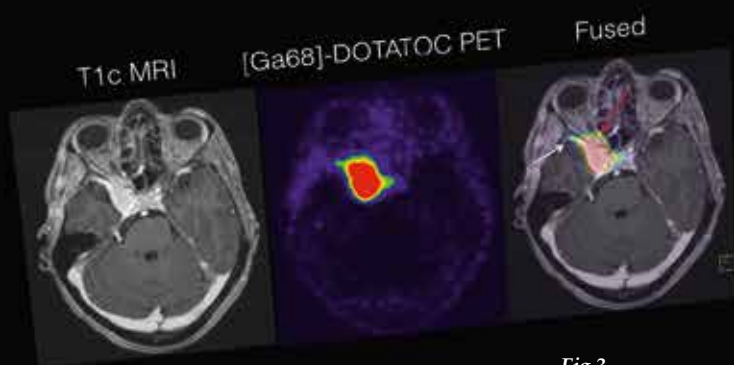


Fig 3.

ViewSonic

Handwritten note on a sticky note:

Handwritten note on a sticky note:

Handwritten note on a sticky note:

Collaboration with Landssygehuset, Faroe Islands



The Department of Clinical Physiology, Nuclear Medicine & PET, Rigshospitalet has a close collaboration with Landssygehuset in Tórshavn, Faroe Islands.

The hospital has a staff of 850 and 170 beds. The 8,000 in-patients and 60,000 out-patients annually are taken care of by 29 specialities, of which 9 are via consultant collaborations, including collaboration with Clinical Physiology and Nuclear Medicine & PET, Rigshospitalet.

The Department of Clinical Physiology and Nuclear Medicine in Tórshavn performed 511 (477 in 2013) scintigraphies of lungs, bones, thyroid, kidneys, sentinel nodes and renography in 2014 on the department's 2-headed Skylight camera. A total of 627 (609 in 2013) lung function tests were performed with the Jaeger whole body plethysmograph. The Norland DXA 840 scanner has been used for a total of 410 routine osteodensitometries as well as research studies of the effect of different types of exercise. Second opinion on scintigraphy and lung function measurements is provided via a direct telemedicine connection. The responsible physician and physicist for Nuclear Medicine in Tórshavn is Consultant, DMSc Jann Mortensen and Physicist Thomas Levin Klausen.

Joined publications (2014) from Departments of Clinical Physiology and Nuclear Medicine in Tórshavn & Rigshospitalet:

- Munkholm ML, Mortensen J. Mucociliary Clearance. Pathophysiological aspects. Clin Physiol Funct Imaging. 2014 May;34(3):171-7. doi: 10.1111/cpf.12085
- Mortensen J, Gutte H. SPECT/CT and pulmonary embolism. Eur J Nucl Med Mol Imaging. Volume 41, Issue 1 (2014), Page 81-90. DOI 10.1007/s00259-013-2614-5.
- Mohr M, Nordsborg NB, Lindenskov A, Steinholt H, Nielsen HP, Mortensen J, Weihe P, Krstrup P. High-Intensity Intermittent Swimming Improves Cardiovascular Health Status for Women with Mild Hypertension BioMed Research International. Volume 2014 (2014), Article ID 728289, 9 pages.
- Mohr M, Lindenskov A, Holm PM, Nielsen HP, Mortensen J, Weihe P, Krstrup P. Football training improves cardiovascular health profile in sedentary, premenopausal hypertensive women. Scan J Med Sci Sports 2014, 24 (suppl. 1): 36-42 doi: 10.1111/sms.12278



Jann Mortensen and Thomas Levin Klausen



Academic and other activities

Andreas Kjær, Professor, Chief Physician, is President of the Scandinavian Society of Clinical Physiology and Nuclear Medicine (SSCPNM), member of the Oncology Committee of the European Association of Nuclear Medicine (EANM), national representative of the European Society for Molecular Imaging (ESMI), board member of the Cancer Research Foundation at University of Copenhagen, previous member of the Scientific Committee of the Danish Cancer Society, Editor-in-Chief of Diagnostics. Leader of a project for development of theranostics for aggressive cancer funded by the Danish National Advanced Technology Foundation, leader of a project on hyperPET, a new method for PET/MRI, funded by the Innovation Fund Denmark and Partner of the Danish Chinese Center for Proteases and Cancer funded by the National Natural Science Foundation of China and the Danish National Research Foundation, National Director and partner of EATRIS (the European Advanced Translational Research Infrastructure in Medicine), Head of the Cluster for Molecular Imaging and Director of the Postgraduate School for Medical & Molecular Imaging at the Faculty of Health Sciences, University of Copenhagen. Member of the Academy of Technical Sciences (ATV).

Anne Kiil Berthelsen, Chief Physician, is a member of the International Lymphoma Radiation Oncology Group, Steering Committee (ILROG), of the European Organisation for Research and Treatment of Cancer Lymphoma Group (EORTC), the Danish Radiology Society, the Danish and the Nordic Society of Gynaecological Oncology, British Institute of Radiology (BIR), Billed-diagnostisk Udvalg Ukendt Primær Tumor (DAHANCA), National PET/CT Group, the Danish Society of Clinical Oncology and the Danish Society of Magnetic Imaging.

Annika Loft Jacobsen, Chief Physician, is involved in a various number of clinical research protocols, teaching at national and international courses pre- and post graduate for medical doctors, technologists, radiographers and nurses and is invited speaker at national and international meetings and congresses. Supervisor for several PhD Students and responsible for the specialist course in Oncology for Nuclear Medicine Physicians. Member of the European Organisation for Research and Treatment of Cancer (EORTC). Member of the EANM, BIR, Danish Society of Oncological Radiology and Danish Society of Clinical Physiology and Nuclear Medicine. Member of Regional Working Groups for implementation of clinical guidelines for: colorectal liver metastases, lymphoma, malignant melanoma, cancer of unknown primary, and suspicion of severe disease. Member of National Working Groups for Lymphoma (Chair of the Diagnostic Imaging Group under Danish Lymphoma Group (DLG) and pharyngeal/laryngeal cancer). Member of the Steering

Group for Danish Liver and Biliary Cancer and board member of DGCG (Danish Gynecological Cancer Group).

Camilla Sloth Knudsen, Nuclear Medicine Technologist, is member of the Board of LSB (Laboratoriemedicinsk Selskab for Bioanalytikere).

Helle Hjorth Johannesen, Chief Physician, is a member of Danish Society of Radiology, President of Danish Society of Oncoradiology, member of Danish Society of Medical Magnetic Resonance Imaging and Danish Society for Good Clinical Practice.

Ian Law, Professor, MD DMSc, PhD, is responsible for the specialist course in oncology and in the central nervous system for nuclear medicine physicians. Member of the Neuroimaging Committee, European Association of Nuclear Medicine (EANM), the PET Response Assessment in Neurooncology working group (RANO) under the European Association of Nuclear Medicine (EANM), European Association of Neurooncology (EANO), and Society of Neurooncology (SNO). Member of the working group for Clinical Guidelines for the Treatment of Brain Metastases, Danish Neurosurgical Society (DNKS). Member of Society for Nuclear Medicine and Molecular Imaging (SNMMI), European Association of Nuclear Medicine (EANM), Danish Neurological Society (DNS), Danish Neuroscience Society (DSNV), European Association of Neurooncology (EANO), Danish Radiological Society (DRS), European Society of Radiology (ESR). Supervisor for several PhD students.

Jacob Madsen, Chief Production Manager, is member of the board of DSKFNM (Danish Society of Clinical Physiology and Nuclear Medicine).

Jann Mortensen, Clinical Associate Professor, Chief Physician, is member of Den Regionale Videnskabsetiske Komité F for Hovedstaden (Regional Ethics Committee). He is a member of the steering committee of Dansk Lungecancer Gruppe (Danish Lung Cancer Group), the subcommittees for Dansk Diagnostisk Lungecancer Gruppe (Danish Diagnostic Lung Cancer Group) and Lungecancer Screeningsgruppen (Screening of Lung Cancer Group). Member of the Regional Working Group for implementation of clinical guidelines for Breast Cancer workup. Member of the steering committee and the quality subcommittee for creating Danish reference values for lung function. He is responsible for the specialist course in Clinical Respiratory Physiology for Nuclear Medicine Physicians and Respiratory Physicians. Member of the editorial board of two medical journals. He is the responsible physician for Nuclear Medicine in the Faroe Islands.

Linda Kragh, Chief Nuclear Medicine Technologist, is member of Sundhedsfagligt Råd i Klinisk Fysiologi og Nuklearmedicin i Region H, SFR, (the Speciality Advisory Committee in Clinical Physiology and Nuclear Medicine in the Capital Region), Head of the DRG Committee of DSKFNM member of Uddannelsesforum for Bioanalytikeruddannelsen i Region H, (the Speciality Council for the Education of Technologists in the Capital Region) and member of Uddannelsesudvalg på Radiografuddannelsen ved Metropolit.

Lise Borgwardt, Chief Physician, is a Scientific Committee member of the EANM, member at the Pediatric Committee under EANM, member of the Pediatric Imaging Harmonization Group, member of the Tumorboard for Pediatric Solid Tumors at Rigshospitalet, Chair of the Pediatric Network Group at Rigshospitalet, Chair of the Pediatric Focus Group at the Department of Clinical Physiology, Nuclear Medicine and PET and member of the Process Group for the development of the Children's Hospital at Rigshospitalet.

Liselotte Højgaard, Professor, Head of Department. Chairman of the board of the Danish National Research Foundation. She is Member of Conseil d'Administration, INSERM, L'Institut National de la Sante et de la Recherches Medicales, Frankrig. Chair of of EC Science Advisory Board in Health Research. She represents the University of Copenhagen, Rigshospitalet in the Medicine and Technology Bioengineer program, the Technical University of Denmark (DTU), where she is also adj. professor. Elected Member of the Royal Danish Academy of Sciences and Letters. Member of The Danish Academy of Technical Sciences, ATV. Advisory Board member of Deutsche Krebsforschungs Zentrum, DKFZ. Member of the board of the Crownprins Frederik and Crownprinsess Mary's Foundation. Member of the board of Arvid Nilssons Foundation and Tagea Brandt's prize.

Maria Helene Pejtersen, Nuclear Medicine Technologist, is member of the Symposiagroup for Technologists at Rigshospitalet.

Marianne Federspiel, Nuclear Medicine Technologist, is member of EANM Technologists Committee.

Otto Mølby Henriksen, Chief Physician, PhD, is member of the DRG Committee and the Course Committee in Danish Society for Clinical Physiology and Nuclear Medicine (DSKFNM).

Peter Oturai, Chief Physician, is responsible for the postgraduate education in the department. He is Danish delegate, representing Danish Society for Clinical Physiology and Nuclear Medicine (DSKFNM), in the European Union of Medical Spe-

cialists (UEMS) and deputy delegate in the European Association of Nuclear Medicine (EANM). He is representing DSKFNM in the Danish Health and Medicines Authority's Committee for Speciality Planning of Clinical Physiology and Nuclear Medicine. He is a member of the board of the Danish Endocrine Society (DES) and member of the Danish Thyroid Cancer Guideline Group. Member of the Doctors Clinical Physiology and Nuclear Medicine Training Committee of the DSKFNM and member of the CME and Educational Committee of the DSKFNM. He is responsible for the specialist course in Endocrine Pathophysiology for nuclear medicine physicians in Denmark. He is webmaster of the website of DSKFNM.

Robin de Nijs, MSc, PDEng, PhD, Specialist Medical Physicist, is member of European Association of Nuclear Medicines Network of Excellence for Brain Imaging and member of the Danish Society for Medical Physics.

Søren Holm, Chief Physicist, is member of the EANM Physics Committee with special tasks in Radiation Protection, a delegate for DSMF to the European and International organizations for Medical Physics (EFOMP and IOMP), board member of the Nordic Society for Radiation Protection (NSFS), member of an IAEA advisory group concerned with QA/QC and image artefacts affecting SPECT/CT, member of Sundhedsfagligt Råd i Klinisk Fysiologi og Nuklearmedicin in the Capital Region, the Specialty Advisory Committee (SFR) in Clinical Physiology and Nuclear Medicine, and external lecturer at Copenhagen University.

Tim Lundby, Deputy Chief Technologist, is member of Lederrådet i Danske Bioanalytikere.

Vibeke Rønn, Head Medical Secretary, is member of the Steering Committee in Head Medical Secretaries Committee at Rigshospitalet.

Studies 2014

CNS and peripheral nervous system

Regional cerebral blood flow, DIAMOX, ^{15}O -H ₂ O	5
Regional cerebral metabolism, ^{18}F -FDG	779
Regional cerebral receptor, ^{11}C -PIB	122
Regional cerebral receptor, ^{18}F -FET	398
Regional cerebral receptor, ^{11}C different tracers human (NRU)	50
Regional cerebral receptor, ^{11}C different tracers animal (NRU)	62
Regional cerebral receptor, ^{18}F -Florbetapir	8
Regional cerebral receptor, ^{18}F -FLT	44
Regional cerebral receptor, ^{68}Ga -Dotatoc	30
Regional cerebral receptor, ^{68}Ga -Dotatoc, therapy	26
CT-scanning of cerebrum	419
MR-scanning of cerebrum	289
Cisternography $^{99\text{m}}\text{Tc}$ -DTPA	1
Total	2,233

Respiratory organs

Lung function test, whole body plethysmography	1,835
Lung function test, whole body plethysmography w / reversibility	394
Lung function test, spirometry,	1,876
Lung function test, spirometry w / reversibility	90
Lung function test, spirometry, physiological provocation	2
Lung function test, diffusion capacity (CO)	4,116
Max. insp. abd exspir. muscle pressure	341
Lung perfusion scintigraphy, $^{99\text{m}}\text{Tc}$ -MAA	10
Lung perfusion scintigraphy, regional, $^{99\text{m}}\text{Tc}$ -MAA	55
Lung perfusion scintigraphy, SPECT, $^{99\text{m}}\text{Tc}$ -MAA	258
Lung ventilation scintigraphy, $^{81\text{m}}\text{Kr}$ -gas	11
Lung ventilation scintigraphy, regional, $^{81\text{m}}\text{Kr}$ -gas	176
Lung ventilation scintigraphy, SPECT, $^{81\text{m}}\text{Kr}$ -gas	276
Lung ventilation scintigraphy, SPECT $^{99\text{m}}\text{Tc}$ -Technegas	1
Mucociliary clearance, $^{99\text{m}}\text{Tc}$ -Venticolloid	17
Total	9,458

Heart and cardiovascular system

Isotope cardiography, RVEF pass, $^{99\text{m}}\text{Tc}$ -HSA	10
Isotope cardiography, LVEF, $^{99\text{m}}\text{Tc}$ -HSA	1,635
Myocardial perf. scintigr. gated, $^{99\text{m}}\text{Tc}$ -MIBI, pharmacol. stress, adeno.	1
Myocardial perf. scintigr. gated, $^{99\text{m}}\text{Tc}$ -MIBI, physiological stress	69
Myocardial perf. scintigr. gated, $^{99\text{m}}\text{Tc}$ -MIBI, NTG	6
Myocardial perf. scintigr. gated, $^{99\text{m}}\text{Tc}$ -MIBI	5
Myocardial perf. scintigr. gated, $^{99\text{m}}\text{Tc}$, MIBG, sympathetic activity	18
Myocardial calcium score	353
PET myocardial metabolism, ^{18}F -FDG	42
PET myocardial perfusion, ^{82}Rb	354
PET myocardial perfusion, ^{82}Rb , pharmacological stress, adeno	317
Exercise electrocardiography	12
Total	2,822

Peripheral vessels

Isolated limb perfusion leakage monitoring, $^{99\text{m}}\text{Tc}$ -erythrocyt	13
Total	13

Gastrointestinal tract, liver, biliary tract and pancreas

Salivary gland scintigraphy $^{99\text{m}}\text{Tc}$ -Pertechnetat	8
Biliary tract scintigraphy, $^{99\text{m}}\text{Tc}$ -Mebrofenin	29
Meckels diverticulum scintigraphy, $^{99\text{m}}\text{Tc}$ -Pertechnetat	1
Bleeding scintigraphy (abdomen) $^{99\text{m}}\text{Tc}$ -erythrocytter	4
Bleeding scintigraphy (abdomen) $^{99\text{m}}\text{Tc}$ -HSA	1
Total	43

Kidneys and urinary tract

Glomerular filtration, ^{51}Cr -EDTA, several samples	197
Glomerular filtration, ^{51}Cr -EDTA, one sample	4,246
Renal scintigraphy, $^{99\text{m}}\text{Tc}$ -DMSA	25
Renography, $^{99\text{m}}\text{Tc}$ -MAG, diuresis	32
Renography, $^{99\text{m}}\text{Tc}$ -MAG 3, graft	3
Renography, $^{99\text{m}}\text{Tc}$ -MAG 3, ACE-inhibitor	36
Renography, $^{99\text{m}}\text{Tc}$ -MAG 3	1,893
Renography, $^{99\text{m}}\text{Tc}$ -MAG 3, dual head	4
Sympaticus activity, kidneys, ^{123}I -MIBG	26
Total	6,462

Bone and joint

Bone scintigraphy, $^{99\text{m}}\text{Tc}$ -HDP, regional, static	25
Bone scintigraphy, $^{99\text{m}}\text{Tc}$ -HDP, whole body, static	568
Bone scintigraphy, $^{99\text{m}}\text{Tc}$ -HDP, SPECT	427
Bone scintigraphy, ^{18}F -Fluorid, whole body, static	50
Osteodens. dual X-ray absorptiometri (DXA), columna lumb.	1,800
Osteodens. dual X-ray absorptiometri (DXA), lat.spine	2
Osteodens. dual X-ray absorptiometri (DXA), radius	125
Osteodensitometri, dual X-ray absorptiometri of collum fem.	3,479
DXA, body composition	671
Total	7,147

Endocrine organs

Thyroid scintigraphy, $^{99\text{m}}\text{Tc}$ -Pertechnetat	601
Thyroid, ultrasound	591
Parathyroid scintigraphy, $^{99\text{m}}\text{Tc}$ -Stamisis	39
Parathyroid scintigraphy, $^{99\text{m}}\text{Tc}$ -Stamisis, SPECT	43
Tumorscintigraphy, ^{123}I -Jodid	2
Tumorscintigraphy, ^{123}I -Jodid, rh-TSH	34
Adrenal marrow scintigraphy, ^{123}I -MIBG	45
Scintigraphy after ^{177}Lu - Dotatate therapy	135
Total	1,490

Blood and lymph system

Erythrocyt volume, $^{99\text{m}}\text{Tc}$ -erythrocytes	11
Plasma volume, ^{125}I -HSA	10
Lymph scintigraphy, extremities, $^{99\text{m}}\text{Tc}$ -HSA, stasis	3
Lymph scintigraphy, extremities, $^{99\text{m}}\text{Tc}$ -HSA, leakage	2
Sentinel node, tumor drainage, $^{99\text{m}}\text{Tc}$ -Nanocolloid	2
Sentinel node scintigr. tumor drainage, c. mammae, $^{99\text{m}}\text{Tc}$ -Nanocolloid	45
Sentinel node scintigr. tumor drainage, mel. malign., $^{99\text{m}}\text{Tc}$ -Nanocolloid	150
Sentinel node scintigr. tumor drainage, c. penis, $^{99\text{m}}\text{Tc}$ -Nanocolloid	12
Sentinel node scintigr. tumor drainage, c. vulvae, $^{99\text{m}}\text{Tc}$ -Nanocolloid	39

Sentinel node scintigr. tumor drainage, head / neck SPECT, ^{99m} Tc-Nanocolloid	57
Sentinel node, peroperative with gamma probe, ^{99m} Tc-Nanocolloid	4
Peritumoral injection of ^{99m} Tc-Nanocolloid for sentinel node	663
Spleen scintigraphy, ^{99m} Tc-erythrocyte, heated	6
Total	1,004

Other diagnostic procedures

Tumor scintigraphy, ¹¹¹ In-Octreotide	7
Aprotinin scintigraphy, ^{99m} Tc-Aprotinin	3
PET tumor scanning, ¹⁸ F-FDG	4,821
PET scanning, ¹⁸ F-FDG	280
PET infection scanning, ¹⁸ F-FDG	85
PET tumor scanning, ⁶⁸ Ga-Dotatoc	614
PET scanning, ⁶⁴ Cu-uPAR	10
White blood cell scintigraphy, ^{99m} Tc-white blood cell	65
White blood cell scintigraphy, ^{99m} Tc-white blood cell, SPECT	27
White blood cell scintigraphy, ¹¹¹ In-white blood cell	43
White blood cell scintigraphy, ¹¹¹ In-white blood cell, SPECT	4
Whole body, contamination measurement	122
Image fusion (PET, SPECT, MRI, CT or planar)	8,782
CT head / neck SPECT / CT	178
CT wb SPECT / CT	523
CT thorax SPECT / CT	572
CT pelvis SPECT / CT	88
CT abdomen SPECT / CT	308
CT lower extremities SPECT / CT	24
CT wb PET / CT (KF)	918
CT wb PET / CT (PET)	4,944
MR wb PET / MR	245
CT lower extremities PET / CT	14
PET / CT therapy scanning, wb	627
Second opinions external PET, PET / CT, SPECT / CT, CT and MR investigations	967
Extra tumor delineation	112
Other investigations	72
Supplementary / repeated imaging	2,358
Total	26,813

Radiotherapy

Treatment with ¹³¹ I, benign thyroid	60
Isotope treatment with ¹⁷⁷ Lu-Dotatate	126
Isotope treatment with ²²³ Ra-Dichlorid	88
Total	274

In vitro analysis

Plasma and protein analysis	6,107
Gene expression analysis	24,242
Immunohistochemistry	2,019
Total	32,368

Animal studies – Cluster for Molecular Imaging

Dogs

¹³ C-Pyruvat	16
¹⁸ F-FDG	16
MR	16

Rats

¹³ C-Pyruvat	1
¹⁸ F-FDG	68
¹⁸ F-FET	7
⁸² Rubidium	49
MR	44

Mice

¹³ C-Pyruvat	26
¹⁸ F-andet	75
¹⁸ F-FDG	453
¹⁸ F-FET	125
¹⁸ F-FLT	40
¹⁸ F-NaF	25
¹⁸ F-XX-AE105	26
⁴⁵ Ti-Salan	13
⁶⁴ Cu-Cl ₂	25
⁶⁴ Cu-DOTA-Herceptin	32
⁶⁸ Ga-DOTATOC	129
⁶⁴ Cu-Herceptin	50
⁶⁴ Cu-Liposomer	782
⁶⁴ Cu-NODAGA-Herceptin	32
⁶⁴ Cu-NOTA-AE105	32
⁸⁹ Zirconium	35
¹⁴⁰ Nd-DOTATATE	6
Optical Imaging	515
Radiotherapy	1,786
MR	625

Pigs

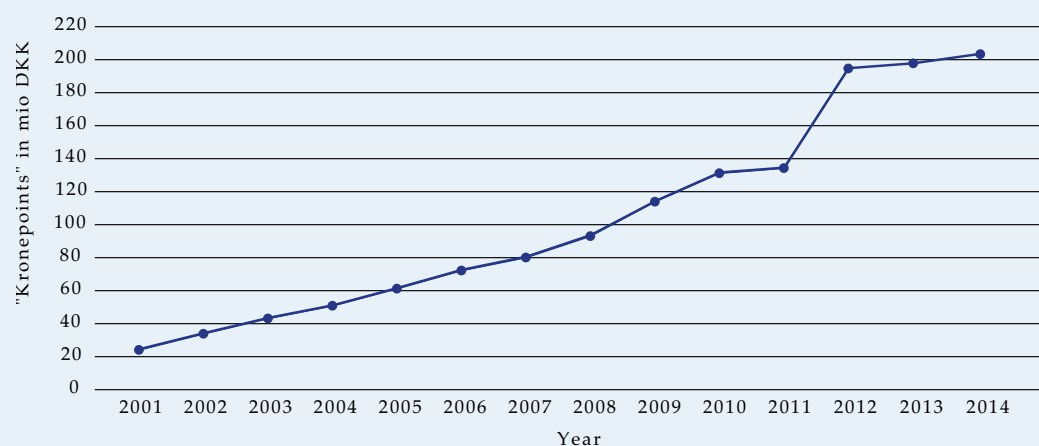
¹⁵ O-H ₂ O	7
¹⁸ F-FDG	6
MR	6

Total	5,068
--------------	--------------

Total number of studies	95,195
--------------------------------	---------------

Finance

Turnover



The increase in activities measured in "krone points" rose from 24.4 mio DKK in 2001 to 203.8 mio DKK in 2014.

"Krone points": Price for each patient investigation multiplied with number of investigations, summarized for all patient studies performed during the year.

Balance 2014

Expenditure (DKK mio.)

Running costs	17,8
Staff	54,6
In total	72,4

Receipts	17,4
----------	------

Publications 2014

Theses

- Clausen MM. PhD thesis. Molecular imaging for radiotherapy planning: a translation study – Hypoxia-guided dose painting based on ¹⁸F-FDG and ⁶⁴Cu-ATSM PET in solid canine tumors. Defended on the 18th of June, 2014. University of Copenhagen.
- Engelmann B. PhD thesis. FDG-PET/CT in Colon Cancer. Diagnostic value and cost-effectiveness in staging follow-up and treatment monitoring. Defended on the 27th of January 2014. University of Copenhagen.
- Pedersen SF. PhD thesis. Molecular Imaging of atherosclerosis: Comparing ¹⁸F-FDG PET and Gene Expression. Defended on the 17th of March 2014. University of Copenhagen.

Patents

- WO/2014/086364: Kjaer A (together with 2 co-inventors): Positron emitting radionuclide labeled peptides for human uPAR PET imaging. Published June 12, 2014.
- US/2014/0341807: Kjaer A (together with 4 co-inventors): PET tracer for imaging of neuroendocrine tumors. Published November 20, 2014.

Publications

- Agn M, Svarer C, Frøkjær VG, Greve DN, Andersen VL, Hansen HD, Herth MM, Knudsen GM, Kristensen JL. ¹¹C-labeling and preliminary evaluation of vortioxetine as a PET radioligand. *Bioorg Med Chem Lett*. 2014 Jun 1;24(11):2408-11.
- Ahtarovski KA, Iversen KK, Christensen TE, Andersson H, Grande P, Holmvang L, Bang L, Hasbak P, Lønborg JT, Madsen PL, Engstrøm T, Vejlsstrup NG. Takotsubo cardiomyopathy, a two-stage recovery of left ventricular systolic and diastolic function as determined by cardiac magnetic resonance imaging. *Eur Heart J Cardiovasc Imaging*. 2014 Aug;15(8):855-62.
- Andersen FL, Ladefoged CN, Beyer T, Keller SH, Hansen AE, Højgaard L, Kjær A, Law I, Holm S. Combined PET/MR imaging in neurology: MR-based attenuation correction implies a strong spatial bias when ignoring bone. *Neuroimage* 2014 Jan 1;84:206-16.
- Andersen KE, Divilov V, Sevak K, Koziorowski J, Lewis JS, Pillarsetty N. Influence of free fatty acids on glucose uptake in prostate cancer cells. *Nucl Med Biol*. 2014 Mar;41(3):254-8.
- Andersson H, Christensen TE, Ahtarovski KA, Bang LE, Hasbak P, Vejlsstrup N, Pedersen F, Holmvang L, Grande P, Clemmensen P, Wagner GS. Prevalence of acute cardiac disorders in patients with suspected ST-segment elevation myocardial infarction and non-significant coronary artery disease. *J Electrocardiol*. 2014 Jul-Aug;47(4):459-64.
- Aznar MC, Sersar R, Saabye J, Ladefoged CN, Andersen FL, Rasmussen JH, Löfgren J, Beyer T. Whole-body PET/MRI: the effect of bone attenuation during MR-based attenuation correction in oncology imaging. *Eur J Radiol*. 2014 Jul;83(7):1177-83. doi: 10.1016/j.ejrad.2014.03.022.
- Benoit D, Ladefoged CN, Rezaei A, Keller SH, Andersen FL, Højgaard L, Hansen AE, Holm S, Nuyts J. Simultaneous Reconstruction of Activity and Attenuation Using UTE Mu-Maps and T1-Weighted MR Images for PET/MR Brain Imaging. *IEEE Nuclear Science Symposium & Medical Imaging Conference Record* 2014.
- Berg RMG, Nürnbergkoden og det informerede samtykkes svære fødsel. *Bibliotek for Læger* 2014 Dec;206(4):338-361.
- Berg RMG, Plovsing RR, Møller K. High versus low blood-pressure target in septic shock. *N Engl J Med*. 2014 Jul;371(3):282.
- Borgwardt L, Berthelsen AK, Loft A, Højgaard L. Clinical Molecular Anatomic Imaging - PET/CT, PET/MR and SPECT CT, 3e. Chapter 71, Special considerations in pediatric hybrid imaging. 2014.
- Borgwardt L, Højgaard L. Clinical Molecular Anatomic Imaging - PET/CT, PET/MR and SPECT CT, 3e. Chapter 73, Inflammation and other non-neoplastic pediatric disease. 2014.
- Børresen B, Clausen MM, Hansen AE, Zornhagen KW, Kristensen AT, Engelholm SA, Kjær A. Canine cancer patients are included in translational research. *Ugeskr Laeger* 2014; 176: V01130041
- Buch I, Hesse B (ed.s): *Klinisk Fysiologi – en basisbog*. Hartmann Ass. 2014.
- Carranza CL, Ballegaard M, Werner MU, Hasbak P, Kjær A, Kofoed KE, Lindschou J, Jakobsen JC, Gluud C, Olsen PS, Steinbrüchel DA. Endoscopic versus open radial artery harvest and mammary-radial versus aorto-radial grafting in patients undergoing coronary artery bypass surgery: protocol for the 2 x 2 factorial designed randomised NEO trial. *Trials* 2014; Apr 23;15: 135.
- Christensen AN, Reichkender MH, Larsen R, Auerbach P, Højgaard L, Nielsen HB, Ploug T, Stallknecht B, Holm S. Calibrated image-derived input functions for the determination of the metabolic uptake rate of glucose with ¹⁸F-FDG PET. *Nucl Med Commun*. 2014 Apr;35(4):353-61.
- Christensen CB, Loft A, Hesse B (ed.s): *Klinisk Nuklearmedicin*, 2011. Danish Society for Clinical Physiology and Nuclear Medicine, 2011. Second edition. 2014
- Christensen TE, Bang LE, Holmvang L, Ghotbi AA, Lassen ML, Andersen F, Ihlemann N, Andersson H, Grande P, Kjær A, Hasbak P. Cardiac ^{99m}Tc sestamibi SPECT and ¹⁸F FDG PET as viability markers in Takotsubo cardiomyopathy. *Int J Cardiovasc Imaging*. 2014 Oct;30(7):1407-16. doi: 10.1007/s10554-014-0453-5
- Christensen TE, Kjær A, Hasbak P. The clinical value of cardiac sympathetic imaging in heart failure. *Clin Physiol Funct Imaging*. 2014 May;34(3):178-82.
- Clausen MM, Hansen AE, Lundemann M, Hollesen C, Pommer T, Rosenschold PM, Kristensen AT, Kjær A, McEvoy FJ, Engelholm SA. Dose painting based on tumor uptake of Cu-ATSM and FDG: a comparative study. *Radiat Oncol*. 2014; 9: 228.
- Comasco E, Frøkjær VG, Poromaa IS. Functional and molecular neuroimaging of menopause and hormone replacement therapy. *Frontiers Neuroscience*. 2014 Dec 8;8:388.

- Dahl EK, Møller S, Kjaer A, Petersen CL, Bendtsen F, Krag A. Diastolic and autonomic dysfunction in early cirrhosis: a dobutamine stress study. *Scand J Gastroenterol* 2014;49(3):362-72.
- de Nijs R, Jensen BN, Mortensen J. Missing head and color banding in low count SPECT reconstructions. *EJNMMI Physics*. 2014 Sep;1:10.
- de Nijs R, Lagerburg V, Klausen TL, Holm S. Improving quantitative dosimetry in ^{177}Lu -DOTATATE SPECT by energy window based scatter corrections. *Nucl Med Commun*. 2014 May;35(5):522-33.
- Due AK, Vogelius IR, Aznar MC, Bentzen SM, Berthelsen AK, Korreman SS, Loft A, Kristensen CA, Specht L. Recurrences after intensity modulated radiotherapy for head and neck squamous cell carcinoma more likely to originate from regions with high baseline ^{18}F -FDG uptake. *Radiother Oncol*. 2014 Jun;111(3):360-5. doi: 10.1016/j.radonc.2014.06.001.
- Edenbrandt L, Höglund P, Frantz S, Hasbak P, Johansen A, Johansson L, Kammeier A, Lindner O, Lomsky M, Matsuo S, Nakajima K, Nyström K, Olsson E, Sjöstrand K, Svensson SE, Wakabayashi H, Trägårdh E. Area of ischemia assessed by physicians and software packages from myocardial perfusion scintigrams. *BMC Med Imaging*. 2014 Jan 31;14:5.
- Elmelund M, Oturai PS, Biering-Sørensen F. 50 years follow-up on plasma creatinine levels after spinal cord injury. *Spinal Cord* 2014 May;52(5):368-72.
- Engelmann BE, Loft A, Kjaer A, Nielsen HJ, Berthelsen AK, Binderup T, Brinch K, Gerds TA, Kristensen MH, Kurt, Latocha JE, Lindblom G, Sloth C, Højgaard L. Positron Emission Tomography / Computed Tomography and biomarkers in colon cancer staging and follow-up. *Scand J Gastroent* 2014;49(2):191-201.
- Engelmann BE, Loft A, Kjaer A, Nielsen HJ, Gerds TA, Benzon EV, Brünner N, Christensen IJ, Hansson SH, Holländer NH, Kristensen MH, Löfgren J, Markova E, Sloth C, Højgaard L. Positron emission tomography / computed tomography and biomarkers for early treatment response in metastatic colon cancer. *Oncologist* 2014;19(2):164-172.
- Eriksson S. E, Elgström E, Bäck T, Ohlsson T, Jensen H, Nilsson R, Lindegren S, Tennvall J. Sequential Radioimmunotherapy with ^{177}Lu and ^{211}At -Labeled Monoclonal Antibody BR96 in a Syngeneic Rat Colon Carcinoma Model. *Cancer Biother Radiopharm*. 2014;29(6): 238-246.
- Ettrup A, da Cunha-Bang S, McMahon B, Lehel S, Dyssegaard A, Skibsted AW, Jørgensen LM, Hansen M, Baandrup AO, Bache S, Svarer C, Kristensen JL, Gillings N, Madsen J, Knudsen GM. Serotonin 2A receptor agonist binding in the human brain with ^{11}C -Cimbi-36. *J Cereb Blood Flow Metab* 2014 July; 34(7):1188–1196.
- Felbo I, Chakera AH, Drejøe JB, Klyver H, Dahlstrom K, Oturai P, Mortensen J, Hesse B, Schmidt G, Drzewiecki KT: Outcome in patients with locally advanced melanoma, treated with hyperthermic isolated limb perfusion. *Dan Med J* 2014: 61: A4741 (Ugeskr Læger 2014; 176:48).
- Feng L, Svarer C, Thomsen G, de Nijs R, Larsen VA, Jensen P, Adamsen D, Dyssegaard A, Fischer W, Meden P, Krieger D, Møller K, Knudsen GM, Pinborg LH. In Vivo Quantification of Cerebral Translocator Protein Binding in Humans Using 6-Chloro-2-(4'-123I-Iodophenyl)-3-(N,N-Diethyl)-Imidazo[1,2-a]Pyridine-3-Acetamide SPECT. *J Nucl Med*. 2014 Dec;55(12):1966-72.
- Finnema SJ, Stepanov V, Ettrup A, Nakao R, Amini N, Svedberg M, Lehmann C, Hansen M, Knudsen GM, Halldin C. Characterization of ^{11}C -Cimbi-36 as an Agonist PET Radioligand for the 5-HT_{2A} and 5-HT_{2C} Receptors in the Nonhuman Primate Brain. *Neuroimage*. 2014 Jan;84:342-53.
- Fisher PM, Holst KK, Adamsen D, Klein AB, Frokjaer VG, Jensen PS, Svarer C, Gillings N, Baare WFC, Mikkelsen JD, Knudsen GM. BDNF Val66met and 5-HTTLPR Polymorphisms Predict a Human In Vivo Marker for Brain Serotonin Levels *Hum Brain Mapp* 2014 Jan; 36(1):313-323.
- Fisher PM, Madsen MK, Mc Mahon B, Holst KK, Andersen SB, Laursen HR, Hasholt LF, Siebner HR, Knudsen GM. Three-week bright-light intervention has dose-related effects on threat-related corticolimbic reactivity and functional coupling. *Biol Psychiatry*. 2014 Aug 15;76(4):332-9.
- Frokjaer VG, Erritzoe D, Holst KK, Madsen KS, Fisher PM, Madsen J, Svarer C, Knudsen GM. In abstinent MDMA users the cortisol awakening response is off-set but associated with prefrontal serotonin transporter binding as in non-users. *Int J Neuropsychopharmacol*. 2014 Aug;17(8):1119-28.
- Frokjaer VG. Molecular Imaging of Depressive Disorders. In: Dierckx RAJO, Otte A, Vries EFJ, Waarde A, Boer JA (Eds.) *PET and SPECT in Psychiatry* (2014). Springer, New York (USA), ISBN: 9783642403835.
- Ghotbi AA, Kjaer A, Hasbak P. Review: comparison of PET Rubidium-82 with conventional SPECT myocardial perfusion imaging. *Clin Physiol Funct Imaging*. 2014 May;34(3):163-70.
- Greve AM, Bang CN, Berg RMG, Egstrup K, Rossebø AB, Boman K, Nienaber CA, Ray S, Gohlke-Baerwolf C, Nielsen OW, Okin PM, Devereux RB, Køber L, Wachtell K. Resting heart rate and risk of adverse cardiovascular outcomes in asymptomatic aortic stenosis: The SEAS study. *Int J Cardiol*. 2015 Feb;180:122-8.
- Greve DN, Svarer C, Fisher PM, Feng L, Hansen AE, Baare W, Rosen B, Fischl B, Knudsen GM. Cortical surface-based analysis reduces bias and variance in kinetic modeling of brain PET data. *Neuroimage*. 2014 May 15;92:225-3.
- Eriksson S. E, Elgström E, Bäck T, Ohlsson T, Jensen H, Nilsson R, Lindegren S, Tennvall J.. Simultaneous hyperpolarized ^{13}C -pyruvate MRI and ^{18}F -FDG PET in cancer (hyperPET): feasibility of a new imaging concept using a clinical PET /MRI scanner. *AM J Nucl Med Mol Imaging*. 2014 Dec;15;5(1):38-45.
- Haahr ME, Fisher PM, Jensen CG, Frokjaer VG, Mahon BM, Madsen K, Baaré WF, Lehel S, Norremolle A, Rabiner EA, Knudsen GM. Central 5-HT₄ receptor binding as biomarker of serotonergic tone in humans: a ^{11}C -SB207145 PET study. *Mol Psychiatry*. 2014 Apr;19(4):427-32.
- Harders SW, Balyasnikowa S, Fischer BM. Functional imaging in lung cancer. *Clin Physiol Funct Imaging*. 2014 Sep;34(5):340-55.
- Håkansson K, Thomsen SF, Konge L, Mortensen J, Zachariae C, Backer V, von Buchwald C. A comparative and descriptive study of asthma in chronic rhinosinusitis with nasal polyps. *American Journal of Rhinology and Allergy* 2014 Sep;28(5):383-7. doi: 10.2500/ajra.2014.28-4076.
- Hansen FH, Skjørringe T, Yasmeen S, Arends NV, Sahai MA, Erreger K, Andreassen TF, Holy M, Hamilton PJ, Neergheen V, Karlsborg M, Newman AH, Pope S, Heales SJ, Friberg L, Law I, Pinborg LH, Sitte HH, Loland C, Shi L, Weinstein H, Galli A, Hjermand LE,

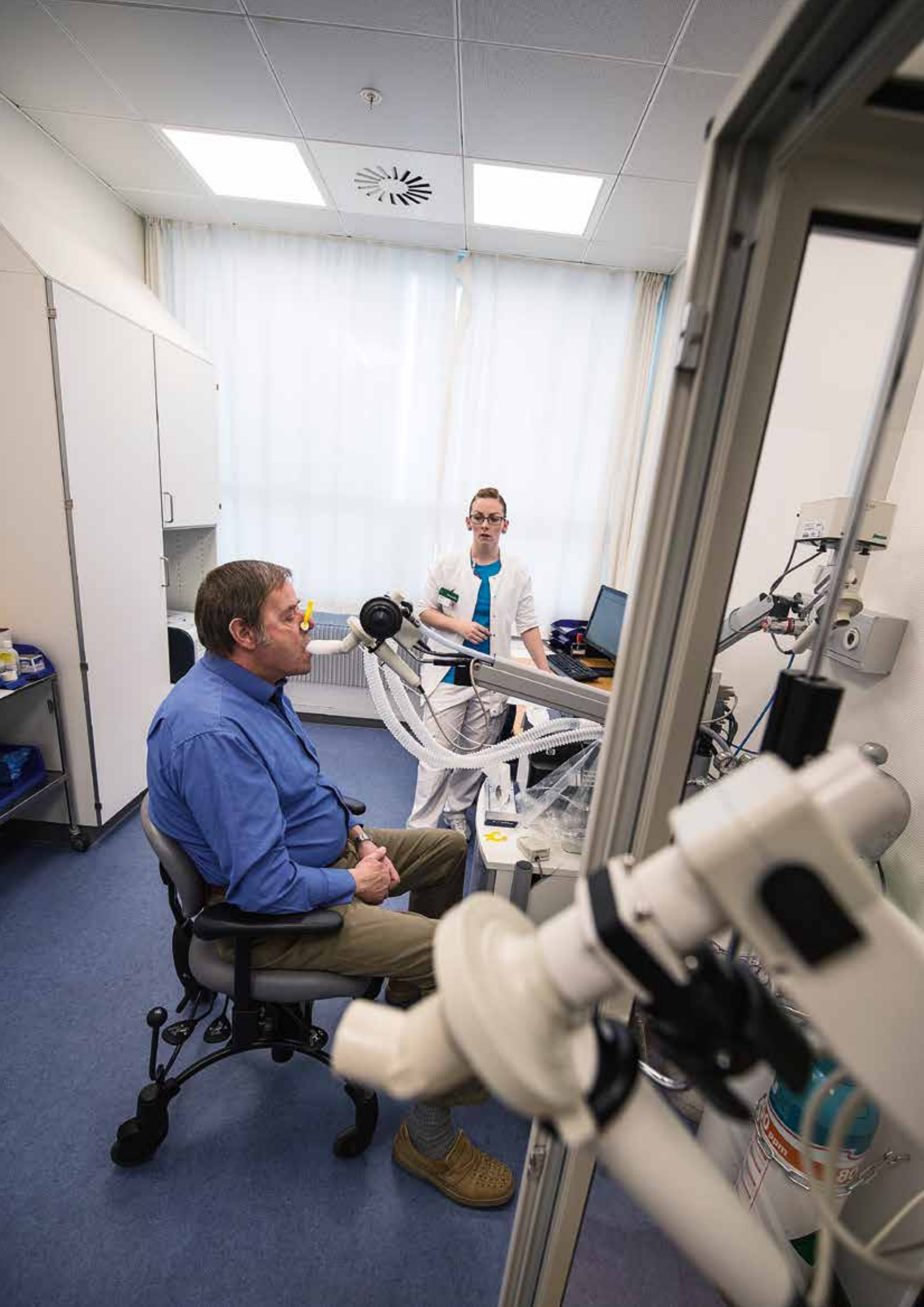
- Møller LB, Gether U. Missense dopamine transporter mutations associate with adult parkinsonism and ADHD. *J Clin Invest*. 2014 Jul 1;124(7):3107-20.
- Hansen HD, Herth MM, Ettrup A, Andersen VL, Lehel S, Dyssegaard A, Kristensen JL, Knudsen GM. Radiosynthesis and In Vivo Evaluation of Novel Radioligands for PET Imaging of Cerebral 5-HT7 Receptors. *J Nucl Med*. 2014 Apr;55(4):640-6.
- Hansen HD, Lacivita E, Di Pilato P, Herth MM, Lehel S, Ettrup A, Andersen VL, Dyssegaard A, De Giorgio P, Perrone R, Berardi F, Colabufo NA, Mauro N, Knudsen GM, Leopoldo M. Synthesis, radiolabeling and in vivo evaluation of [¹¹C](R)-1-[4-[2-(4-methoxyphenyl)-phenyl]piperazin-1-yl]-3-(2-pyrazinyloxy)-2-propanol, a potential PET radioligand for the 5-HT7 receptor. *Eur J Med Chem*. 2014 Mar 29;79C:152-63.
- Hasbak P, Kjaer A. Scintigraphy of the heart using noradrenaline has a prognostic value when visualising heart failure. *Ugeskr Laeger*. 2014 Jun 23;176(26)
- Li F, Joergensen JT, Hansen AE, Kjaer A. Kinetic modeling in PET imaging of hypoxia. *Am J Nucl Med Mol Imaging* 2014; 4: 490-506.
- Hasbak P, Sheykhzade M, Schifter S, Edvinsson L. Potentiated adrenomedullin-induced vasorelaxation during hypoxia in organ cultured porcine coronary arteries. *J Cardiovasc Pharmacol*. 2014 Jan;63(1):58-67.
- Henriksen OM, Jensen LT, Krabbe K, Guldberg P, Teerlink T, Rostrup E. Resting brain perfusion and selected vascular risk factors in healthy elderly subjects. *PLoS One*. 2014 May 19;9(5):e97363.
- Henriksen OM, Jensen LT, Krabbe K, Larsson HB, Rostrup E. Relationship between cardiac function and resting cerebral blood flow: MRI measurements in healthy elderly subjects. *Clin Physiol Funct Imaging*. 2014 Nov;34(6):471-7
- Herth, MM, Leth-Petersen S, Lehel S, Hansen M, Knudsen GM, Gillings N, Madsen J, Kristensen, JL. Accelerating preclinical PET-screening: Reductive amination with ¹¹C-methoxybenzaldehydes. *RSC Adv* 2014 April; 4(41):21347-21350.
- Hesse S, van de Giessen E, Zienteka F, Petroff D, Wintere K, Dickson JC, Tossici-Bolt L, Serah T, Asenbaum S, Darcourt J, Akdemir UO, Knudsen GM, Nobili F, Pagani M, Vanderborght T, Van Laere K, Varrone A, Tatsch K, Sabri O, Booi J. Association of central serotonin transporter availability and body mass index in healthy Europeans. *Eur Neuropsychopharmacol*. 2014 Aug;24(8):1240-7.
- Hofland KE, Hansen S, Sorensen M, Engelholm S, Schultz HP, Muhic A, Grunnet K, Ask A, Costa JC, Kristiansen C, Thomsen C, Poulsen HS, Lassen U. Neoadjuvant bevacizumab and irinotecan versus bevacizumab and temozolomide followed by concomitant chemoradiotherapy in newly diagnosed glioblastoma multiforme: A randomized phase II study. *Acta Oncol*. 2014 Jul;53(7):939-44. doi: 10.3109/0284186X.2013.879607.
- Højgaard L, Berthelsen AK, Loft A. Head and neck: normal variations and benign findings in FDG positron emission tomography / computed tomography imaging. *PET Clin*. 2014 Apr;9(2):141-5.
- Illidge T, Specht L, Yahalom J, Aleman B, Berthelsen AK, Constine L, Dabaja B, Dharmarajan K, Ng A, Ricardi U, Wirth A; International Lymphoma Radiation Oncology Group. Modern radiation therapy for nodal non-Hodgkin lymphoma-target definition and dose guidelines from the International Lymphoma Radiation Oncology Group. *Int J Radiat Oncol Biol Phys*. 2014 May 1;89(1):49-58. doi: 10.1016/j.ijrobp.2014.01.006
- Izquierdo-Garcia D, Hansen AE, Stefan F, Benoit D, Schachoff S, Sebastian F, et al. An SPM8-Based Approach for Attenuation Correction Application to Simultaneous PET/MR Brain Imaging. *J Nucl Med*. 2014 Nov;55(11):1825-30.
- Janson ET, Sorbye H, Welin S, Federspiel B, Grønbaek H, Hellman P, Ladekarl M, Langer SW, Mortensen J, Schalin-Jääntti C, Sundin A, Sundlöv A, Thiis-Evensen E, Knigge U. Nordic Guidelines 2014 for Diagnosis and Treatment of Gastroenteropancreatic Neuroendocrine Neoplasms. *Acta Oncol*. 2014 Aug 20;1-14.
- Jensen AI, Binderup T, Kumar Ek P, Kjaer A, Rasmussen PH, Andresen TL. Positron emission tomography based analysis of long-circulating cross-linked triblock polymeric micelles in a U87MG mouse xenograft model and comparison of DOTA and CB-TE2A as chelators of copper-64. *Biomacromolecules* 2014; 15: 1625-33.
- Johnbeck CB, Jensen MM, Nielsen CH, Hag AMF, Knigge U, Kjaer A. ¹⁸F-FDG and ¹⁸F-FLT-PET imaging for monitoring everolimus effect on tumor-growth in neuroendocrine tumors: studies in human tumor xenografts in mice. *PLoS ONE* 2014; 9: e91387 (8 pages).
- Johnbeck CB, Knigge U, Kjaer A. PET tracers for somatostatin receptor imaging of neuroendocrine tumors: Current status and review of the literature. *Future oncol* 2014;10: 2259-2277.
- Jølcck RI, Binderup T, Hansen AE, Scherman JB, Munch af Rosen-schold P, Kjaer A, Andresen TL. Injectable colloidal gold in a sucrose acetate isobutyrate gelating matrix with potential use in radiation therapy. *Adv Healthc Mater* 2014; 3: 1680-7.
- Keller SH, Hansen AE, Holm S, Beyer T. Image Distortions in Clinical PET/MR Imaging. In *PET/MRI* (Carrio I, Ros P; Editors), 2014 Jan, p. 21-41, Springer, ISBN 978-3-642-40691-1.
- Keller SH, Svarer C, Sibomana M. Validation of Scatter Simulation in 3D and Count-Rate Dependent Component-Based Normalization for the HRRT. *IEEE Nuclear Science Symposium & Medical Imaging Conference Record* 2014.
- Knudsen A, Katzenstein TL, Benfield T, Jørgensen NR, Kronborg G, Gerstoft J, Obel N, Kjaer A, Lebech AM. Plasma plasminogen activator inhibitor-1 predicts myocardial infarction in HIV-1-infected individuals. *AIDS* 2014;28(8):1171-9.
- Knudsen GM, Hasselbalch SG. Imaging of the Serotonin System: Radiotracers and Applications in Memory Disorders. In: Dierckx RAJO, Otte A, de Vries EFJ, van Waarde A, Luiten PGM (Eds.) *PET and SPECT of Neurobiological Systems* (2014). Springer, New York (USA), ISBN: 9783642420139.
- Krag A, Bendtsen F, Dahl EK, Kjaer A, Petersen CL, Møller S. Cardiac Function in Patients with Early Cirrhosis during Maximal Beta-Adrenergic Drive: A Dobutamine Stress Study. *PLoS One* 2014; 9: e109179 (6 pages).
- Kristoffersen K, Nedergaard MK, Villingshøj M, Borup R, Broholm H, Kjaer A, Poulsen HS, Stockhausen MT. Inhibition of Notch signaling alters the phenotype of orthotopic tumors formed from glioblastoma multiforme neurosphere cells but does not hamper intracranial tumor growth regardless of endogene Notch pathway signature. *Cancer Biol Ther* 2014; 15:862-77.
- Lacivita E, Niso M, Hansen HD, Di Pilato P, Herth MM, Lehel S, Ettrup A, Montenegro L, Perrone R, Berardi F, Colabufo NA, Leopoldo M, Knudsen GM. Design, synthesis, radiolabeling and in vivo evaluation of potential positron emission tomography

- (PET) radioligands for brain imaging of the 5-HT₇ receptor. *Bioorg Med Chem*. 2014 Mar 1;22(5):1736-50.
- Ladefoged CN, Andersen FL, Keller SH, Beyer T, Højgaard L, Lauze F. Correction of dental artifacts within the anatomical surface in PET/MRI using active shape models and k-nearest-neighbors. *Proc. SPIE 9034, Medical Imaging 2014 Mar*;90341M.
- Ladefoged CN, Hansen AE, Keller SH, Holm S, Law I, Beyer T, Højgaard L, Kjær A, Andersen FL. Impact of incorrect tissue classification in Dixon-based MR-AC: fat-water tissue inversion. *EJNMMI Physics* 2014 Dec;1:101.
- Langer NH, Christensen TN, Langer SW, Kjaer A, Fischer BM. PET/CT in therapy evaluation of patients with lung cancer. *Expert Rev Anticancer Ther*. 2014 May;14(5):595-620.
- Larsen JR, Vedtofte L, Holst JJ, Oturai P, Kjær A, Corell CU, Vilsbøll T, Fink-Jensen A. Does a GLP-1 receptor agonist change glucose tolerance in patients treated with antipsychotic medications? Design of a randomised, double-blinded, placebo-controlled clinical trial. *BMJ Open* 2014 Mar;4(3):e004227. doi: 10.1136/bmjopen-2013-004227.
- Larsen SS, Vilmann P, Krasnik K, Dirksen A, Clementsen P, Skov BG, Jacobsen GK, Lassen U, Eigved A, Berthelsen AK, Mortensen J, Højgaard L. A comparison of endoscopic ultrasound guided biopsy and positron emission tomography with integrated computed tomography in lung cancer staging. *Curr Health Sci J*. 2009 Jan;35(1):5-12. (PubMed 2014).
- Lassmann M, Treves ST; EANM/SNMMI Paediatric Dosage Harmonization Working Group. Paediatric radiopharmaceutical administration: harmonization of the 2007 EANM paediatric dosage card (version 1.5.2008) and the 2010 North American consensus guidelines. *Eur J Nucl Med Mol Imaging*. 2014 May;41(5):1636-41.
- Lauritsen J, Gundgaard MG, Mortensen MS, Oturai PS, Feldt-Rasmussen B, Daugaard G. Reliability of estimated glomerular filtration rate in patients treated with platinum containing therapy. *Int J Cancer* 2014 Oct;135(7):1733-9.
- Law I, Borgwardt L, Højgaard L. Clinical Molecular Anatomic Imaging - PET/CT, PET/MR and SPECT CT, 3e. Chapter 26, Pediatric hybrid imaging of the brain. 2014.
- Lawler M, Le Chevalier T, Murphy MJ Jr, Banks I, Conte P, De Lorenzo F, Meunier F, Pinedo HM, Selby P, Armand JP, Barbacid M, Barzach M, Bergh J, Bode G, Cameron DA, de Braud F, de Gramont A, Diehl V, Diler S, Erdem S, Fitzpatrick JM, Geissler J, Hollywood D, Højgaard L, Horgan D, Jassem J, Johnson PW, Kapitein P, Kelly J, Kloezen S, La Vecchia C, Löwenberg B, Oliver K, Sullivan R, Tabernero J, Van de Veide CJ, Wilking N, Wilson R, Zielinski C, Zur Hausen H, Johnston PG. A catalyst change: the European cancer Patient's Bill of Rights. *Oncologist* 2014 Mar;19(3):217-24.
- Lindegren S, Jensen H, Jacobsson L. A radio-high-performance liquid chromatography dual-flow cell gamma-detection system for on-line radiochemical purity and labeling efficiency determination. *J Chromatogr. A*. 2014;1337:128-132.
- Loft A, Khong P, Borgwardt L, Berthelsen AK, Højgaard L. Clinical Molecular Anatomic Imaging - PET/CT, PET/MR and SPECT CT, 3e. Chapter 72, Pediatric body oncology hybrid imaging. 2014.
- Londero SC, Mathiesen JS, Kroghdal A, Bastholt L, Overgaard J, Bentsen J, Hahn CH, Schytte S, Pedersen HB, Christiansen P, Godballe C; study from the Danish Thyroid Cancer Group. Completeness and validity in a national clinical thyroid cancer database: DATHYRCA. *Cancer Epidemiol* 2014 Oct;38(5):633-7.
- Lundsgaard Hansen M, Fallentin E, Lauridsen C, Law I, Federspiel B, Baeksgaard L, Svendsen LB, Nielsen MB. Computed tomography (CT) perfusion as an early predictive marker for treatment response to neoadjuvant chemotherapy in gastroesophageal junction cancer and gastric cancer – a prospective study. *PLoS ONE*. 2014;9:e97605.
- Lyckesvård MN, Delle U, Kahu H, Lindegren S, Jensen H, Bäck T, Swanpalmer J, Elmroth K. Alpha particle induced DNA damage and repair in normal cultured thyrocytes of different proliferation status. *Mutation Res*. 2014;765:48-56.
- Madsen F, Mortensen J, Hanel B, Pedersen OF. Lung function testing: Spirometry, Diffusion Capacity and Interpretation. In: *Mechanics of Breathing*. Eds. Aliverti A & Pedotti A. 2014, chapter 9, page 123-137, Springer-Verlag Italia. DOI 10.1007/978-88-470-5647-3_9.
- Madsen K, Torstensen E, Holst KK, Haahr ME, Knorr U, Frokjaer VG, Brandt-Larsen M, Iversen P, Fisher PM, Knudsen GM. Familial risk for major depression is associated with lower striatal 5-HT₄ receptor binding. *Int J Neuropsychopharmacol*. 2014 Oct 31;18(1).
- Maraldo MV, Jørgensen M, Brodin NP, Aznar MC, Petersen PM, Vogelius IR, Berthelsen AK, Christensen CB, Hjalgrim LL, Specht L. The impact of involved node, involved field and mantle field radiotherapy on estimated radiation doses and risk of late effects risks for pediatric Hodgkin lymphoma. *Pediatric Blood and Cancer*, 2014;61(4):717-722.
- Mohr M, Lindenskov A, Holm PM, Nielsen HP, Mortensen J, Weihe P, Krstrup P. Football training improves cardiovascular health profile in sedentary, premenopausal hypertensive women. *Scan J Med Sci Sports* 2014, 24 (suppl. 1): 36-42 doi: 10.1111/sms.12278
- Mohr M, Nordsborg NB, Lindenskov A, Steinholt H, Nielsen HP, Mortensen J, Weihe P, Krstrup P. High-Intensity Intermittent Swimming Improves Cardiovascular Health Status for Women with Mild Hypertension BioMed Research International. Volume 2014 (2014), Article ID 728289.
- Mortensen J, Gutte H. SPECT/CT and pulmonary embolism. *Eur J Nucl Med Mol Imaging*. Volume 41, Issue 1 (2014), Page 81-90. DOI 10.1007/s00259-013-2614-5.
- Mortensen J, Højgaard L. Radium-223 treatment of bone metastases from castration-resistant prostate cancer. *Ugeskr Laeger*. 2014 Jul 21;176(30). Danish.
- Munkholm ML, Mortensen J. Mucociliary Clearance. Pathophysiological aspects. *Clin Physiol Funct Imaging*. 2014 May;34(3):171-7. doi: 10.1111/cpf.12085.
- Nedergaard MK, Kristoffersen K, Michaelsen SR, Madsen J, Poulsen HS, Stockhausen MT, Lassen U, Kjaer A. The use of Longitudinal ¹⁸F-FET microPET imaging to evaluate response to irinotecan in orthotopic human glioblastoma multiforme xenografts. *PLoS ONE* 2014; 9: e100009 (10 pages).
- Olsen IH, Knigge U, Federspiel B, Hansen CP, Skov A, Kjaer A, Langer SW. Topotecan monotherapy in heavily pretreated patients with progressive advanced stage neuroendocrine carcinomas. *J of Cancer* 2014; 5: 628-32.
- Oxboel J, Brandt-Larsen M, Schjoeth-Eskesen C, Myschetzky R, El-Ali HH, Madsen J, Kjaer A. A comparison of two new angiogenesis PET tracers ⁶⁸Ga-NODAGA-E[c(RGDYK)]₂ and ⁶⁴Cu-NODA-

- GA-E[c(RGDYK)]₂; in vivo imaging studies in human xenograft tumors. *Nucl. Med. Biol.* 2014; 41(3): 259-267.
- Paulsen IF, Chakera AH, Drejøe JB, Klyver H, Dahlstrøm K, Mortensen J, Oturai PS, Hesse B, Schmidt G, Drzewiecki K. Tumour response after hyperthermic isolated limb perfusion for locally advanced melanoma. *Dan Med J* 2014. Jan;61(1):A4741.
- Pedersen SF, Hag AM, Klausen TL, Ripa RS, Bodholdt RP, Kjaer A. Positron emission tomography of the vulnerable atherosclerotic plaque in man – a contemporary review. *Clin Physiol Funct Imaging*. 2014 Nov;34(6):413-25.
- Pedersen SF, Ludvigsen TP, Johannesen HH, Löfgren J, Ripa RS, Hansen AE, Ettrup AJ, Christoffersen BØ, Pedersen HD, Olsen LH, Højgaard L, Kjaer A. Feasibility of simultaneous PET/MR in diet-induced atherosclerotic minipig: a pilot study for translational imaging. *Am J Nucl Med Mol Imaging*. 2014 Aug 15;4(5):448-58.
- Persson M, El Ali HH, Binderup T, Pfeifer A, Madsen J, Rasmussen P, Kjaer A. Dosimetry of ⁶⁴Cu-DOTA-AE105, a PET tracer for uPAR imaging. *Nucl Med Biol* 2014;41(3):290-5.
- Persson M, Juhl K, Rasmussen P, Brandt-Larsen M, Madsen J, Ploug M, Kjaer A. uPAR targeted radionuclide therapy with ¹⁷⁷Lu-DOTA-AE105 inhibits dissemination metastatic prostate cancer. *Molecular Pharmaceutics*. 2014, 11, 2796-2806.
- Qayyum AA, Hasbak P, Larsson HB, Christensen TE, Ghotbi AA, Mathiasen AB, Vejstrup NG, Kjaer A, Kastrup J. Quantification of myocardial perfusion using cardiac magnetic resonance imaging correlates significantly to Rubidium-82 positron emission tomography in patients with severe coronary artery disease: a preliminary study. *Eur J Radiol*. 2014 Jul;83(7):1120-8.
- Rasmussen H, Ebdrup BH, Oranje B, Pinborg LH, Knudsen GM, Glenthøj B. Neocortical serotonin2A receptor binding predicts quetiapine associated weight gain in antipsychotic-naïve first-episode schizophrenia patients. *Int J Neuropsychopharmacol*. 2014 Nov;17(11):1729-36.
- Rehfeld A, Plass M, Døssing K, Knigge U, Kjaer A, Krogh A, Friis-Hansen L. Alternative polyadenylation of tumor suppressor genes in small intestinal neuroendocrine tumors. *Front Endocrinol (Lausanne)* 2014;15 :46.
- Reichkender MH, Rosenkilde M, Auerbach PL, Agerschou J, Nielsen MB, Kjaer A, Højgaard L, Sjödin A, Ploug T, Stallknecht B. Only minor additional metabolic health benefits of high as opposed to moderate dose physical exercise in young, moderately overweight men. *Obesity (Silver Spring)*. 2014 May;22(5):1220-32.
- Ripa RS, Kjaer A, Hesse B. Non-invasive imaging for subclinical coronary atherosclerosis in patients with peripheral artery disease. *Curr Atheroscler Rep*. 2014 Jun;16(6):415.
- Roed T, Kristoffersen US, Knudsen A, Wiinberg N, Lebech AM, Almdal T, Thomasen RW, Kjaer A, Weis N. Increased prevalence of coronary artery disease risk markers in patients with chronic hepatitis C – a cross-sectional study. *Vasc Health Risk Manag* 2014;10:55-62.
- Saghir Z, Dirksen A, Ashraf H, Bach KS, Brodersen J, Clementsen PF, Døssing M, Hansen H, Kofoed KE, Larsen KR, Mortensen J, Rasmussen JF, Thomsen LH, Wille MM, Seersholm N, Skov BG, Thorsen H, Tønnesen P, Pedersen JH. Lung cancer screening with low-dose CT – Danish and international results. *Ugeskr Laeger*. 2014 Oct 13;176(42). pii: V05140283. Danish. PMID: 25316371.
- Schiodt M, Reibel J, Oturai P, Kofod T. Comparison of nonexposed and exposed bisphosphonate-induced osteonecrosis of the jaws: a retrospective analysis from the Copenhagen cohort and a proposal for an updated classification system. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2014 Feb;117(2):204-13.
- Sebbesen L, Bilde A, Therkildsen M, Mortensen J, Specht L, von Buchwald C. 3 years follow-up of sentinel node negative patients with early oral cavity squamous cell carcinoma. *Head Neck*. 2014 Aug;36(8):1109-12. doi: 10.1002/hed.23414.
- Skovgaard D, Hasbak P, Kjaer A. BNP predicts chemotherapy-related cardiotoxicity and death: comparison with gated equilibrium radionuclide ventriculography. *PLoS One*. 2014 May 6;9(5):e96736.
- Specht L, Yahalom J, Illidge T, Berthelsen AK, Constine LS, Eich HT, Girinsky T, Hoppe RT, Mauch P, Mikhaleel NG, Ng A; ILROG: Modern radiation therapy for Hodgkin lymphoma: field and dose guidelines from the international lymphoma radiation oncology group (ILROG). *Int J Radiat Oncol Biol Phys*. 2014 Jul 15;89(4):854-62.
- Thomas A, Hanel B, Marott JL, Buchwald F, Mortensen J, Nielsen KG. The Single Breath Diffusing Capacity of CO and NO in Healthy Caucasian children of European descent. *PLoS One*. 2014 Dec 16;9(12).
- Toksvang LN, Berg RMG. Teaching basic haemorheology to medical students by individual and collaborative strategies. *MEFANET Journal* 2014 Dec; 2(2):51-55.
- Watson CC, Panin VY, Keller SH, Holm S, Nuyts J. A Sparse Transmission Method for PET Attenuation Correction in the Head. *IEEE Nuclear Science Symposium & Medical Imaging Conference Record* 2014.
- Wey HY, Catana C, Hooker JM, Dougherty DD, Knudsen GM, Wang DJ, Chonde DB, Rosen BR, Gollub RL, Kong J. Simultaneous fMRI-PET of the Opioidergic Pain System in Human Brain. *Neuroimage*. 2014 Nov 15;102 Pt 2:275-82.

Equipment 2014

Equipment	Product	Purchase year
Gamma cameras	Mie-Scintatron	2004
	Mediso N-TH45-D	2008
	DDD SoloMobile	2012
SPECT cameras	Philips ADAC Skylight	2002
	Mediso Nucline X-Ring-R/HR	2009
SPECT/CT cameras	Philips, Precedence 16-slice CT	2006
	Philips, Precedence 16-slice CT	2008
	Siemens Symbia 16-slice CT	2011
PET scanners	HRRT Siemens/CTI	2007
PET/CT scanners	Siemens Biograph TrueV 40-slice CT	2007
	Siemens Biograph TrueV 64-slice CT	2009
	Siemens mCT-S (64)	2010
	Siemens mCT-S (64)	2011
	Siemens mCT-S (128)	2013
PET/MR scanner	Siemens mMR	2011
	GE SPINlab MR Hyperpolarizer	2014
Lung function	Jaeger Masterscreen w/bodybox	2005
	Jaeger PFT pro w/bodybox	2007/13
DXA scanner	GE Lunar Prodigy	2011
Whole body counter	WBC w/Nal counting chamber	1977
	WBC w/plast counting chamber	1978
Cyclotrons	Scanditronix 32 MeV	1991
	RDS Eclipse cyclotron, CTI	2005
Cluster for Molecular Imaging	Provivo/ADAC mobile gamma camera	1990
	PET scanner GE 4096	1991
	SPECT Mediso Nucline X-Ring/R	2004
	Siemens Micro-PET Focus 120	2006
	Micro-CT Siemens Micro-CAT II	2006
	Phosphor Imager Perkin Elmer cyclone	2007
	Bruker preclinical MRI PharmaScan 7T	2013
	Siemens preclinical PET/CT Inveon	2013
	PX Inc. preclinical RT X-RAD 320	2013



Research



Andreas Kjær

A strong focus on research and development is a cornerstone of the department. Over the years, we developed a comprehensive research program and build strong national and international collaborations. We continuously adjust our research to study and develop solutions to health challenges in patients. Our research program focuses on development of new tracers for PET, PET/MRI hybrid imaging, *theranostics*, clinical evaluation of new diagnostic methods, and on the use of methods from clinical physiology and nuclear medicine to study pathophysiology. Translational research in molecular imaging is given special attention in order to accelerate translation of new tracers into clinical use in patients. Some current major research areas, many of which are seeing to fulfill (unmet) patient needs, are mentioned below

New tracers

Numerous current projects are targeted at development of new, specific tracers for non-invasive tissue characterization. These tracers are to be used for the diagnosis of different cancer types as well as for planning and monitoring of therapy. The projects, translational in nature, are carried out in collaboration with other departments and laboratories both nationally and internationally to obtain the necessary expertise in molecular biology, chemistry, radiochemistry, cancer biology and imaging. A recent example of such new tracers developed at the department is ^{64}Cu -DOTATATE. This tracer is now used in patients with neuroendocrine tumors at Rigshospitalet

as well as for patients from abroad, e.g. USA, that come to our department to obtain such a scan. Another example is our development of the (first) PET tracer to visualize the invasive cancer phenotype, ^{64}Cu -DOTA-AE105 targeting uPAR. This tracer was recently taken into first-in-human. In addition, we test targeted nanoparticles for PET. We have developed a comprehensive platform for validation of new tracers which includes cell laboratory, molecular biology (proteomics and genomics), histology and biomarker laboratory facilities at the department.

PET/MRI

With installation of the first integrated PET/MRI scanner in the Nordic Countries, we have developed an extensive research program with focus on the added value of combining PET and MRI. A large number of clinical trials as well as projects on method development are currently undertaken with focus on the combined use of the modalities for improved tissue characterization and response monitoring in cancer treatment, pediatric studies, brain studies and atherosclerotic plaque characterization. Focus on MRI includes the use of diffusion weighted images (DWI)/apparent diffusion coefficient (ADC) and magnetic resonance spectroscopy (MRS). Most recently, the use of PET/MRI for radiation therapy is being evaluated. With availability of preclinical PET and MRI, we are capable of working translational when developing and evaluating new methods.

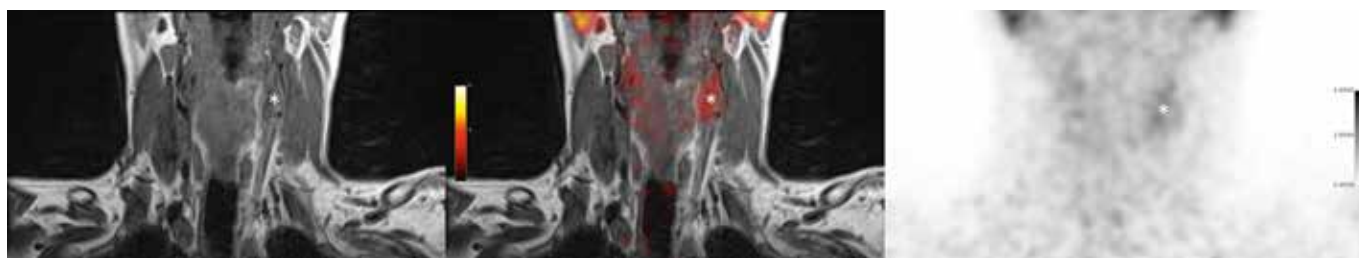


Figure showing imaging of activated macrophages in vulnerable carotid plaque using our new PET tracer (image provided by Sune Folke Pedersen).

Hyperpolarized ^{13}C -MRSI

With the installation of equipment for dynamic nuclear polarization of ^{13}C -labeled compound, e.g. ^{13}C -pyruvate we have developed a research program with focus on the use of this technique for tissue characterization in cancer, but not limited to this field. Since the system is the first in the World that is installed next to a PET/MRI scanner, special attention is given to how the combination of hyperpolarized ^{13}C -MRS and PET can be combined in what we have named hyper-PET. Recently, we demonstrated how hyper-PET with FDG can be used to discriminate the Warburg effect from other causes of increased glucose uptake. We aim at developing methods which through use of the combined modalities are superior in cancer phenotyping and therapy monitoring compared to the techniques alone with the intention of providing better tools for tailoring therapy. Also in this research area our approach is translational.

Clinical PET/CT in oncology

A large number of prospective protocols are undertaken to evaluate the diagnostic and prognostic value of PET/CT with different tracers in various forms of cancer both in children and in adults. Head-to-head comparison studies of new PET tracers and established imaging methods are also performed. The use of PET/CT for the planning of radiation therapy ("dose-painting") and the use of respiratory gating are also currently being evaluated. Many of these studies now also include PET/MRI to study the added value compared to PET/CT.

Pediatric nuclear medicine investigations

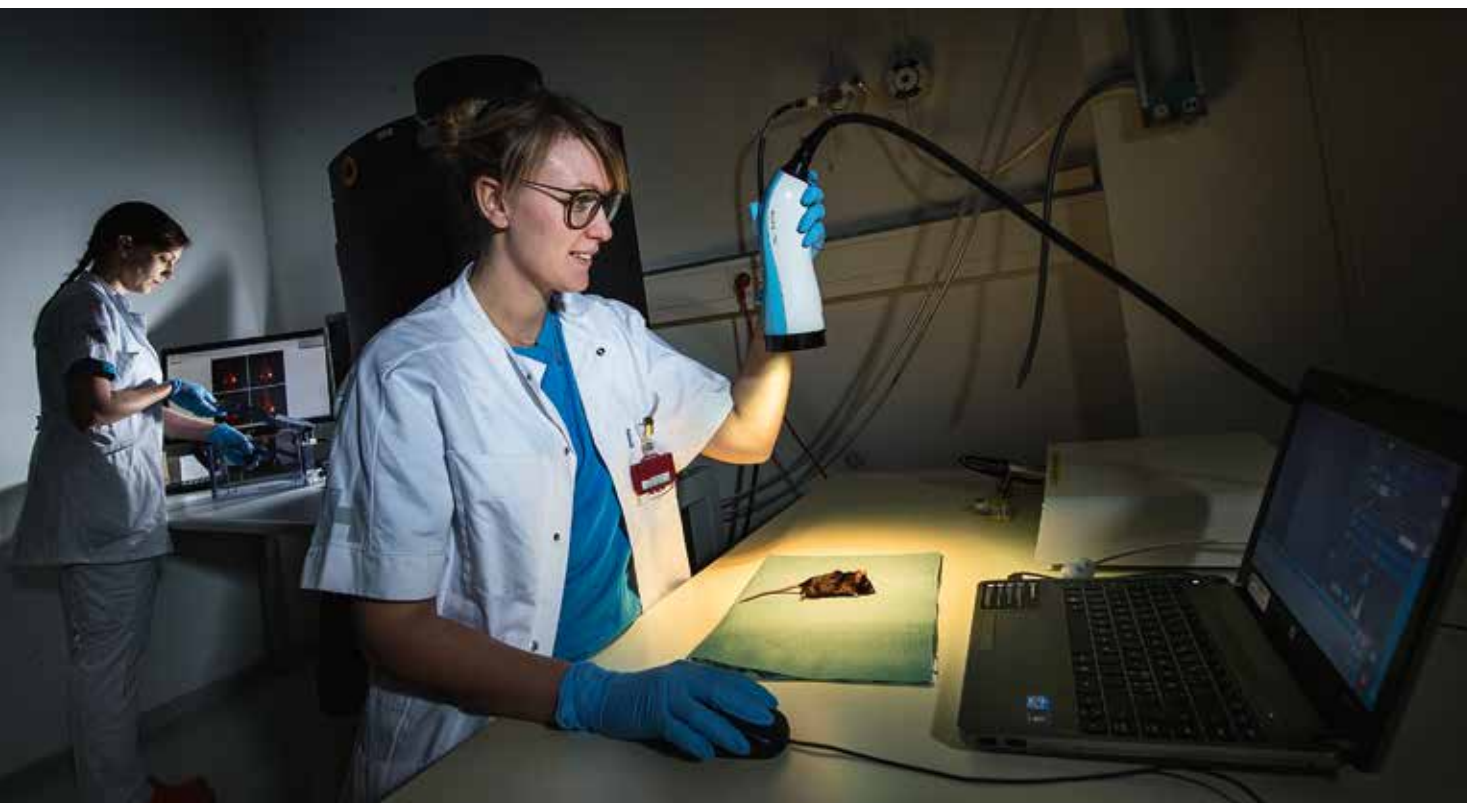
The department conducts many pediatric investigations. Several research protocols with the use of PET and SPECT are carried out in cooperation with clinical departments, particularly within oncology. The use of PET/MRI in children to save radiation dose is also the subject of investigations.

Neuro PET

With the use of PET/CT, including HRRT, studies on brain tumors are undertaken. Studies of brain perfusion using PET or DCE-CT are also performed. In addition, imaging of dementia with new tracers and brain tumors with FET is studied. PET/MRI is now fully integrated into many of these studies. In cooperation with Neurobiology Research Unit and Centre for Integrated Molecular Brain Imaging, neuroreceptor ligands have been developed and used for research in neurobiology. The focus has mainly been on the serotonergic system.

Atherosclerosis

With the use of PET/CT and PET/MRI we can non-invasively visualize atherosclerosis and probably predict vulnerability of atherosclerotic plaques. With this technique, several studies in different groups of patients at risk and with the use of new PET tracers are currently undertaken. The goal is to develop an image-based algorithm for identification of patients at risk that will benefit from surgery. Recently, we published as the first, the use of PET/MRI for carotid artery imaging and its advantage over PET/CT.



Nuclear cardiology

With the introduction and use of ^{82}Rb PET coronary flow regulation is studied quantitatively in connection with a variety of cardiovascular diseases and the influence of interventions including gene therapy, pharmacological treatment and exercise. With the use of SPECT/CT or PET/CT the development of ischaemic heart diseases is studied in selected groups of patients, e.g. HIV patients. On basis of this, screening algorithms for detection of ischaemic heart disease are evaluated. Some of the studies are combined with PET tracers characterizing other aspects of the myocardium and its viability. Several of the studies are performed using PET/MRI to obtain additional information.

Lung studies

Research using lung function testing and lung scintigraphy in different patient groups, e.g. lung transplantation and endobronchial stenting for emphysema, are undertaken. The value of combined use of SPECT/CT for diagnosing pulmonary embolism has recently been evaluated. The value of biomarkers in combination with imaging is also studied. In addition, evaluation of the different ventilation tracers for assessment of ventilation inhomogeneity is undertaken. Research is also being conducted into mucociliary clearance, a method pioneered at the department, of the nose and lungs.

Inflammation, infection and rejection

Research with non-invasive imaging of inflammation and infection is currently being undertaken at the department.

Also studies on how rejection reactions can be visualized and evaluated are now performed. In some studies, the added value of MR-derived parameters of PET/MR is studied. Finally, on a translational basis development of new PET ligands for inflammation is currently being pursued.

Radionuclide treatment and theranostics

Localized radiation therapy using specific ligands binding to certain cancer forms has recently been implemented. The department takes part in research within this area by testing new ligands and producing relevant isotopes. We also develop several new theranostics based on promising imaging ligands labeled with beta or alpha emitting radionuclides. Cancers that are currently being targeted clinically include neuroendocrine tumors and ovarian cancer. Treatment with radionuclides will in part be based on imaging using new tracers for molecular profiling or the same ligand as the therapy (theranostics) for better outcome and fewer side effects. The concept of a tracer that visualizes the target prior to starting therapy is also known as companion diagnostics.

Whole body counting

Together with external partners, whole body counting is used for exact measurements of body composition in a series of studies. In addition we are investigating absorption of certain minerals from the gastrointestinal tract.



Cluster for Molecular Imaging



Andreas Kjær

The paradigm of precision medicine, i.e. tailoring therapy to the individual characteristics of each patient, has led to a need for diagnosing at the molecular level. Molecular biology methods need tissue sampling for *in vitro* analysis. In contrast, molecular imaging allows for non-invasive studies at the molecular level in intact organisms. Also such non-invasive imaging is not prone to sampling error since representative, whole-body imaging is obtained. With PET it is possible to label almost any molecule with radioactive isotopes. Therefore, this method can be used for non-invasive visualization of tumor specific receptors and tissue characteristics such as angiogenesis and ability to metastasize. Especially within cancer biology the technique is expected to lead to a break-through in diagnosing and treatment. Among the different techniques for molecular imaging, the nuclear medicine based technologies have the greatest translational potential since methods developed in animal models may directly be transferred and used in humans. In addition, successful imaging ligands may be developed into radionuclide therapy, such an imaging-therapy pair is known as theranostics.

Our current molecular imaging and theranostics research program is aimed through use of molecular biology and imaging techniques in both animals and humans to develop, evaluate and use non-invasive molecular imaging for human tissue characterization. Major applications of these tracers are expected to be: 1) planning of individualized, tailored therapy, 2) testing of new drug candidates

and 3) basis for development of radionuclide therapy (theranostics).

The development of new molecular imaging tracers for PET is a very complex process that involves many steps from definition of target to final use of the tracer in patients.

Major steps involved in PET tracer development and translation into patients

- Selection of key-processes involved in the pathophysiology of the disease
- Definition of relevant molecular targets of the key-processes
- Design of specific ligands
- Radioactive labelling of ligands
- Test of imaging ligands in relevant animal models
- Use of imaging data for therapy planning and monitoring of response
- Use for diagnosing, therapy planning and monitoring in patients
- Use for testing of new drugs
- Use as starting point for new targeted therapies, in particular radionuclide based therapies

Through establishment in 2003 of Cluster for Molecular Imaging at the Faculty of Health and Medical Sciences, University of Copenhagen (headed by Professor Andreas Kjær) a facility at the Panum Institute for molecular imaging in animals with PET, SPECT, CT, MRI and op-

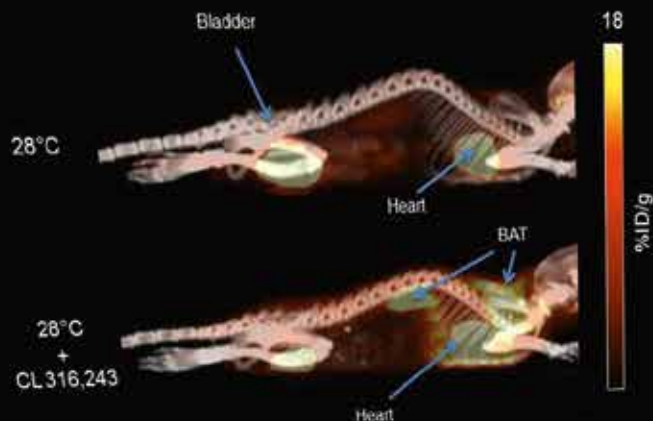
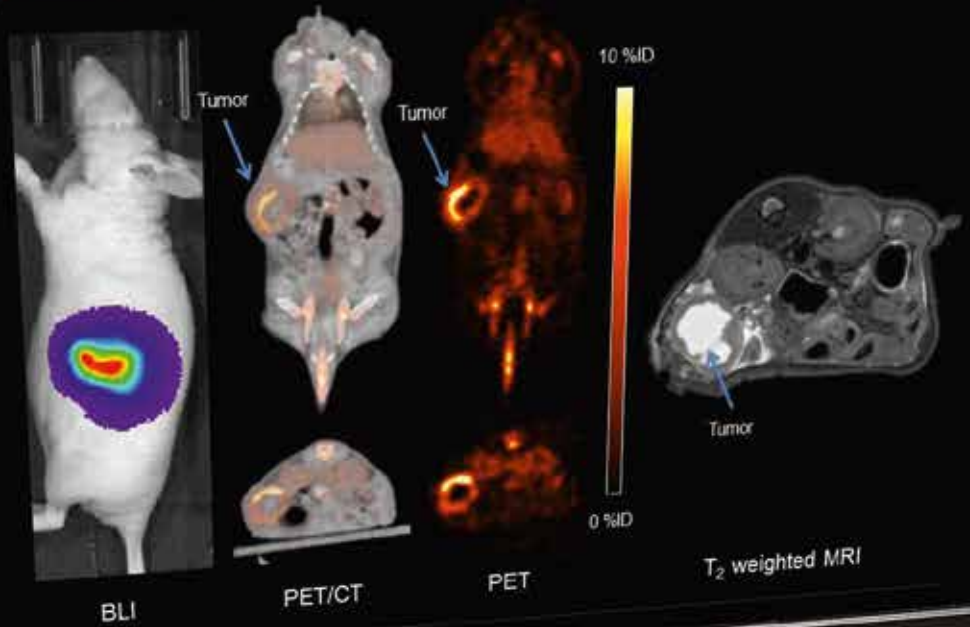


Figure 2. PET/CT of brown adipose tissue (BAT) activation in rats using an adrenergic agonist (lower) compared with saline (upper). Note the activation along aorta and inter-scapularly. The model is used for evaluation of new drug candidates for BAT activation (image provided by Carsten H. Nielsen).

Figure 1. Human pancreatic cancer xenograft implanted orthotopically to improve clinical relevance of preclinical cancer models. Tumor cells are transfected with luciferase so they can be detected with optical imaging (BLI). Also shown is tumor visualized with PET/CT using an in-house developed tissue factor targeting PET tracer. Finally, tumor growth was followed using 7 T MRI (image provided by Carsten H. Nielsen).

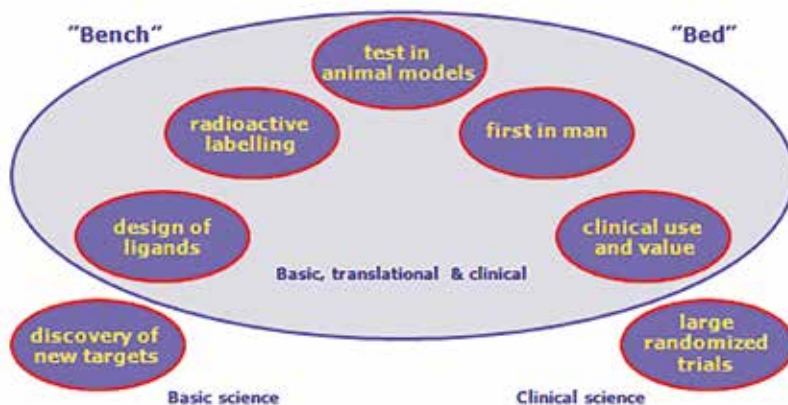


ViewSonic

PHILIPS



***Translation into patients:
from new targets to randomized trials***



tical imaging has been established. This has improved our translational capacity since we are now able to test new tracers and radionuclide therapies in animal models prior to clinical use. In accordance with this we have currently several new tracers in pre-clinical testing in animal models that already have or soon will become available for human use. A strong focus has recently been on the use of more clinically relevant animal cancer models, which include orthotopic human xenograft tumors as well as metastatic cancer models using human cancer cell lines (Figure 1). Most recently, we also implemented the use of patient-derived tumors (PDX) for orthotopic implantation to even better mimic the conditions in cancer patients. Furthermore, we have also introduced and developed animal models of cardiovascular diseases including atherosclerosis, myocardial infarction and takotsubo. For studies of atherosclerosis also mini pigs and rabbits are used.

Over the last years 10 years we have build a translational platform for development of new PET tracers in cancer. The platform includes, after testing in orthotopic human xenograft tumors in mice, early use of promising PET tracers in companion dogs with spontaneous tumors scheduled for cancer therapy. The latter allows for testing in "full-size" as well as evaluation of tumor-stroma interaction due to the syngeneic tumor environment. In this way we bridge between xenograft models and first-in-human studies.

At Cluster for Molecular Imaging we always seek to match our clinical methods to be able to develop new techniques for use in patients. Recent examples include the establishment of PET/MRI/MRS capabilities to be used in oncology and cardiology studies. Also, we currently perform preclinical studies in the field of hyperpolarized ^{13}C -MRS in collaboration with Hvidovre Hospital and DTU.

Cluster for Molecular Imaging is imaging partner in the European Advanced Translational Infrastructure in Medicine (EATRIS) under EU 7FP.

Currently the main focus of the translational research in tracers for non-invasive tissue characterization is on the use in cancer and cardiovascular disease and new targeted radionuclide therapies for cancer. However, more recently we also perform studies within molecular imaging of inflammation and metabolism, e.g. activation of brown adipose tissue (Figure 2).

Some tissue characteristics currently targeted for imaging:

- Cancer specific receptors (numerous projects)
- Glycolytic activity
- Cell proliferation
- Amino acid transport
- Hypoxia
- Apoptosis
- Angiogenesis
- Invasive phenotype

Global Excellence Prize



Moving towards personalized cancer treatment

In 2010 the Global Excellence program was launched to recognize and highlight the leading research environments in the field of healthcare in hospitals and universities.

Professor Andreas Kjær and his cross-disciplinary research team at the Department of Clinical Physiology, Nuclear Medicine & PET were among the first to be awarded the Global Excellence in Health Prize as well as to obtain status of Global Excellence for a 5-year period. The prize was awarded for their research within molecular imaging for tailored cancer therapy. The research program was focused on neuroendocrine tumors and undertaken in close collaboration with other departments at Rigshospitalet including departments of abdominal surgery, endocrinology, pathology and oncology as well as institutes at the University of Copenhagen and the Technical University of Denmark.

In 2014 the team reapplied for the Global Excellence Prize and a 5-year extension. Following review by an international assessment panel it was decided to reappoint the research environment as Global Excellence in Health. Major achievements during the last years include translation of new PET tracers developed at our department into use in patients. Accordingly, we now use an in-house developed PET tracer for imaging in patients with neuroendocrine tumors. The research is still focused on how molecular imaging can be used for tailored therapy. One such method currently being developed in our team is a PET ligand for visualization of the invasive phenotype. The information obtained from this PET scan can then be used for selection of therapy. We believe such innovative imaging technologies may become game-changers in implementing precision medicine. As previously, our research over the next 5 years will be performed in close collaboration with national and international partners.



Danish Chinese Scientific Collaboration



Andreas Kjær

In 2014 the Department continued its collaboration with leading research institutions in China. Our Danish-Chinese collaborations are focused on development of new PET imaging probes for cancer and their use in evaluation of anti-cancer therapies.

Professor Andreas Kjær is partner in the Danish-Chinese Centre for Proteases and Cancer funded by the National Natural Science Foundation of China and the Danish National Research Foundation (Danmarks Grundforskningsfond). The Centre is funded until the end of 2014. The main focus of the Centre is to perform high level research leading to new molecular imaging ligands and tailored therapies. Our current focus is on new PET imaging ligands to identify the invasive cancer phenotype and the translation into clinical use. In 2014 there has been a major break-through as we successfully performed a first-in-human phase 1 study with one of these tracers. Furthermore, additional tracers are in the pipeline and planned for clinical testing in 2015. In addition to Rigshospitalet, the partners are Aarhus University, Chinese Academy of Sciences, Fuzhou and Soochow University, Suzhou.



Danish-Chinese Centre for Proteases and Cancer
The Danish National Research Foundation and
The National Natural Science Foundation of China

Danish Indian Scientific Collaboration



Professor Andreas Kjær gave a lecture on the use of PET for tailored cancer therapy at the 2014 ICRB conference held in Delhi, India.

In 2014 we continued our collaboration with Professor Abhijit De from the Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) of the Tata Memorial Centre and Hospital in Navi Mumbai, the largest cancer hospital in Asia. The collaboration seeks through basic, translational and clinical studies to develop new and cost-effective methods for targeted radionuclide therapy in patients with breast cancer. Joint experimental work is currently undertaken both in India and Denmark. As part of the ongoing collaboration Professor Andreas Kjær served as invited speaker at the International Conference in Radiation Biology 2014 held in Delhi, India.





Young Investigator Prizes



Postdoc Tina Binderup at TMII symposium, Mount Sinai, New York, USA, May 2014. Best abstract and oral presentation in Nanomedicine: *PET/MRI to predict and quantify the uptake of ^{89}Zr -labeled nanoparticles in the aortic wall of atherosclerotic rabbits.*

PhD student Carsten H Nielsen with head of PhD School, Faculty of Medical and Health Sciences, University of Copenhagen, PhD Day, May 2014. Poster group winner.

PhD student Anders Christensen (joint with Dept. of ORL, H & N Surgery & Audiology): Danish Academy of Head & Neck Surgeons, Hindsgavl, Denmark, October 2014. Prize for best oral presentation: *Added value of near-infrared fluorescence tracer imaging in sentinel node biopsy for oral cavity cancer patients.*

Anniversaries



*Nuclear Medicine Technologist
Susanne Svalling celebrated her 25
years anniversary in January 2014*



*Nuclear Medicine Technologist
Dorthe Baunbjerg Nielsen
celebrated her 25 years anniversary in
October 2014*



*Medical Secretary
Mette Gylling Myltoft celebrated
her 25 years anniversary in
December 2014.*

CIMBI

Center for Integrated Molecular Brain Imaging,
University of Copenhagen, Rigshospitalet



We appreciate the excellent collaboration with Professor Gitte Moos Knudsen, Chair of the Neurobiology Research Unit at Rigshospitalet, University of Copenhagen and also Director of the CIMBI, Center for Integrated Molecular Brain Imaging, funded by the Lundbeck Foundation. The focus of the research program is on neurobiology, physiology and pathophysiology, molecular imaging and neuroreceptor ligands with focus on the serotonergic system. Professor Gitte Moos Knudsen received the 9th of September 2014 the Carlsberg Foundations Research Award 2014, and we are very proud to contribute and collaborate with her and her team.





Education 2014

Educational – undergraduate as well as postgraduate – activities have high priorities in most functions of our department. In November 2014 representatives from the *Danish Health and Medicines Authority* visited the department in order to evaluate the conditions for the specialist education of physicians in clinical physiology and nuclear medicine. This resulted in a fine report. The department has four educational positions for young physicians training to become specialists in clinical physiology and nuclear medicine. Other roles in the specialist education of physicians are related to the dedicated courses in oncology, cardiology, pulmonology, endocrinology and pathophysiology, all held at our department and arranged by our chief physicians.

Furthermore, we contribute to the specialist education of physicians from other specialties such as urology, nephrology, radiology, oncology, haematology, pulmonology and thoracic surgery. A high number of PhD students are associated with the research activities in the department.

Regarding *undergraduate education*, the department contributes to the activities of the Faculty of Health Sciences at the University of Copenhagen for Medical students, Human Biology students and Medicine & Technology students in collaboration with DTU in various subjects, e.g. physiology, nuclear medicine, and medical technology. Nuclear medicine technologist students and radiogra-



Peter Oturai and Jann Mortensen

phy students receive part of their education from the department.

The department delivers extensive training programmes to staff from other nuclear medicine and radiological departments in Denmark and the Nordic countries.

Colleagues, both students and postgraduate from Denmark and abroad, have visited the department for educational purposes for periods ranging from weeks to months.

The departments educational activities have furthermore been accredited by the *the Accreditation of*

Nuclear Medicine Training Centres Committee of the Section of Nuclear Medicine of the European Union of Medical Specialists (UEMS).

Chief Physician Peter Oturai is responsible for the postgraduate education of physicians in the department. Clinical Associate Professor Jann Mortensen is responsible for the undergraduate education of medical students. Professor Liselotte Højgaard is responsible for under- and postgraduate education for bioengineers.

Nuclear medicine technologists, radiographers and lab technicians



Tim Mølgaard Lundby, Kate Pedersen and Anne Sørensen

Also this year we have had a rising production in the whole department, and the nuclear medicine technologists, radiographers and lab technicians make a fantastic effort to secure our core services: Patient investigations, research and education on a very high level. They all accept willingly and with few days of notice long hours and extended work schedules to secure, that there is no waiting time for our patients. We do this approximately twice every month. The waiting time for our patients is in line with the political demands, and patients are not delayed in our department. With regard to research projects everyone are engaged from early morning to late evening with scanning from before 7 AM to after 10 PM.

New infrastructure for production

The ventilation in radiopharmacy was improved. This means a stable pressure in the room and ventilation for all three LAF benches. This allows more cell labelling procedures, and this was needed due to new research projects with labelling of white blood cells with both ^{99m}Tc and ^{111}In and new labelling procedures for blood plates.

New treatment ^{223}Ra for prostate cancer

This new treatment of patients with prostate cancer with bone metastases with severe pain, demands three nuclear medicine technologists for a whole day, even though the

treatment for each patient only takes 15 minutes. The Danish Health and Medicine Authority, Institute for Radiation Protection, demands very tough radiation protection means, and the nuclear medicine technologists have to be controlled in the departments whole body counter before and after they have given the patients their treatment. Three nuclear medicine technologists are educated in this special procedure and 2-3 times per month we have 10-15 patients for treatment.

Research

New area for nuclear medicine technologists: Hyperpolarization/SpinLab

In March 2014 a SpinLab system was installed in a separate laboratory next to the PET/MR scanner. The SpinLab system can produce hyperpolarized ^{13}C -Pyruvate, which is a part of a new functional imaging technique using magnetic resonance spectroscopy. Two technologists are allocated to prepare the fluid paths for the 4-channel, 5T “polarizer”. They must start this process early in the morning to be able to have the polarized product ready at 12 Noon for injection. The process is timeconsuming and consists of several steps all performed manually. The Fluid Paths (FP) are unpacked, flow checked and dried before the syringe is filled with the desired amount of dissolve media. Next,



the tubing is cut to correct for sample volume and the desired volume is weighed and pipetted into a vial. The vial and tubing is glued with a UV source. A systematic and precise assembling of all parts to a nearly packed FP is then completed. The last step is a helium purge and a seal pressure check. The FP is then ready to be loaded into one of the four channels undergoing a 2 hours polarizing process before the hyperpolarized ^{13}C -Pyruvate is ready for use. This procedure of preparing the FP is an interesting, yet very demanding process, requiring an excellent understanding of the system and a very precise working routine.

Radiochemistry meeting Rigshospitalet, October 2014

In Denmark there are 5 radiochemistry units, and the nuclear medicine technologists working in these units are a small group where exchange of knowledge and information is crucial. The Radiochemistry Unit at Rigshospitalet arranged the annual meeting with both lectures and exchange of knowledge from the practical everyday life in the lab. The participants were informed about ^{18}F -FDG scans, the process validation of the new FastLab, ^{18}F -FDG and ^{68}Ga -Dotatoc production and also treatment with ^{177}Lu -Dotatate to patients with neuroendocrine tumors. They had a walk around the department and a debate on the necessity of visibility, about exchange of staff for educational purposes and sharing of knowledge from

everyday lab life. The meeting was a great success with participation of 19 nuclear medicine technologists and lab technicians from Aarhus University Hospital, Odense University Hospital, Herlev Hospital, the Hevesy Lab DTU Risø and of course ourselves from Rigshospitalet.

Clinical instructors

To secure recruiting and education on an international level we have changed the organisation of the education of nuclear medicine technologist and radiographers. We previously had 1.5 nuclear medicine technologist instructor, this we have changed to 1 teaching nuclear medicine technologist responsible for the overall studies and 2 clinical instructors in the PET-section and 2 clinical instructors in the KF-section. This will run as a project for 2 years, and then we will evaluate. The 2 clinical instructors from the PET-scanner section have fulfilled the instructors education on Metropol, and their report: "How can the clinical instructor enhance motivation among those students, who are reluctant to learn, so that they involve in the short educational periods in clinical practice with us?" The conclusion of the report was, that it is very important to explain to the students about the infrastructure in our department and their everyday life in clinical practice. Both the physical environment; where is the staff room and the lavatory, where can they sit and work etc. But also the psychological



aspects around working with cancer patients are important. For some students it is the first time they meet patients, and it can be overwhelming and shocking to be face to face with seriously ill patients, if you are not properly prepared. By adjusting to individual needs and giving them tasks which push their boundaries, we can enhance their motivation.

Clinical Instructor Lasse Lawaetz Hansen is engaged in the education both in the department and at Metropol, including lectures on PET/CT for radiographers nuclear medicine section (M11), production of radiopharmaceuticals and PET-cases, nuclear medicine technologists (M7 and 11), gamma camera experiments for radiographer students and nuclear medicine technologist students (M6) and myocardial scintigraphy with Rubidium-82 PET both for Rigshospitalet internally and also for Siemens user meetings.

Nuclear Medicine Technologist Bente Dall has lectured nuclear medicine technologist students at Metropol on: "The professional meeting with the patient", and Nuclear Medicine Technologist Viktoria Setterberg has lectured on a DBIO course: "Multimedia on the Children Section, entertainment of children from the waiting room until examination is finished; what to remember when your patient is a child".

Deputy Chief Technologist Kate Pedersen and Camilla Sloth Knudsen was on a study visit on Memorial Sloan Kettering Cancer Center, June 2014

Technologist Day, May, Rigshospitalet

Our nuclear medicine technologists gave very fine presentations and presented posters:

Nuclear Medicine Technologist Annette Cortsen

Lecture: "The Annual Technologist Award 2013", Annette Cortsen held a lecture for the sponsors.

Research Technologist Jytte Oxbøl

Lecture: From mouse to human - Development of new angiogenesis PET tracers for cancer diagnosis and planning of personalized treatment.

Nuclear Medicine Technologist Victoria Setterberg

Lecture: Multimedia in Children Section - Entertainment of children from the waiting area to the end of study.

Nuclear Medicine Technologists Elin Lindell and Maria Pejtersen

Poster: Can intake of water with gas increase the distance between the myocardium and the subdiaphragmatic ⁸²Rubidium uptake in PET scans?



Nuclear Medicine Technologists Karin Stahr, Marianne Federspiel and Radiographer Jákup Poulsen
Poster: Fluently demarcations between radiographers and medical laboratory technologists at the PET/MR scanner. How to collaborate and gain new core competences.

LSB Congress Copenhagen, October
 Our nuclear medicine technologists gave very fine presentations and posters:

Research Technologist Jytte Oxbøl
Lecture: From mouse to human - Development of new angiogenesis PET tracers for cancer diagnosis and planning of personalized treatment.

Nuclear Medicine Technologist Eunice Saxtoft
Poster: Synchronized mobile tool (tablets) in a busy day - A user-friendly and effective tool to prevent failures and to secure greater efficiency in one of Europe's largest PET Centers

Nuclear Medicine Technologist Susanne Svalling
Poster: The Whole Body Counter at Rigshospitalet

EANM Congress in Göteborg, October
 Our nuclear medicine technologists participated with:

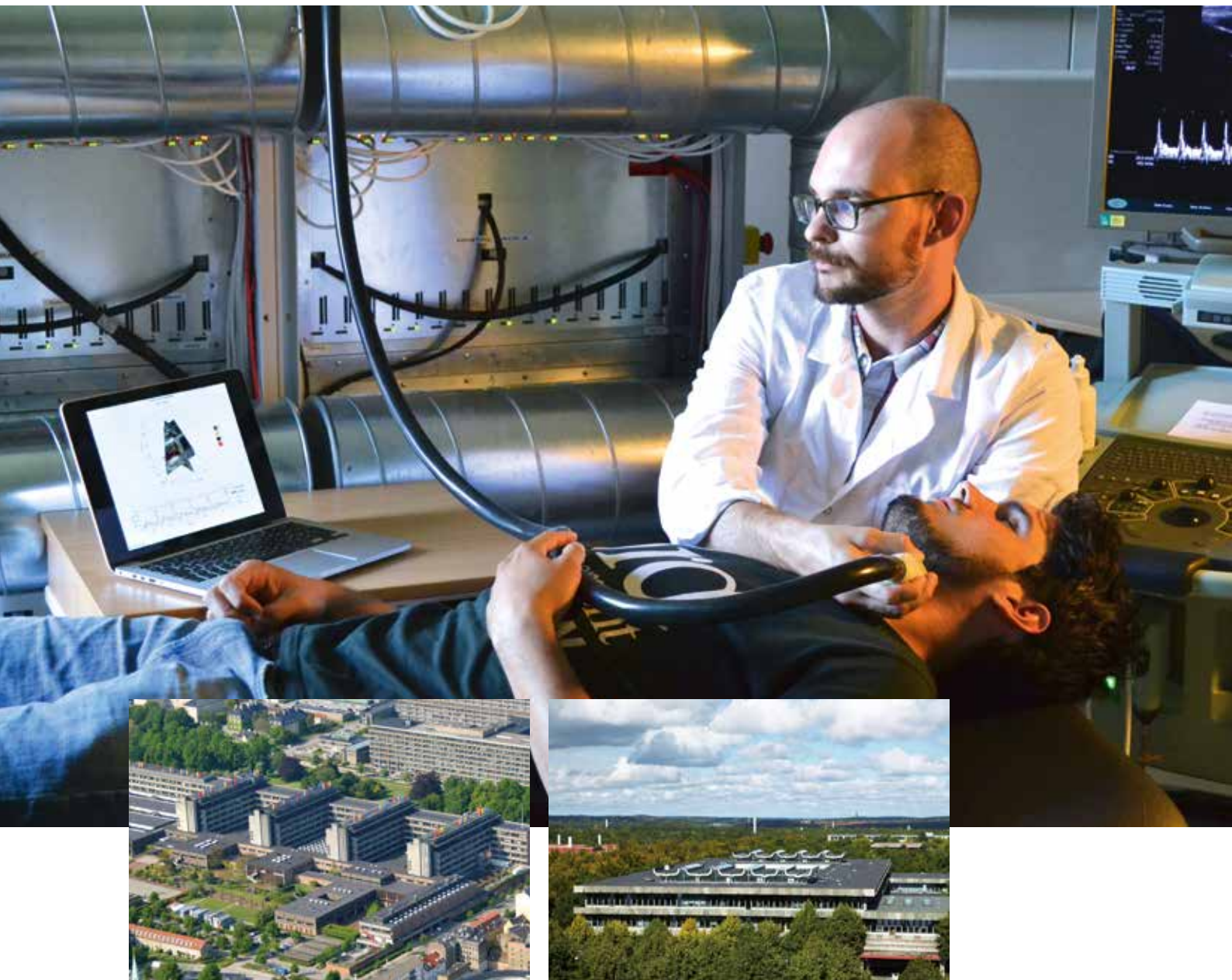
Nuclear Medicine Technologists Viktorija Setterberg and Anja Vallin Hansen
Poster: Multimedia Entertainment in a Pediatric Nuclear Medicine Unit - before, during and after.

Nuclear Medicine Technologist Susanne Svalling and Physicist Søren Holm
Poster: Whole Body counting of Radium-223 for monitoring of staff, preparing for radionuclide therapy.

Nuclear Medicine Technologist Anne Sørensen participated in the GE User Meeting

SNM Congress in Saint Louis
 Nuclear Medicine Technologists Marianne Federspiel and Karin Stahr, Radiographer Jákup M. Poulsen, Chief Physician Otto Mølby Henriksen, Chief Physician Vibeke André Larsen and Professor Ian Law
Poster: Patient convenience for glioblastoma patients in a PET/MRI environment

MSc in Medicine and Technology





Liselotte Højgaard

In cooperation with the Technical University of Denmark (DTU) and the University of Copenhagen (KU), the Department represented by Professor Liselotte Højgaard is involved in the MSc program in Medicine and Technology. It is a five year bioengineering degree at bachelor and master level. The first master graduated in 2008. Since the launch of the program in 2003 more than 200 students have applied for the 60 available places each year. You can read more about the program at www.medicin-ing.dk.

At present several of these bioengineers are seconded to the Department as PhD students and we have numerous students working with bachelor and master reports in collaboration with DTU, IMM (Institute for Mathematical Modelling), Professor Rasmus Larsen and DTU, Electro with Professor Jørgen Arendt Jensen and our department here at Rigshospitalet. In 2010 the course was subject to accreditation with a positive result. A warm thank you to Professor Jørgen Arendt Jensen, Associate Professor Kaj-Åge Henneberg, Reader Jens E. Wilhelm, DTU and Associate Professor Bente Stallknecht, University of Copenhagen, for their great effort and our great collaboration both on education and research.



PET and PET hybrid systems



Søren Holm

The department has one dedicated, stand-alone brain PET system, five combined whole-body PET/CT systems and one integrated PET/MR system in the hospital itself. We are also involved in the experimental work with PET, CT and MR at Cluster for Molecular Imaging at the Faculty of Health Sciences, University of Copenhagen.

In the Cluster for Molecular Imaging, we operate three research scanners for PET and CT of small animals. The “older” systems (from 2006) are a separate PET (Focus 120) and CT (microCAT II). More recently, an integrated PET/CT system, the Inveon, was acquired and a Bruker 7T MR scanner for small animals was installed.

In the hospital brain research continues on the PET-only HRRT (High Resolution Research Tomograph) in close collaboration with the neurobiology research group (NRU), but the system also works as a clinical instrument.

The four PET/CT's in the PET-section (Finsen building) are all Siemens systems. Two are Biograph TrueV, one with

40 and one with 64 slice CT, acquired in 2007 and 2009. The other two (from 2010 and 2011) are mCTs with 64 slice CT and time-of-flight but overall with rather similar specifications, which provides an important flexibility in patient scheduling. The majority of the studies in the PET section continue to be FDG whole-body scans for cancer diagnosis, staging, planning and follow-up, but in recent years a significant number of FET, FLT, ^{11}C -PiB, and ^{68}Ga -Dotatoc examinations have been added. All these scans are routinely performed with the use of combined PET and CT, and most CT scans are performed as full diagnostic quality CT including contrast enhancement. One of the mCTs is run in a unique well-functioning collaboration with the Department of Radiotherapy, and it is extensively used for therapy planning, for which purpose its large opening (78 cm) is an important design improvement over the previous generation of systems.

The most recent (fifth) PET/CT is similar to the two previous mCTs, but with 128 CT-slices. It is installed “upstairs” in the nuclear medicine section. This scanner mainly per-



forms pediatric PET scans and scans with ^{82}Rb (heart perfusion), ^{68}Ga -Dotatoc (neuroendocrine tumors), and ^{18}F -NaF, replacing some bone scintigraphy or SPECT/CT.

The fully integrated PET/MR scanner (Siemens mMR) was among the first in the world to become operational in early 2012. Previous attempts to combine the two modalities have either been limited in use (brain “insert” only) or not fully integrated (two separate gantries). In the mMR, a new amplifier principle in the PET detectors makes them insensitive to the magnetic field, and small enough to allow the PET scanners detector ring to be placed inside the 3-tesla MR-magnet between the gradient coils and the RF transmitter. The receiver coils have been redesigned to minimize absorption of the PET photons. This makes it possible to perform truly simultaneous measurements of PET or MR. The combined scanner improves the diagnostic power (in particular soft tissue differentiation) but also has the potential of reducing radiation exposure, which is particularly important in children examinations. The physics group is working on the issues of attenuation

correction and artefact suppression in order to support the clinical research protocols. In particular for quantitative results in brain scanning, the lack of direct attenuation measurements is a challenge, and we are addressing these issues with a postdoc and a PhD-project in collaborations with Siemens (Erlangen and Knoxville), University of Leuven, and the institute of Computer Science at Copenhagen University.

In 2014, the PET/MR installation was complemented with an MR hyperpolarizer (GE SPINlab), allowing the production of ^{13}C -labelled pyruvate, although not yet for human use.

Danish National Research Foundation



Professor Liselotte Højgaard is Chair of the Board of the Danish National Research Foundation. The board members are: Professor Liselotte Højgaard, Professor Eivind Hiis Hauge, Professor Bo E. Honoré, Professor Kirsten Hastrup, Professor Svend Erik Larsen, Professor Birgitte Possing, Professor Eero Vuorio, Professor Dr. Bart De Moor and Professor Christina Moberg.

The Foundation is run by Director, Professor Thomas Sinkjær together with Vicedirector Mogens Klostergaard Jensen and the team in Holbergsgade.

The Danish National Research Foundation (DNRF) is an independent organisation established by the Danish Parliament in 1991 with the objective to promote and stimulate basic research at the highest international level at the frontiers of all scientific fields. The Center of Excellence (CoE) program is the main funding mechanism. Since 1991 the Foundation has committed itself to support Danish research with more than 6 billion DKK (more than 800 mio €).

The Center of Excellence is the primary funding mechanism and the foundations flagship. A center grant is large and

flexible, and a center may have a lifetime up to 10 years. Only top researchers with the most ambitious ideas will be awarded a CoE through fierce competition involving a two-stage application process.

The objective of the CoE program is to strengthen Danish research by providing the best possible working conditions and organisational setup for selected top researchers. Centers may be established within or across all fields of research.

A total of 100 Centers of Excellence have been established so far, and a new generation of 12 centers are up and running by the 1st of January, 2015 as a result of the 8th application round.

The DNRF also has the Niels Bohr professorships. In 2013 DNRF was evaluated by an international panel leader by Dr. Wilhelm Krull. The outcome was very positive, and a continuation of DNRF was recommended to the Danish Parliament and Government.

The Danish Parliament gave the Foundation 3 bio DKK on the State Budget for 2015 to secure the Foundation to 2036.



2014 was a landmark year for the Danish National Research Foundation, Danmarks Grundforskningsfond, as the Government decided a new capital injection of 3 bio DKK for the Foundation on the state budget for 2015. It was a landmark year, as we selected 12 new Centers of Excellence to start in 2015, and with these 12 new centers the Foundation could celebrate Center of Excellence number 100



© René Magritte / Billedkunst.dk

Accreditation

Rigshospitalet and our department have been accredited succesfully by:

- » Center of Excellence by the European Neuroendocrine Tumor Society
- » Certified by SIS, National Institute of Radiation Protection, The Danish National Board of Health
- » Danish Medicines Agency
- » The Danish National Board of Health, MD Specialist education
- » EURATOM, The European Atomic Energy Community
- » Section of Nuclear Medicine of the European Union of Medical Specialists (UEMS)s
- » Accreditation of Nuclear Medicine Training Centers Committee, MD Specialist Education
- » European Association of Nuclear Medicine
- » The Specialty Advisory Committee (SFR) in Clinical Physiology and Nuclear Medicine
- » The Danish Healthcare Quality Programme, DDKM

Editors

Liselotte Højgaard
Vibeke Rønn

Layout

Eckardt Aps

Print

Specialtrykkeriet Viborg

Photos

Andreas Kjær
Esben Salling
Frederiksberg Luftfoto
Joachim Rode

Issues

1000 ex.

Copyright

Department of Clinical Physiology,
Nuclear Medicine & PET
Rigshospitalet
University of Copenhagen
Blegdamsvej 9
DK 2100 Copenhagen Ø
Denmark

Contact

Professor Liselotte Højgaard
E-mail: lottepet@rh.dk
Phone: +45 3545 4215/1792

Clinical Physiology and Nuclear Medicine
KF 4011
Rigshospitalet, University of Copenhagen
Blegdamsvej 9, DK 2100 Copenhagen Ø, Denmark
Telephone: +45 3545 4011
Fax no: +45 3545 4015
KF@rh.dk
rh.kfnm.dk

PET & Cyclotron Unit
PET 3982
Rigshospitalet, University of Copenhagen
Blegdamsvej 9, DK 2100 Copenhagen Ø, Denmark
Telephone: +45 3545 3919
Fax no: +45 3545 3898
PET@rh.dk
rh.kfnm.dk