REGION H Rigshospitalet

Department of Clinical Physiology, Nuclear Medicine & PET

Annual Report 2016

Rigshospitalet · University of Copenhagen

Rigshospitalet
King Frederik V founded Rigshospitalet in 1757. Today it has app. 1,400 beds and 12,000 employees. 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.

Glostrup Hospital
Glostrup Hospital were established in 1958, and 1st of January 2015 Rigshospitalet, Blegdamsvej and Glostrup Hospital were unified as Rigshospitalet.

University of Copenhagen
The University of Copenhagen was founded in 1479. The Faculty of Health and Medical Sciences has 10,000 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 and LERU, League of the European Research Universities. www.ku.dk

REGION Rigshospitalet DTU UNIVERSITY OF COPENHAGEN

Contents

Preface

The research in our department has reached unpresidented hights in 2016 with a new uPAR tracer from Professor Andreas Kjær, who is at the helmet as responsible for research at the department. Andreas has an ERC Advanced Grant, and we are privileged to house his comprehensive program of molecular imaging. We are proud of the uPAR PET tracer developed for grading invasiveness and malignancy in PET/CT scanning. To all other researchers in the department: also a warm thank you and honors for your fine effort.

To all experts and staff members a warm thank you for a busy year with high standards and the implementation of "Sundhedsplatformen", the new electronic patient record. The acitivity in 2016 was very high with a busy clinical everyday practice with >111,000 investigations.

In 2016 Rigshospitalet implemented the new electonic patient record, the EPIC SP "Sundhedsplatformen". Preparations with education and training started before the summer, and on the 5th of November 2016 when we had "go live". Rigshospitalet has 12,700 employees, and is the only hospital in Denmark with a trauma center level 1. Due to good collaboration and a great effort and resilience from all it is now onboard. Thank you to all our staff members for the great dedication and the effort. Our consultant in PET, Dr Johan Löfgren was responsible for the operation in our department, and we would like to convey a warm thank you to Johan for the successful effort. Also a warm thank you to our "super users" Head of Section, Consultant Peter Hovind, Consultant Peter Oturai and all other employees involved. During the "go live" period we got great help from "The Student Team" formed under the leadership of Bioengineer Student David Kovacs, previous president of the student organization "Engineering World Health". David and his 35 student colleagues were second to none during the "go live" period, worked 24/7 and were essential for the success of the implementation. We would like to say a warm thank you to all students involved.

Before we could implement the new electronic patient record we had to upgrade the patient booking system Carestream RIS in our section in Glostrup, so that we had the same all over Rigshospitalet, both on the premises in town, Blegdamsvej (the old Rigshospitalet), and the section in Glostrup. It was a big effort, well prepared and with a good collaboration with Carestream and CIMT, Susanne Thomassen. A warm thank you also to our own experts Annegrethe Jørgensen, Bryan Haddock, Peter Hovind, Lis Larsen, Katrine Cappelen, Maria Pejtersen, Marianne Stahlfest, Tina Vikmann Nielsen, Gudrun Semitoje and Vibeke Rønn.

The unification between Glostrup and Rigshospitalet is now in place, and works well with teleconference facilities and integration on patient studies, research and education.

The highlight of the year was the introduction of the new PET/CT scanner in Glostrup; the first PET/CT in Glostrup. We would like to say a warm thank you to Head of Section, Consultant Peter Hovind, Staff Nuclear Medicine Technologist Lis Larsen and Physicist Bryan Haddock, Glostrup and the team in PET, Blegdamsvej, Head of Section, Consultant Annika Loft, Consultant Anne Kiil Berthelsen and Staff Nuclear Medicine Technologist Kate Pedersen for helping the Glostrup Section. Our idea was, that PET in all our sections should have the same quality – the highest obtainable – for the sake of patients and research.

Thank you to our directors at the Center of Diagnostics, Rigshospitalet, Center Director Bettina Lundgren, MD DMSc and Vice Director Lene Ørnstrup and their team for important positive and helpful collaboration. Thank you to Department of Radiology, Head of Department Ilse Vejborg and Chief Radiographer Johnny Madelung. We appreciate the positive collaboration very much.

Thank you to all staff, collaborators and international colleagues for making this possible.

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

Liselotte Højgaard
Professor, Head of Department

Linda M. Kragh
Chief Technologist

Mission and objectives

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

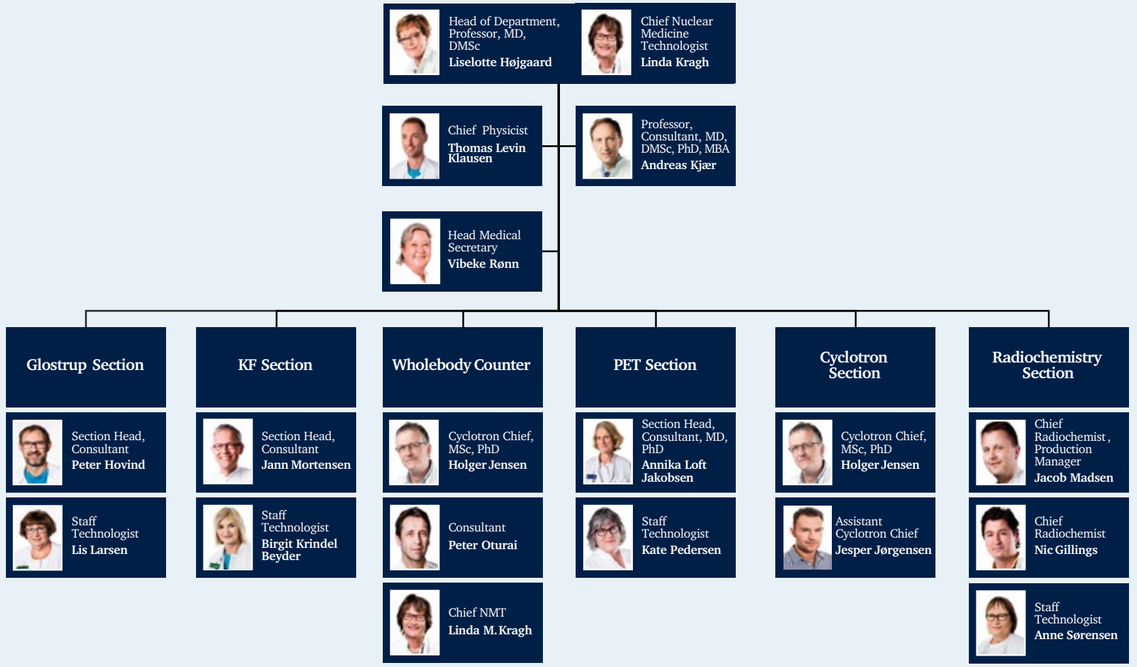
- to provide optimal clinical physiology and nuclear medicine for patient investigations and patient treatment with radiopharmaceuticals
- to carry out research at the highest international level in clinical physiology and nuclear medicine with special emphasis on molecular imaging, isotopes and radiopharmaceuticals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

We aim high – we strive to be one of the five best departments worldwide before 2020.

Organisation and staff 2016

Abrahamsson, Elisabeth, Radiographer.
Aggergaard, Amalie, Student.
Agner, Elissaveta Castella, Radiographer.
Ahmadi, Amir, Radiographer.
Albers, Mia C. Hjorth, Teaching NMT.
Albrecht-Beste, Elisabeth, MD, Consultant.
Alslev, Louise, MD, Staff Specialist.
Al-Tai, Reya Tarik Hamid, NMT.
Amtoft, Annemarie Gjelstrup, MD, Consultant.
Anderberg, Lasse, Student.
Andersen, Flemming Littrup, MSc, PhD, Chief Computer Scientist.
Andersen, Julie Bjerglund, MD, PhD, Registrar.
Andersen, Kim Francis, MD, Consultant.
Andersen, Ulrik Bjørn, MD, Consultant.
Anthony, Erwin Jørry, Cyclotron Technician.
Awwal, Zara Amalie Krog, Radiographer.
Azizi, Nadia, Radiographer.
Barløse, Mads Christian Johannes, MD, Registrar.
Bay, Emma Therese, Student.
Beich, Laura Tange, Student.
Bentsen, Simon, PhD Student.
Benzon, Eric von, MD, Consultant.
Berthelsen, Anne Kiil, MD, Consultant.
Beyer, Birgit Krindel, Staff Technologist.
Binderup, Tina, MSc Human Biology, PhD, Postdoc.
Birch, Kirsten Junker, NMT.
Bisgaard, Sissel, Student.
Borgwardt, Lise, MD, PhD, Consultant.
Brandt-Larsen, Malene, MSc, PhD, Chemist.
Brittain, Jane Maestri, MD, Senior Registrar.
Buhelt, Sophie, Student.
Bærentsen, Christian Ørtoft, Student.
Børresen, Betina, DVM, PhD Student.
Calvo, Oriol Puig, PhD Student.
Cappelen, Anna, Student.
Cappelen, Katrine Louise, Engineer.
Chehri, Sarah, Scholarship.
Choudry, Aisha Bilal, Student.
Christensen, Anders, MD, PhD Student.
Christensen, Camilla, Chemist.
Christensen, Camilla, NMT.
Christensen, Charlotte Birk, MD, Staff Specialist.
Christensen, Esben, MSc Bio Med, PhD Student.
Christensen, Helle, NMT and Nurse.
Christensen, Jan Damgaard, Cyclotron Technician.
Christensen, Kirstine Kjær, Student.
Christensen, Line-Marie Neumann, Student.
Christensen, Thomas Emil, MD, PhD Student.
Christensen, Tine Nøhr, MD, PhD Student.
Christophersen, Daniel Vest, MSc Human Biology, PhD, Postdoc.
Clausen, Malene Martini, MD, PhD, Postdoc.
Clemmensen, Andreas Ettrup, MSc Med.Tech., PhD Student.
Cortsen, Annette, NMT.
Costa, Junia, MD, Staff Specialist.
Cramer, Stig Præstekjær, MD, PhD, Postdoc.
Dahan, Daniel, Cyclotron Technician.
Dall, Bente, NMT.
Dalsgaard, Birthe Hunnerup, NMT.
Damgaard, Jeannette, Radiographer.
Damm, Kristina, Secretary.
de Nijs, Robin, Medical Physicist, MSc, PDEng, PhD.
Dejanovic, Danijela, MD, Staff Specialist.
Denholt, Charlotte Lund, MSc, PhD, Chemist.
Do, Manh Tan, Student.
Drachmann, Anders Paaske, Student.
Dunbar, Douglas, NMT.
Dähnhardt, Andreas, System Administrator.
Døssing, Kristina Benedikte Vangsted, MSc Biology, PhD Student.
Edem, Patricia Edim, MSc Chem., PhD, Postdoc.
Elkington, Sakeena, NMT.
Ellebæk, Sofie, MSc Biotech., PhD Student.
Ellegaard, Andreas Høyby, Student.
Enevoldsen, Lotte Hahn, MD, Consultant.
Engberg, Astrid, Student.
Eschen, Christian, Student.
Esmail, Mona Jasmin Ali, NMT.
Federspiel, Marianne, NMT.
Fischer, Barbara Malene, MD, DMSc, PhD, Consultant.
Fliedner, Frederikke Petrine, MSc Biotech., PhD Student.
Foldager, Annette, Teaching NMT.
Folkmann, Nanna Freja, Secretary.
Fosbøl, Marie Øbro, MD, PhD Student.
Frederiksen, Mette, Quality Coordinator.
Frost, Nadia, Student.
Frydendahl, Christina Schjøth, MSc Chem, PhD, Postdoc.
Fuchs, Annette, Student.
Gelle, Liibaan Mohamed, NMT.
Ghotbi, Adam Ali, MD, PhD Student.
Gillings, Nic, MSc, PhD, Chief Radiochemist.
Ginsborg, Lone Agervold, Medical Secretary.
Grave, Tine, Medical Secretary.
Grøndahl, Veronica Lykke, Scholarship.
Gudmundsdóttir, Edda Rós, NMT.
Gutt, Lars Emil, Student.
Haddock, Bryan Thomas, Chief Physicist.
Hag, Anne Mette Fisker, MSc Human Biology, PhD, Postdoc, Research Coordinator.
Hansen, Adam Espe, Physicist.
Hansen, Anders Elias, DVM, PhD, Postdoc.
Hansen, Anja Vallin, NMT, Clinical Instructor.
Hansen, Camilla Josephine Teglgaard, NMT.
Hansen, Caroline Lind Hansen, NMT.
Hansen, Casper, Student.

Department of Clinical Physiology, Nuclear Medicine & PET



Organisation and Staff 2016

Hansen, Christian Engelsborg, Student.
Hansen, Christian, Student.
Hansen, Helena, Student.
Hansen, Joachim Pries, Student.
Hansen, Matilde Bro, Student.
Hansen, Michele Zaugg, Student.
Hansen, Ole Michael Raun, NMT.
Hasbak, Philip, MD, Consultant.
Hasler, Signe Walther, Student.
Hassan, Mariam, NMT.
Hassing, Christina, Student.
Henriksen, Otto Mølby, MD, PhD, Consultant.
Hercman, Alexandra Regina Nowacka, NMT.
Hildebrand, Sanne, Secretary.
Hirsi, Abdi Hafied, Registrar.
Holm, Stine, NMT.
Holm, Søren, MSc, PhD, Chief Physicist.
Holten, Victoria, Student.
Holtz, Simon Herken, MSc Molecular Biology, QA Academic.
Hovind, Peter, MD, DMSc, Consultant.
Hurry, Preetee Kapisha, MD, Senior Registrar.
Højgaard, Liselotte, MD, DMSc, Professor, Head of Department.
Iljazovska, Cejlan Zulfovska, NMT.
Ismaili Abd, Scholarship.
Jakobsen, Annika Loft, MD, PhD, Consultant.
Jakobsen, Mette Høy, Human Biology, PhD Student.
Jensen, Berit, NMT.
Jensen, Holger, MSc, PhD, Chief Cyclotron Physicist.
Jensen, Julie Milbak, Student.
Jensen, Mads Radmer, Registrar.
Jensen, Martin Juul Ravn, NMT.
Jensen, Mathilde Daniele Ørbæk, Scholarship.
Jensen, Mette Munk, MSc Human Biology, PhD, Postdoc.
Jensen, Michael Lundemann, Engineer.
Jensen, Vibeke, NMT.
Jeppesen, Troels Elmer, MSc Chem, PhD Student.
Johannesen, Helle Hjorth, MD, Consultant.
Johannesson, Rasmus Skov, Student.
Johansen, Shakti Nicolai, NMT.
Johnbeck, Camilla Bardram, MD, PhD, Postdoc.
Juhl, Karina, MSc Human Biology, PhD Student.
Jørgensen, Annegrethe, NMT.
Jørgensen, David, Student.
Jørgensen, Jennifer Solgaard, MSc Engineer Biotech., PhD Student.
Jørgensen, Jesper Tranekjær, MSc Human Biology, PhD, Postdoc.
Jørgensen, Jesper, MSc, Cyclotron Physicist.
Jørgensen, Louise, MD, Research Assistant.
Jørgensen, Mads Wissenberg, Registrar.
Jørgensen, Mette Møller, NMT.
Kaijer, Michelle Westergaard, Technologist, PA Professor Andreas Kjær.
Karnov, Kirstine, MD, PhD Student.
Keller, Sune Høgild, MSc, PhD, Computer Scientist.
Kjær, Andreas, MD, DMSc, PhD, MBA, Consultant, Professor.
Kjær, Kristian Skov, Student.
Klausen, Thomas Levin, MSc, Chief Physicist.
Kleczewski, Karina, Medical Secretary.
Knigge, Pauline Natalie Seindal, Student.
Knudsen, Camilla Sloth, NMT.
Knudsen, Lisbet Lomholdt, Consultant.
Korsholm, Kirsten, MD, Senior Registrar.
Kragh, Linda M., Chief Technologist.
Krarup, Marie Manon Krebs, Scholarship.
Kristensen, Lotte Kellemann, MSc Human Biology, PhD Student.
Kristiansen, Jonas Frimer, Student.
Krogager, Louise, Student.
Kronvall, Johanna, NMT.
Ladefoged, Claes Nøhr, Computer Scientist, PhD Student.
Langer, Jonathan Andreas Wang, Student.
Langer, Natasha Hemicke, Student.
Larsen, Anne Fensløv, Student.
Larsen, Bjarke Follin, MSc Ind.Med., PhD Student.
Larsen, Christina Vang, NMT.
Larsen, Lis, Staff Technologist.
Larsen, Mette Fabiansen, Medical Secretary.
Larsen, Trine Bjørnbo, MSc Pharm Tech, PhD Student.
Larsson, Henrik Bo Wiberg, MD, DMSc, Consultant, Professor.
Lass, Jakob, Student.
Laugesen, Monika, Student.
Law, Ian, MD, PhD, Consultant, Professor.
Lehel, Szabolcs, MSc Chemistry, PhD.
Lind, Camilla Louise Nordvig, NMT.
Lindberg, Ulrich, MSc Med.Tech, PhD.
Lindell, Elin, NMT.
Linnet, Simone, Student.
Linnet, Solveig, NMT.
Ljunggren, Anna, NMT.
Loft, Mathias Dyberg, Scholarship.
Ludvig, Helle, NMT.
Lundberg, Helena Inez Sofia, MD, Registrar.
Lundby, Tim Mølgaard, Staff Technologist.
Lundsgaard, Christoffer Cramer, Student.
Lærke, Sonja Pedersen, Technician.
Löfgren, Johan, MD, Consultant.
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, MD, Scholarship.
Marner, Lisbeth, MD, DMSc, PhD, Staff Specialist.
Martín, Marina Simón, Student.
Mehlsen, Anne-Birgitte, MD, Consultant.
Mikkelsen, Henny, NMT.
Mikkelsen, Mathias, Student.
Mohebbi, Ali, Student.
Morsing, Anni, MD, Consultant.
Mortensen, Jann, MD, DMSc, Consultant, Ass. Professor.
Mose, Camilla, NMT.
Mottelson, Mathis Nygaard, Student.
Munkholm-Larsen, Mathias, Clinical Assistant.
Myltoft, Mette Gylling, Medical Secretary.
Myschetzky, Rebecca Sue Main, NMT.
Mølvig, Bjørn Hübschmann, Student.
Nielsen, Anders Bo, Student.
Nielsen, Carsten Haagen, MSc Med.Tech., PhD, Postdoc.
Nielsen, Cora Schaumann, NMT.
Nielsen, Kasper With, Animal Technologist.
Nielsen, Mariane, Service Assistant.
Nielsen, Tina Vikmann, Medical Secretary.
Nyrnberg, David Enslev, Student.
Nørgaard, Martin, Engineer.
Nørregaard, Kamilla, MSc Physicist, PhD, Postdoc.
Nørst, Tim Niclas, NMT.
Olesen, Oline Vinter, MSc Engineer, PhD.
Olin, Anders. Student.
Olsen, Ingrid Marie Holst, MD, PhD, Postdoc.
Olsen, Paw Winther, Engineer.
Oturai, Peter, MD, Consultant.
Oxbøl, Jytte, Technologist, Lab. Manager.
Pedersen, Kate, Staff Technologist.
Pedersen, Kirsten Foldberg, Radiographer.
Pedersen, Maria Badir, Student.
Pedersen, Sune Folke, MSc Human Biology, PhD, Postdoc.
Pejtersen, Maria, NMT.
Petersen, Lars Ringgaard, MSc Bio.Med., PhD Student.
Petersen, Lotte Pia, Service Assistant.
Philipsen, Frederik Ersø, Student.
Porojan, Monica, Technician.
Poulsen, Constance Eline Grandjean, Student.
Poulsen, Jákup Martin, Radiographer.
Poulsen, Sidsel Højklint.
Pourhassan, Houman, MSc Bio.Chem., PhD Student.
Raghava, Jayachandra Mitta, MSc Biology, Postdoc.
Rahbek, Rikke Sofie, Student.
Rasmussen, Camilla Kuhre, Medical Secretary.
Rasmussen, Gregers Brünnich Damgaard, MD, PhD Student.
Rasmussen, Sine Hvid, Student.
Rasmussen,Thomas, MD, PhD, Postdoc.
Reichkendler, Michala, MD, Senior Registrar.
Rexhepi, Lume, NMT.
Ripa, Rasmus Sejersten, MD, DMSc, Staff Specialist.
Risør, Louise Madeleine, MD, PhD Student.
Rosiek, Christian Anker, Student.
Rostrup, Egill, MD, DMSc, Consultant.
Ruager, Martin Siim, Student.
Rønbirk, Lilian, Medical Secretary.
Rønn, Vibeke, Head Medical Secretary, PA Professor Liselotte Højgaard.
Rønne, Frederik Malmborg, MD, Senior Registrar.
Salihu, Armend, NMT.
Saxtoft, Eunice, NMT, Clinical Instructor.
Schulze, Christina, NMT.
Segur, Liva, Student.
Semitoje, Gudrun, Medical Secretary.
Setterberg, Victoria, NMT.
Simonsen, Helle Juhl, NMT.
Skou, Katrine Bugge, MSc Med.Tech, Research Assistant.
Skovgaard, Dorthe Charlotte, MD, PhD, Postdoc.
Sommer, Niyan, NMT.
Stahlfest, Marianne, Medical Secretary.
Stahr, Karin, NMT.
Strandberg, Sandra, Student.
Suetta, Charlotte Arneboe, MD, PhD, Consultant, Ass. Professor.
Sunde, Christine Høj, NMT.
Svalling, Susanne, NMT.
Svendsen, Nini Hvidtfeldt, NMT.
Sørensen, Anne, Staff Technologist.
Sørensen, Jette Bitten, Service Assistant.
Sørensen, Louise Lendorf Sørup, NMT.
Tayyab, Mahvish, NMT.
Teksen, Alime Sema, Student.
Therkildsen, Pia, Secretary.
Tolstrup, Britt Maria Jæger, Radiographer.
Vestergaard, Mark Bitsch, PhD Student.
Vignisdottir, Lilja Dögg, Radiographer.
Vinther, Johanne Constance Ilve, Management Secretary.
Weihrauch, Per, Cyclotron Technician.
Wikke, Tina, NMT.
Wittekind, Anne-Mette Nielsen, QA Pharmacist.
Wrang, Helene, NMT.
Yerst, Joo Lærke, NMT.
Yousaf, Roma Urooj, Student.
Østergaard, Daniella Elisabet, Student.
Aagaard, Christina Byrne Faurholt, MD, PhD Student.

Highlights 2016

New staff room
the KF Section 2016.

Our Head of Department, Professor Liselotte Højgaard was invited by the Swedish Government to join the Board (Konsistoriet) of the Karolinska Institute in Stockholm. The Karolinska Insitute is one of the leading medical universities and hands out the Nobel Prizes in physiology or medicine.

Rigshospitalet is at the moment building a new North Wing, a 2 bio project, and in 2016 the constructions have necessitated that the PET Section was covered by a heavy lid of concrete.

The staff survived with a little sunshine in an intermistic pavilion.

Professor Andreas Kjær got the JNM Editors Choice Award for the best article at the Society of Nuclear Medicine Annual Meeting: "^{64}Cu-DOTATATE PET for Neuroendocrine Tumours: A Prospective Head-to-Head Comparison with ^{111}In-DTPA-Octreotide in 112 Patients".

New electronic patient record, "Sundhedsplatformen" at Rigshospitalet.

Chief Technologist Linda M. Kragh got the speciality's prize as the first non-academic at the DSKFNM's Annual Meeting.

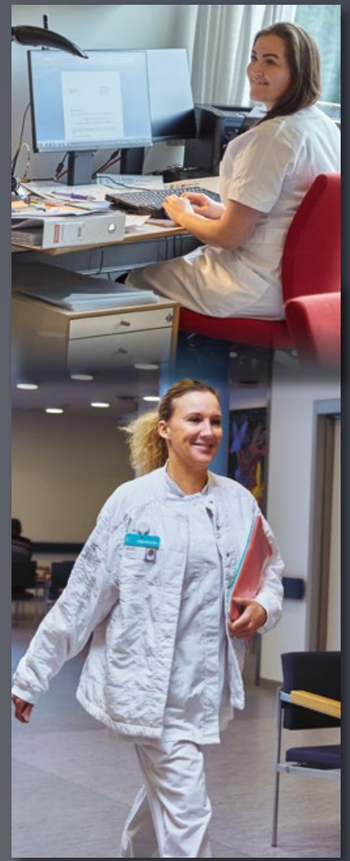
Professor Liselotte Højgaard was invited to join the Board of Die Robert Bosch Stiftung who owns 92 % of Robert Bosch GMBH, a world wide company with an annual return of 70 billion € and 350,000 employees. The foundation owns the company and Die Robert Bosch Krankenhaus in Stuttgart, a hospital like Rigshospitalet, and the foundation supports research, art, humanities and humanitarian actions all over the world.

Annual Education Conference for all staff members in Department of Clinical Physiology, Nuclear Medicine & PET.

Medical secretaries

In the department we have highly competent medical secretaries important for referral of patients, organisation of the flow of patients through the department, writing the reports and sending them to the clinical departments. They do a dedicated effort , and we have no waiting lists for patients or reports. In all three sections we have been challenged by staff members who have been ill for longer periods, but in spite of that the teams have performed brilliantly. The medical secretaries master the complicated booking and secure that the waiting lists, the patient control examinations and research scans can be done in spite of a high work load. A dedicated thank you to Tina Vikmann Nielsen, Gudrun Semitoje, Mette Gylling Myltoft, Lilian Rønbirk, Lone Agervold Ginsborg, Marianne Stahlfest, Mette Fabiansen Larsen, Kristina Damm, Camilla Kuhre Rasmussen, Nanna Folkmann and Pia Therkildsen.

Our Head Medical Secretary Vibeke Rønn is assistant to the management of the department and also a great help in the daily work, when needed. We would like to say a warm thank you to everyone for the high quality and performance.



“Sundhedsplatformen”

Johan Löfgren

After more than two years of preparations of “Sundhedsplatformen” - a new hospital information system was implemented at Herlev/Gentofte Hospital in May 2016 as the first hospital in Denmark. Sundhedsplatformen a modern Electronic Medical Record (EMR) software delivered by Epic will be implemented at all hospitals in Region Hovedstaden and Region Sjælland over the next years. Sundhedsplatformen replaces many prior IT-systems and gather all relevant information and data in one platform which enables easy chart overview, advanced decision support and statistical functionality. The vision is to optimize the quality and enhance the effectivity for the benefit of patients and health care professionals - Sundhedsplatformen will make it easier to be patient and easier to be a health care professional.

Changing an EMR involves a lot of preparations, including large configuration work, workflow harmonization and software training of the health care professionals. Rigshospitalet was the second hospital in line to take on this challenge. At our department we use RIS/PACS (Radiology Information System and Picture Archiving and Communication System) for registration and documentation of data including images. RIS/PACS was not to be replaced by Sundhedsplatformen. Instead integrations between the two systems should fulfil the clinical needs allowing our staff to work mainly in RIS/PACS and clinicians to work in Sundhedsplatformen.

Software training of our staff started in September and “Go-live” of Sundhedsplatformen at Rigshospitalet took place on the 5th of November 2016. Even though a lot of small obstacles emerged, the implementation went rather smooth. One of the greatest challenges has been the integrations to other IT-systems, especially to the clinical laboratory information system (LABKA) but also to our RIS/PACS.

In order to secure the success of the project, Student in Engineer in Medicine & Technology David Kovacs organized the “Diagnostic Center Student Team”, a team with 36 dedicated and intelligent students. After initial training they have since “Go-live” been at the hospital day and night to assist physicians and other staff members to manage and overcome hurdles within Sundhedssplatformen. Their help has been highly appreciated and their initial 4 weeks’ support has been extended to at least the double.

For our department this EMR change has only meant minor change in our daily work, but for the clinicians it has caused a real paradigm shift in their way of working. Just 6 weeks after “Go-live” we can conclude that in some areas it looks promising and health care professionals have adapted the new workflows, but in other areas there is still a long way to go before Sundhedsplatformen can be summarized as a success story.

Clinical physiology and nuclear medicine

The KF Section

Jann Mortensen and Peter Oturai

The KF Section at Blegdamsvej offers a variety of nuclear medicine and clinical physiological examinations. Among these are PET/CT for cardiac (^{82}Rb), neuroendocrine (^{68}Ga-DOTATOC), paediatric (^{18}F-FDG) diseases, lung (ventilation/perfusion SPECT/CT; mucociliary clearance scintigraphy; lung physiology measurements), and oncological (sentinel node scintigraphy; bone SPECT/CT; MUGA) investigations. Other frequent investigations are SPECT/CT and scintigraphy for various endocrine disorders, renography and DMSA-scintigraphy for nephro-urologic diseases, DXA-scan for bone mineral density and whole body composition, and ^{51}Cr-EDTA-clearance for GFR measurement.

To provide these state-of-the-art nuclear medicine investigations to most clinical departments in the hospital, the department makes use of: 1 PET/CT scanner, 3 hybrid SPECT/CT cameras, 1 dual-head gamma camera, 4 single-head cameras, 2 Jaeger body plethysmographs and 1 DXA-scanner. All the equipment is extensively used for both routine patients and for research investigations. Diagnostic ultrasound is used as an adjunct to thyroid scintigraphy in patients having thyroid diseases.

Treatment with ^{223}Radium (^{223}Ra) was initiated in Denmark at Rigshospitalet in May 2014. Until the end of 2016 the department has given 575 ^{223}Ra treatments to 157 patients with castration resistant prostate cancer and symptomatic bone metastases. The treatment is given to outpatients from all over the country as an intravenous injection typically every four weeks for a total of six planned series. Since ^{223}Ra is an alpha-emitter extra safety handling procedures are needed to protect the staff involved in the direct handling and administration. These procedures include whole body counter measurements to ensure no internal contamination to the staff.

Since 2009 treatment with ^{177}Lu-DOTATATE to patients with neuroendocrine tumours (NET) has been performed in the department. Until the end of 2016, 188 patients have been given a total of 681 treatments. We are an active part of the NET-Center at Rigshospitalet working in close collaboration with the Departments of Gastro Surgery, Oncology, Radiology, Pathology and Endocrinology at Rigshospitalet. Our performance of more than 550 ^{68}Ga-DOTATOC-PET/CT scans specific for NET diagnostics is a central function for the care of the patients at the NET-Center. Patients from Odense University Hospital, Aarhus University Hospital and abroad are referred to us for ^{177}Lu-DOTATATE treatment. The NET-Center at Rigshospitalet has been accredited as *Center of Excellence* by the European Neuroendocrine Tumour Society (eNETS).

^{177}Lu-DOTATATE - synthesized and labelled at the Hevesy Laboratory at Risø, DTU, and is administered in our facilities - binds to neuroendocrine tumours expressing somatostatin receptors. Beta-particles from the ^{177}Lu-isotope destroy the tumour 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 2016 we have had weekly and monthly conferences dealing with neuroendocrine tumours, thyroid diseases, paediatric oncology, cardiology, and lung, adrenal and orthodontic diseases.

Clinical physiology and nuclear medicine

The Glostrup Section

Peter Hovind

In the Glostrup Section we have a long tradition of combining classical clinical physiology with modern nuclear medicine methods.

Our section examines patients hospitalized at the Glostrup location of Rigshospitalet, patients from Glostrup outpatient clinic, as well as patients from general practice in the surrounding area.

Parallel to the new possibilities, we continue to perform routine nuclear medicine imaging and with our 3 dedicated gamma SPECT/CT cameras and 2 single head gamma cameras. One of the latter has just been replaced with a new NephroCam for kidney examinations. In addition, we perform many different types of planar and SPECT/CT examinations. This includes DAT-scanning which visualize dopamine transport receptor binding in the brain for diagnosing Parkinson's disease and other neurological diseases involving dopamine transport receptors. Other examples are bone scintigraphy for rheumatologic diseases and evaluation of surgery performed in the spine with various prosthesis, as well as renography for kidney diseases and follow-up on kidney function in patients with spinal cord injury.

Using the tilt test examination under standardized situations with our 2 Task Force tilt test monitors, we examine patients with dizziness, episodes of falling and syncope episodes. We can measure blood pressure on the extremities, where blood pressure in the lower limbs can be evaluated in patients with claudication or ulcers, as well as equipment for measurement of systemic blood pressure over 24 hours for detection and evaluation of hypertension in adults and children. We assist in diagnosing secondary hypertension with Captopril renography, Doppler ultrasound of renal arteries and analysis of urinary steroid metabolism, and receive patients from the Capital Region and Region Zealand.

In patients with stroke, we examine the arteries to the brain for plaques and eventual stenoses of the vessels. Diagnostic ultrasound is also used together with thyroid scintigraphy in patients with disease in the thyroid.

For measuring of lung function, we have a Jaeger body pletysmograph where patients with COPD, asthma and preoperative lung testing are performed. We participated as a part of a large multicenter study collecting a Danish reference material which was completed this year.

We have 3 DXA-scanners, 2 Lunar Prodigy scanners and 1 Lunar iDXA scanner. The two Prodigy scanners are mainly used for the measurement of bone mineral density in patients with or suspected for osteoporosis. The Lunar iDXA scanner is at present exclusively used for research purposes with respect to musculoskeletal research, led by Associate Clinical Research Professor Charlotte Suetta, who is studying the plasticity of skeletal muscle in respond to ageing, inactivation and various disease states by combining whole muscle function with DXA, fMRI, PET/MR, molecular signaling and stem cell analyses. Within the last three years, we have established a Danish reference material consisting of 1,400 healthy controls for body composition, bone mineral density in parallel with muscle strength and physical performance in collaboration with the Copenhagen City Heart study. Within the next year we are planning to move further with these assessments of muscle mass and function in various patient groups. At present the research group consists of 2 PhD students and 4 graduate students.

Paediatric Nuclear Medicine

Lise Borgwardt

In 2016 we performed more than 3,000 paediatric nuclear medicine investigations. 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 its parents. The department is a member of the EANM Paediatric Committee and the Paediatric Imaging Harmonization SNM/EANM.

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. We find the combination of regional PET/MR and WB PET/CT on the same tracer injection especially useful, since we get the hybrid scan information with high soft tissue discrimination from PET/MR and the good hybrid staging scan with the highest diagnostic value of the lung parenchyma from PET/CT and it all in an acceptable timeframe. Also our clinicians are very impressed by this combination of modalities.

In 2016 we continued participating in randomized clinical trials for experimental immunotherapy for children with cancer as a part of the Nordic Center for these treatments.

In our children section we have a children-friendly PET/128SliceCT, a SPECT/CT, an EDTA Clearance and a renography room. PET/MR-scans are performed in the PET Section. In each scanner room in the children section, high quality projectors are showing films 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 films at the tablets giving when entering the section or play in the toy corner. We offer 20 specially produced films and audio essays: “20 stories for the children of Rigshospitalet”, both films for projection on the ceiling and audios essays to listen to while walking around looking at the wall decoration during tracer uptake period, that make our children have less sedation and feel entertained and secure while visiting our department.

Our multidisciplinary paediatric 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.

Our Glostrup Section is specialized in detection and evaluation of hypertension in children with equipment for measurement of systemic blood pressure over 24 hours and assist in the assessment for secondary hypertension in children with Doppler ultrasound of renal arteries, receiving patients from the Capital Region and the Region Zealand.

Research in paediatric nuclear medicine and PET is necessary, as we have an increasing amount of medical doctors, PhD students and technicians involved in the field and we conduct research protocols in children with PET/MRI in order to develop this interesting area, but also methods for evaluating regional liver function in children.

The work in the EANM Paediatric Committee this year has been very interesting and inspiring, and we are looking forward to next year’s work as vice chair in the committee.

Cardiac ^{82}Rb-PET/CT

Philip Hasbak

Rigshospitalet was the first hospital in Scandinavia and one of the first in Europe to diagnose ischemic heart disease using cardiac ^{82}Rb-PET/CT as a new type of advanced imaging system.

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 revascularization strategy. Patients with unstable angina or non-STEMI should be revascularized 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 cardiac ^{82}Rb-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. 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 tools now makes this state-of-the-art technology readily available. Further, we offer CT coronary angiography (CTCA) which is useful for planning many invasive cardiac procedures, particularly complex PCI procedures including chronic total occlusions (CTOs) and bifurcation stenting.

Cardiac and renal ^{123}I-MIBG scintigraphy

In 2010 we introduced cardiac ^{123}I-metaiodobenzylguanidine (^{123}I-MIBG). Radiotracer analogues 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, ^{123}I-MIBG has consistently shown a strong, independent ability to risk stratify patients with advanced congestive heart failure. Recently we have evaluated ^{123}I-MIBG as an estimate of renal sympathetic nervous activity.

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

Education

Jann Mortensen, Peter Oturai & Peter Hovind

All together the facilities at the KF Section and the Glostrup Section comprize seven 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 as well as more basic courses in methodology (MR and kinetics), all held at our department and arranged by our professors and consultants. Furthermore, we contribute to the specialist education of physicians from other specialities 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, nuclear medicine technologist students and radiographer students receive part of their education at the department. 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.

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

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

The departments educational activities have been accredited by the Accreditation of Nuclear Medicine Training Centres Committee of the Section of Nuclear Medicine of the European Union of Medical Specialists (UEMS) and The Danish Health Authorities.

Consultant Peter Oturai and Consultant Peter Hovind are responsible for the postgraduate education of physicians in the department. Associate Professor Jann Mortensen and Professor Henrik Larsson are responsible for the undergraduate education of medical students in the department. Professor Liselotte Højgaard is responsible for under- and postgraduate education for bioengineers.

Nuclear medicine technologists, radiographers and lab technicians

Kate Pedersen, Anne Sørensen, Birgit Krindel Beyer og Lis Larsen

Nuclear medicine technologists, radiographers and lab technicians have also this year participated in post graduate education, meetings and congresses, along with busy everyday life with an increasing number of patient investigations and participation in research projects together with education of many groups. All of it with the highest quality and a positive attitude to the many different tasks. The group of radiographers are now 9 in total, and a union represensative has been elected. All participate in securing a good working environment in the sections, and it is a privilege to lead the group.

In June 2016 the KF Section welcomed the new Staff Nuclear Medicine Technologist Birgit Krindel Beyer. Birgit has more than 20 years of experience in clinical physiology and nuclear medicine. Birgit has just finished the leadership education program at the Capital Region of Copenhagen this fall and as our new leader we are all very enthusiastic for her abilities and her open, professional and positive attitude to all tasks and everyday life.
Nuclear Medicine Technologist Tina Wikke and lab technician Sonja Pedersen Lærke have optimized and process validated a method for production of ^{68}Ga-PSMA for the diagnosis of prostate cancer. This was done simultaneously with a renovation of the radiochemistry laboratories and a tough autumn with absent colleagues due to maternity leave and disease.

October 2016 a PET/CT-scanner was installed in Glostrup. Three nuclear medicine technologists from Glostrup were in training in the PET Section at Blegdamsvej to assure readiness for implementation of the scanner. In the month following nuclear medicine technologists and radiographers from the PET Section at Blegdamsvej have been in Glostrup to assist in the learning period. Maria Pejtersen started the first six weeks and Bente Dall has helped with the PET brain scans. Following this the well trained nuclear medicine technologists and radiographers from Blegdamsvej have been working in Glostrup to secure the same high level everywhere in our department. It is very positive to see how the experienced staff members have collaborated with those learning the new PET technique; it has been a very positive experience for all. It has increased the knowledge about our two different sections, the PET Section and the Glostrup Section, and the collaboration between them has worked very nicely. Thank you to Staff Nuclear Medicine Technologist Lis Larsen, the Glostrup Section and Staff Nuclear Medicine Technologist Kate Pedersen, the PET Section for the fine planning and support.

In the summer 2016 the Glostrup Section finalized the large project on population based studies on muscular strength and DEXA investigations. Almost 1,500 volunteers from the general public were DEXA scanned, had impedance and muscular strength measurements performed.

Nuclear medicine technologists, radiographers and lab technicians

One of the focus areas at the KF Section this year has been to optimize the working conditions and the booking schedule at our PET/CT scanner. It is used for various studies: ^{82}Rb rest/stress myocardial scans with cardiac CT, ^{18}F-FDG myocardial metabolism, ^{68}Ga-DOTATOC scans diagnosing neuroendocrine tumours and ^{18}F-FDG scans primarily on children.

A typical day at the scanner starts at 7 A.M. with quality control of the ^{82}Rh generator and starting up the scanner. After injection the first patient is scanned at 8.15 A.M. The daily program consists of a mix of the mentioned investigations, and 6-9 patients are examined every day. Logistically it is a challenge to ensure a flow that secures that the PET/CT scanner is in use all day, and we have therefore expanded the daily staffing from 2 to 3 nuclear medicine technologists/radiographers. In addition we have introduced monthly meetings with physicians, physicists, secretaries, nuclear medicine technologists and radiographers to ensure that logistics is continuously optimized.

The paediatric task force in our department has participated in a balloon course for nuclear medicine technologists and radiographers with the aim of learning how to make balloon animals for children referred to paediatric nuclear medicine investigations. Now we can make professional balloon animals like in the circus and it has given good results and improved the childrens perception of our complicated scanning investigations.

As Nuclear Medicine Technologist Douglas Dunbar says: "When I have made a balloon animal, they don't see me as the guy in the white uniform, but the guy with the balloon animals and it is an ice breaker moving the kids concern and the investigation can be performed quietly".

Working environment
The PET Section have had a tough year with roof over the open atrium due to building the new North Wing. All the offices and staff rooms have been in the dark. After a great effort with economy and bureaucracy we succeeded in having "daylight" light in all rooms, and it has been an improvement for the very day working life. There are several arrangements to secure a good working life in the sections; in the PET Section a PET party and in the KF Section creativity afternoons with knitting, homemade cookies and nice conversation, including both the department and private life.

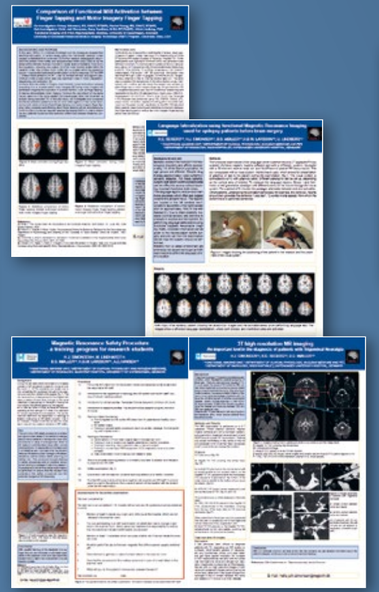
Physical exercise
Of course we participate in the annual DHL.

Nuclear Medicine Technologist Elin Lindell past the clinicial instructor education with the project: "Portfolio – How can it be used as an educational tool?"

Annual meeting DSKFNM (Danish Society of Clinical Physiology and Nuclear Medicine)
Linda Kragh and Mia Hjorth Albers gave a talk about clinical instructors in our department.

Linda M. Kragh, our Chief Nuclear Medicine Technologist and part of the leadership of our department, got the speciality's prize as the first non-academic and with a very honourable speech from the president of the society.

Presentations at EANM in Barcelona
Poster from Mette Møller Jørgensen, Søren Holm & Jann Mortensen.
Poster from Eunice Saxtoft and Kirsten Junker Birch
Poster from Bente Dall, Christina Schulze, Camilla Sloth Knudsen and Anna Ljunggren – they got the third place for their poster.



Presentation at the International MR meeting in Singapore
Posters from Helle Juhl Simonsen.

Presentation at SNM in USA
Poster from Marianne Federspiel, Karin Stahr, Adam Espe Hansen, Liselotte Højgaard and Andreas Kjær.

Cyclotron Section

Holger J. Jensen and Jesper Jørgensen

During the last years we have experienced a stable number of productions at our two cyclotrons of approximately 1,200 productions per year, see figure 1. In 2016 we had in total 1,180 successful productions (532 and 648 for our Scanditronix MC32 and Siemens RDS Eclipse cyclotrons respectively) and only 1 cancelled production. As in the previous years we also managed to keep the average radiation dose to the employees in the Cyclotron- and Radiochemistry Section at a low level, see figure 2.

Examples of ongoing and/or finished upgrade projects for our Scanditronix MC32 cyclotron:

- The new target for production of ^{81}Rb for our Rb/Kr generators, designed and built last year, was taken into successful use this year. The target was replacing the 24 year old original target.
- A new system for loading and unloading the ^{81}Rb target was developed and the control system was programmed in our new Siemens Simatic S7 PLC SCADA system.
- A new helium cooling system for the ^{81}Rb target was designed and build this year. The control system will be integrated in the existing cyclotron SCADA system in early 2017. The cooling system is designed for 8 targets in total and will be used for future new targets planned to be build and mounted at the coming new beamline-2 system. The work on the new beamline 2 is planned to start late 2017.
- The upgrade of the electronics in the RF system (RLC, RPM, RDRC and RDRA) described in previous annual reports was finalized this year by purchasing a complete new spare RLDC unit form the company AXCON Aps.

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

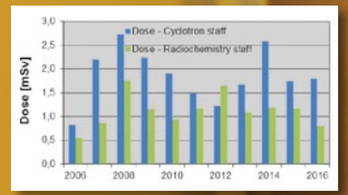


Figure 2. Average received doses per year for employees in the Cyclotron- and Radiochemistry unit since 2006.

Figure 3. The new RLDC unit from Axon Aps.

Cyclotron Section

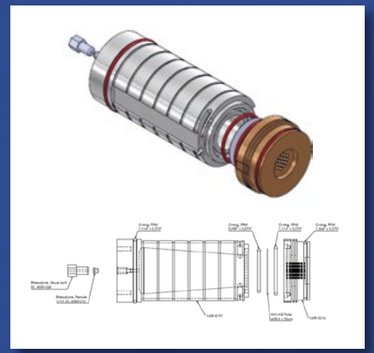


Figure 4. The new home made ^{11}C target.

Figure 5. Visualization of chimney and building for filter units.

The most important development for our Siemens/CTI RDS Eclipse cyclotron this year was the development of a new ^{11}C target. The goal of the new target is to improve both target yields and specific activities. In addition to this it is the hope to be able to produce [^{11}C]-Methane in the target. In the standard ^{11}C target design from CTI/Siemens only the less interesting [^{11}C]-Carbondioxide can be produced. The testing and validation is ongoing.

The project, described in previous annual reports, for building a new chimney for release of radioactive gases produced in our radiopharmacy production, which were initiated in 2011 and planned to be finished in 2016, had to be redesigned this year due to major financial problems. In the new design the chimney has been moved from the original position at the house end of "Centralkomplekset" to a position close to the entrance from Blegdamsvej, see figure 5.

A partly underground bunker for all filter units is planned to be built at the same corner. The project is expected to be finished October 2017.

Radiochemistry Section

Nic Gillings and Jacob Madsen

Highlights

- The first human studies using our in-house developed angiogenesis imaging agent, [^{68}Ga]Ga-NODAGA-cRGDyK$_2$ started in November 2016.
- 2 new PET-tracers, [^{18}F]FE-PE2I and [^{68}Ga]Ga-PSMA-HBEC-CC were validated in 2016. Applications to the Danish Medicines Agency for clinical use were submitted at the end of the year.
- In 2016 one of our GMP radiochemistry production laboratories was refurbished including installation of 5 new hotcells.

Production for clinical and research PET investigations in humans

Production of [^{18}F]FDG and [^{81m}]Krypton generators along with [^{18}F]FET, [^{18}F]FLT, [^{68}Ga]Ga-DOTATOC and [^{11}C]PIB continued a similar level compared to 2015. From February 2016 we moved totally over to the GE FASTlab synthesis platform for [^{18}F]FDG production. This system minimizes the risk of failures and gives higher radiochemical yields compared with the old system. This has enabled us to reduce the number of productions by around 10 % whilst still meeting demand. Following a phase I clinical trial in 2015 to evaluate the uPAR imaging agent [^{68}Ga]Ga-NOTA-AE105, five new phase II clinical trials were commenced in 2016. For angiogenesis imaging, a Phase I clinical trial with [^{68}Ga]Ga-NODAGA-cRGDyK$_2$ commenced in November 2016. 11 different radiopharmaceuticals were produced for human use in 2016 (see Figure).

In order to keep up with regulatory requirements for good manufacturing practice (GMP), one of our production laboratories was completely renovated in 2016, including installation of 5 new hotcells and a new dispensing system. Along with complying with GMP, this will also increase our capacity to introduce new tracers for human use.

Production of neuroreceptor PET tracers for human use, for various research projects conducted by the Neurobiology Research Unit at Rigshospitalet continued at a similar level to previous years.

Radiopharmaceutical development

Neurology
A dopamine transporter ligand, [^{18}F]FE-PE2I, which is used for studying patients with Parkinson's disease was set up and validated in 2016 and an application for human use was submitted in December. For Alzheimer's disease imaging, production of a new PET tracer for imaging tau proteins is being implemented, and an application for human use is expected to be submitted in 2017.

Oncology
The prostate cancer imaging agent, [^{68}Ga]Ga-PSMA-HBED-CC was validated in 2016 and an application for human use was submitted at the end of the year. The production of [^{18}F]ASIS (active site-inhibited factor VIIa) for human use is currently being validated and a clinical trial application will be submitted in 2017. Several other tracers targeting biological processes related to cancer are available for preclinical investigations, for example [^{18}F]ApoPep-1 for imaging of apoptosis and [^{18}F]HX-4 for hypoxia imaging.

Radiochemistry Section

Radiopharmaceutical	Batches Produced	Usage/Target
[^{18}F]FDG	312	Oncology/Glucose metabolism
[^{68}Ga]Ga-DOTATOC	250	Neuroendocrine tumours/Somatostatin receptors
Krypton-81m generator	151	Lung ventilation
[^{11}C]PIB	106	Alzheimer's Disease/β-amyloid plaques
[^{18}F]FET	84	Oncology/amino acid transport
[^{18}F]FLT	11	Oncology/cell proliferation tracer
[^{68}Ga]Ga-NOTA-AE105	52	Oncology/uPAR imaging
[^{15}O]Water	12	Cerebral blood flow
[^{11}C]AZ10419369	35	Brain Research/5-HT$_{1B}$ receptors
[^{11}C]SB207145	47	Brain Research/5-HT$_{4}$ receptors
[^{11}C]Cimbi-36	6	Brain Research/5-HT$_{2A}$ receptors
[^{68}Ga]Ga-NODAGA-cRGDyK$_2$	2	Oncology/angiogenesis imaging

◂ *Radiopharmaceuticals produced for human use in 2016*

Neurobiology
Our collaboration with the Neurobiology Research Unit, Rigshospitalet and the Department of Drug Design and Pharmacology, Faculty of Health and Medical Sciences, University of Copenhagen continued as in previous years. Development and evaluation of new PET tracers for a number of targets was undertaken in 2016. Among these are [^{11}C]Martinostat for imaging histone deacetylase (HDAC) and various analogues for imaging phosphodiesterase type 1 (PDE1). Several other new tracers are currently in the pipe-line.

Radiopharmaceutical research and PhD projects

Troels Elmer Jeppesen continued his PhD project searching for new protein radiolabelling strategies. In particular the project is focused on radiolabelling chemically modified derivatives of ASIS (active site-inhibited factor VIIa) using fluorine-18 and copper-64.

The promising results obtained with our 5-HT$_{2A}$ PET ligand, [^{11}C]Cimbi-36, encouraged us to try to develop a fluorine-18 labelled analogue. In her PhD project, Ida Nymann Petersen has labelled a number of analogues using various labelling strategies and these have been evaluated in animals. Ida will submit her PhD thesis in early 2017.

Elina Nyberg L' Estrade started her PhD project in January 2016. She will develop combinatorial-like fluorine-18 labelling approaches for 5-HT$_7$ selective ligands, which will ultimately result in easy access to a broad variety of derivatives. These will be used to screen and identify efficiently the best tracer candidates for imaging the 5-HT$_7$ receptor. Furthermore, Fraser Edgar started a master's project in May 2016 aimed at developing phenylpiperazine based PET tracers, for 5-HT$_7$ receptors imaging. The 5-HT$_7$ receptor is involved in many brain disorders such as depression and currently no validated PET tracer exists.

Johanna Steen continued her PhD project in 2016 focussed on carbon-11 and fluorine-18 labelled click agents for pre-targeted imaging. This approach can potentially allow imaging of long-circulating nanostructures with short-lived isotopes. Also, Patricia Edem started a postdoc position in April 2016. She will work in the same field, developing PET tracers for pre-targeted imaging of internalised targets. Lara Ali and Placid Orji, who started master's projects in September 2016, will also work on the development of pre-targeted imaging agents.

Abdallah Omar A Abdelmawjoud started a master's project in September 2016 aimed at the development of new fluorine-18 labelled derivatives of ligands targeting uPAR.

Education in radiopharmaceutical chemistry

A new teaching program in radiopharmaceutical chemistry led by Associate Professor Matthias Herth was initiated in spring 2016 at the Faculty of Health and Medical Sciences, University of Copenhagen. 7 students successfully passed the theoretical and practical exams. Several of these have decided to continue as master students within the field of radiopharmaceutical science.

New PET/CT scanner Glostrup

Peter Hovind

For a long period of time, the Glostrup Section was one of the few places in the entire country, where PET/CT were not a part of the armamentarium of examinations offered. As part of a larger department with extended possibilities of collaboration accross geographical localities, a new PET/CT-scanner became a more viable investment than ever. In December 2015 the department management made acquiring the PET/CT for the Glostrup Section its top priority. Late February 2016, the news came that the funds for the scanner were granted after which the bidding process concluded with the purchase of a new Siemens Biograph mCT. After the contract was signed at the end of June, a rather quick process ensued where Physicist Bryan Haddock lead a building project to create our sections PET facility in just two months with lot of assistance from the experienced staff in the PET Section at Blegdamsvej. Just three months after signing the contract with Siemens, the first patient scan was performed and a close and successful collaboration between the section at Blegdamsvej and the section in Glostrup has ensued. Three days a week whole-body scans are preformed and the remaining two days we perform dedicated brain scans with regular rotations of doctors and technicians between the two sections in a fruitful collaboration ensuring high quality of PET/CT examinations at our section.

PET/CT

Annika Loft Jakobsen and Anne Kiil Berthelsen

In oncology and in infectious and inflammatory diseases the use of FDG PET/CT is increasing tremendously around the world – and we have been part of this from the very beginning! We now perform more than 10,000 PET/CT scans per year. The trend in oncology treatment is personalized medicine and PET/CT plays a natural role in this new paradigm.

With clinical research imbedded in our everyday work, we have had the opportunity to take part in many clinical trials with results that now are implemented in our clinical routine, e.g. deep inspiration breathhold PET/CT for radiotherapy planning of malignant lymphoma and the use of PET/CT for gynaecological cancers.

One of our new focus areas is the implementation of PET/CT in multidisciplinary team conferences or tumour boards participating in almost 20 every week. Another important issue is testing new tracers and investigating the clinical indications for these.

In 2016 we have been fortunate to be able to expand our scanner park - now we have 6 whole-body PET/CT scanners with the newest scanner placed in new surroundings at our Glostrup Section with important logistic challenges to solve in an inspiring collaboration with new colleagues.

PET scanning of the brain

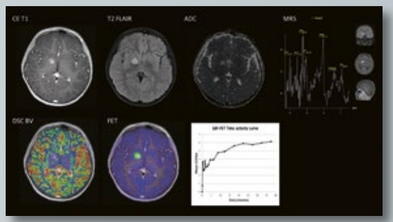


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Figure 1. Example of multi-modality PET/MRI characterization performed in a 7 year old boy with an incidentally found lesion in the right basal ganglia area. Within a single 40 minute session dynamic [F18] Flouro-Ethyl-Tyrosine (FET) PET, standard structural MRI and various advanced MRI sequences were obtained. Post-contrast T1 (CE T1) and T2 FLAIR showed a solitary contrast-enhancing lesion without edema. Diffusion weighted imaging did not show reduced ADC and thus not indicative of increased cellularity and MR spectroscopy (MRS) demonstrated only moderately increased choline, which is considered a marker of malignancy. Perfusion MRI (DSC BV) did not show increased blood volume. Dynamic FET PET found moderately increased uptake with an increasing time-activity curve. Based on the combined imaging a differentiation of a neoplasm from inflammatory (or other non-neoplastic) pathology could not be made, but it was concluded that a high grade glioma or other aggressive malignancy was unlikely. Follow-up MRI after 3 months showed regression of contrast enhancement pointing towards a demyelinating lesion. [Figure reproduced from Marner et al., Clinical and Translational Imaging, *in press]*

Otto Mølby Henriksen and Ian Law

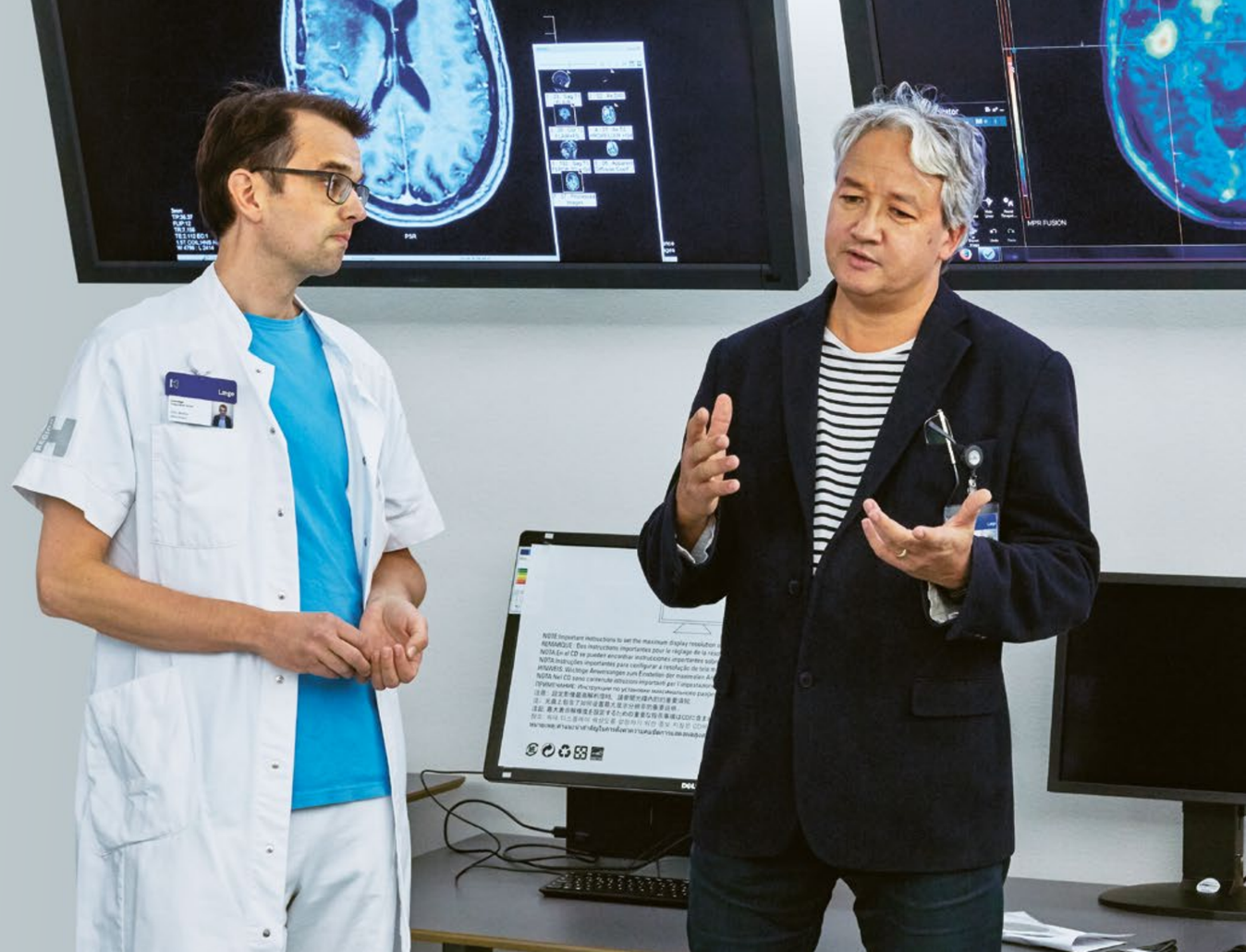
The overall goal of the neuro-PET group is to continuously improve use of PET and hybrid imaging in routine clinical brain imaging and to further explore hybrid imaging of brain physiology in both the diseased and healthy brain.

The Siemens hybrid PET/MR scanner has been implemented into clinical routine investigations for dementia. The diagnostic package consisting of 4-5 standard MR sequences focused at localizing structural and vascular pathology are combined with primarily FDG in a short and very comprehensive one-stop imaging shop for dementia. An automated hippocampus volumetric report now adds to the assessment of patients with early stages of neurodegenerative disease. 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 15 min. session a patient may receive a thorough and comprehensive structural and function neuroimaging examination of outstanding image quality.

Our non-FDG radiotracers have had a relative increase in the overall production. They consist of the amino acid analogue [F18] Flouro-Ethyl-Tyrosine (FET), the somatostatin II receptor ligand [Ga68]-DOTATOC, and [C11]-PiB. FET has an established role in the management of brain tumour, and is increasingly been evaluated using PET/MR. We are in the process of developing FET PET/MR as a multiparametric tool in paediatric neurooncology. An example is shown in Figure 1. By a close collaboration with anesthesiologists, simultaneous PET and MR assessment of disease is available also to smaller children, and thereby reduces the stress of repeated anesthesia otherwise required 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. [C11]-PiB amyloid binds to amyloid plaques, a pathological hallmark for Alzheimer's disease and is used to support the diagnosis.

Collaborating with international and clinical research partners and the Functional Imaging Unit at Glostrup, a number of clinical and basic science projects explore the use of the most recent development in radiopharmaceuticals and MR imaging.



PET/MR

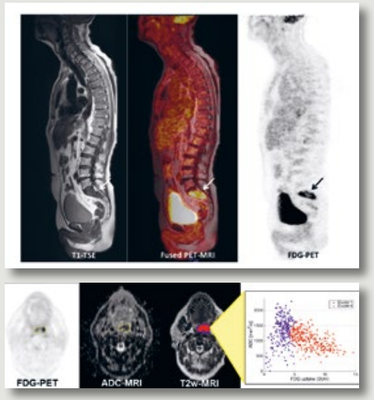


Figure 2: PET/MRI examination of a 72 year old male with a metastatic gastrooesophageal junction cancer. The patient is scanned on a prototype flat table top in a project evaluating the use of PET/MRI in target definition in radiotherapy treatment of spinal metastases. Sagittal PET/MR images (from left, anatomic MRI (T1 TSE), fused PET/MRI and PET) show a metastatic transformed S1- and S2-segment (arrow) which affects both S1- and S2-nerve roots

Figure 3.PET/MRI examination of a patient with head/neck squamous cell carcinoma. The voxel wise relation of the Apparent Diffusion Coefficient (ADC) and FDG uptake (right) was studied in an anatomically defined region of interest (yellow contour). A cluster analysis of the tumour heterogeneity carried out in combined parameter space. Reference: J Rasmussen et al, Journal of Nuclear Medicine (online December 2016)

Johan Löfgren and Adam Espe Hansen

The integrated PET/MRI system offers a unique combination of functional and molecular imaging with state-of-the-art anatomic imaging. These capabilities are being exploited in clinical, translational and basic research, as well as for clinical examinations. Since installation, the number of clinical examinations performed has been growing steadily.

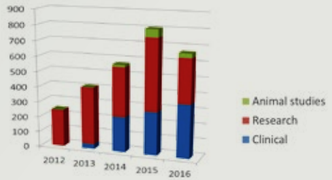


Figure 1: The number of PET/MR examinations per year since installation is shown

The experience and expertise gained through PET/MRI research studies has helped to identify relevant clinical applications. The main areas of clinical PET/MRI at the department are neurology, neuro-oncology and paediatric oncology. Here the PET/MRI provides a time-efficient and logistically advantageous examination for patients with all relevant imaging being obtained in a single scanning session. For children an additional advantage is reduction of radiation exposure compared to traditional PET/CT where CT normally accounts for 2/3 of the total radiation dose. The most frequent clinical indication is dementia (see section on PET scanning of the brain). Examples of other indications currently under investigation at the department, where PET/MRI appears promising include RT planning of head/neck cancer and spine metastases (Figure 2), response evaluation of lung and cardia cancer and chronic multifocal osteomyelitis in children.

To take full advantage of the PET/MRI multimodality imaging combination a few technical challenges have had to be addressed. At the department we have early pointed to the issue of attenuation correction, in particular of the brain. A multi-center study led by the department, which included the evaluation of in-house developed methods, has recently concluded that this issue can be considered solved. Imaging for RT planning requires attenuation correction of the RT flat table top, which has been implemented for the project shown in Figure 2. Another methodological accomplishment has been the demonstration of simultaneous PET and hyperpolarized Carbon-13 based MR spectroscopic imaging, which has been investigated in phantoms and in animals.

Current research directions include the analysis of multi-modality functional imaging data as shown in Figure 3, here with combined FDG-PET and diffusion weighted MRI. Other current research topics include atherosclerosis, neurobiology and the combination of PET and hyperpolarized MRI. We have at the end of 2016, 25 active research protocols.

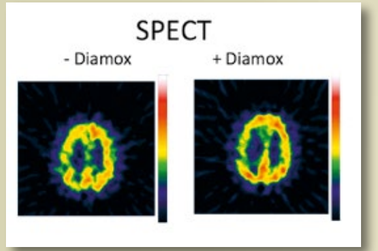
MR imaging of the brain

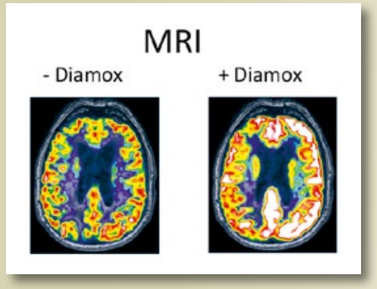
Henrik Larsson

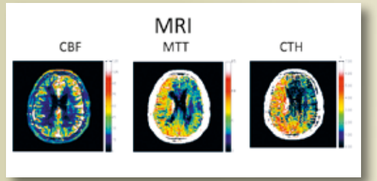
Functional Imaging Unit (FIU) is involved in basic neuro-physiological research and development of new diagnostic methods. As an example, we have during the last couple of years, together with Department of Neurology developed a test battery allowing us to obtain detailed information about the vascular system in patients with small and large brain vessel diseases, of relevance in diseases as stroke, Mb Binswanger (subcortical leucoencephalopathy or small vessel vascular dementia) and Alzheimer's disease where vascular insufficiency likely augment disease progression. The so-called cerebral vascular reserve capacity (CVR), i.e. the ability of the brain vessels to dilate and increase perfusion, is important to secure a sustained oxygen delivery to the brain. Traditionally, the CVR is measured by performing a SPECT scan before and after injection of acetazolamide (Diamox – acting as a vasodilator) using the radioactive tracer ^{99m}Tc-HMPAO.

The new test employs Magnetic Resonance Imaging (MRI), where perfusion is measured in one session before and after injection of Diamox, using Arterial Spin Labelling (ASL), a fast and non-invasive method. Figure 1 and figure 2 shows SPECT and MRI ASL scans before and after Diamox administration, respectively. We generally find a high degree of concordance between the two kinds of measurement. The versatile MRI allows measurements of other important metrics, as absolute total brain flow through the basilar and internal carotid arteries and the brains total oxygen consumption. Incorporating a Dynamic Contrast Enhanced (DCE) MRI gives information about capillary mean transit time and transit time heterogeneity and blood brain barrier permeability. Figure 3 shows DCE MRI measurements of the same patient as in the previous figures.

These physiological images can be compared to structural MRI images, such as white matter lesions, infarctions, and local brain atrophy, and provides detailed information about the well-being of the brain.







◂
Figure 1. SPECT perfusion scan using the radioactive tracer ^{99m}Tc-HPMAO before and after injection of Diamox of a 75 year old patient with severe right internal carotid artery stenosis. The right sided diminished perfusion is easily seen with no increase after Diamox.

◂
Figure 2. MRI perfusion scan using Arterial Spin Labelling before and after Diamox of the same patient and same slice as presented in Figure 1. As in Figure 1, the asymmetric perfusion pattern can be seen.

◂
Figure 3. The figures show results of the Dynamic Contrast Enhanced MRI of the same subject as in the above figures after injection of Diamox. Perfusion (CBF) is asymmetrically decreased in the right hemisphere; the Mean Transit Time (MTT) is prolonged and the Capillary Transit Time Heterogeinity (CTH) is increased in the right hemisphere including deep grey matter. Interpretation of CTH is currently an active area of research, especially in relation to oxygen transport.

PET and PET hybrid systems

Thomas Levin Klausen and Søren Holm

In 2016 we installed one new PET/CT scanner in the Glostrup Section, and the department now has 1 dedicated, stand-alone brain PET system, 6 combined whole-body PET/CT systems and 1 integrated PET/MR system.

In the PET Section brain research continues on the PET-only HRRT (High Resolution Research Tomograph) in close collaboration with the Neurobiology Research Unit (NRU), but the system also works as a unique clinical instrument.
The 6 PET/CT's in the department are all Siemens systems. 2 are Biograph TrueV, 1 with 40 and 1 with 64 slice CT, acquired in 2007 and 2009. The other 4 (from 2010, 2011, 2014 and 2016) are mCT's, 3 with 64 slice CT and 1 with 128 slices, all of them with time-of-flight and overall with very 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 therecent 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 mCT's 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 128 slice PET/CT is installed in the KF Section. This scanner mainly performs paediatric PET scans and scans with ^{82}Rb (heart perfusion), ^{68}Ga-Dotatoc (neuroendocrine tumours) 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 were either limited in use (brain “insert” only) or not fully integrated (two separate gantries). In the mMR a new amplifier principle in the PET detectors made them insensitive to the magnetic field and small enough to allow the PET scanner’s detector ring to be placed inside the 3-tesla MR-magnet between the gradient coils and the RF transmitter. This made it possible to perform truly simultaneous measurements of PET or MR. The combined scanner offers better soft tissue differentiation than PET/CT, but also has the potential of reducing radiation exposure, which is particularly important in childrens examination. The physics group has been 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 was a challenge, and we have been addressing these issues in collaborations with Siemens (Erlangen and Knoxville), University of Leuven and the institute of Computer Science at Copenhagen University, resulting in a correction method which is clinical feasible and with high precision.

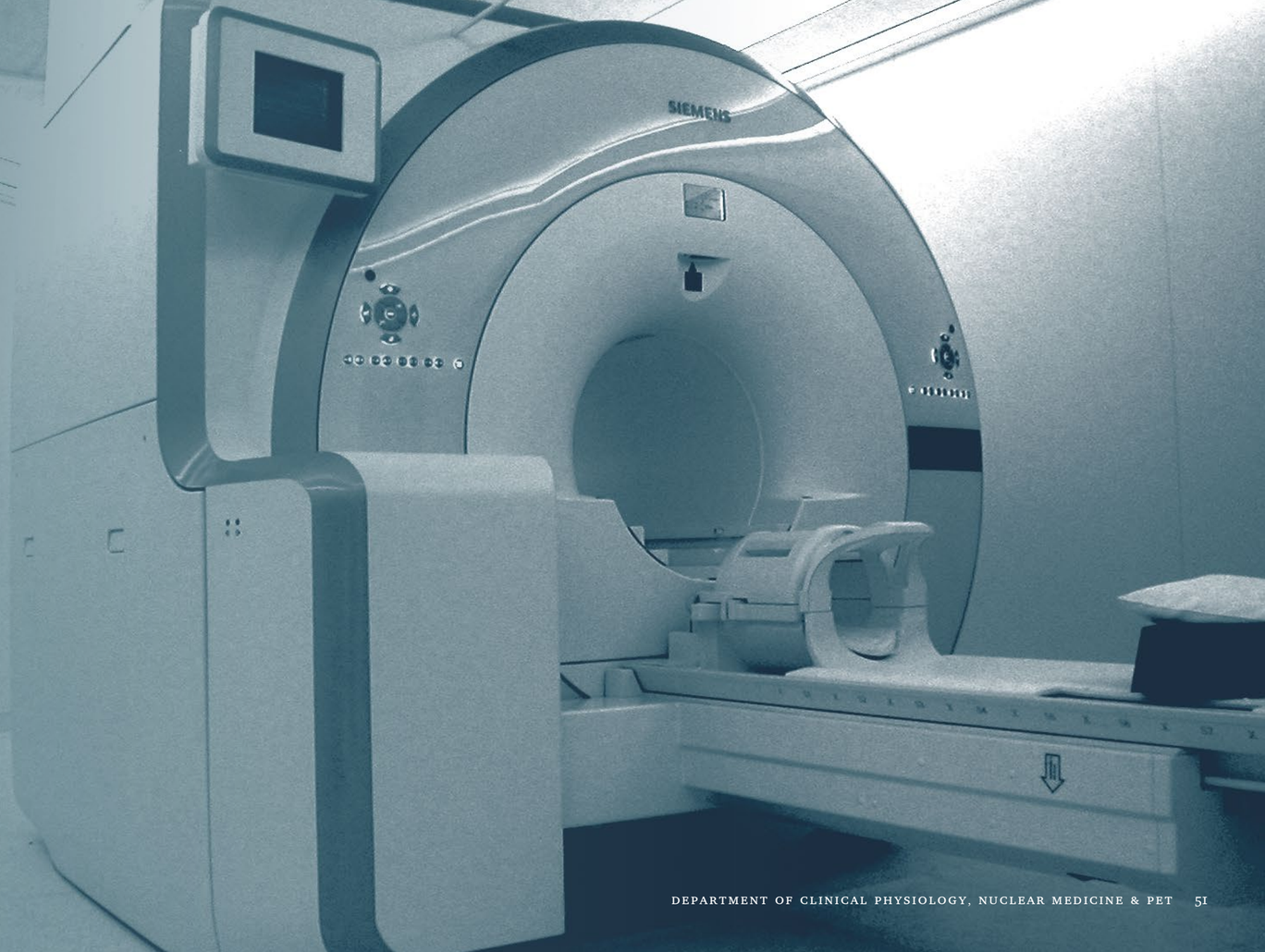
Recently the PET/MR installation was complemented with an MR hyperpolarizer (GE SPINlab), allowing the production of ^{13}C-labelled pyruvate, although not yet for human use.

At the Cluster for Molecular Imaging at Panum, the Faculty of Health Sciences, University of Copenhagen, we also operate 3 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.

Equipment 2016

Equipment	Product	Purchase year
Gamma cameras	Mediso Nucline X-Ring	2003
	Mie-Scintron	2004
	Mediso TH45	2007
	Mediso N-TH45-D	2008
	DDD SoloMobile	2012
	DDD NephroCam System	2016
SPECT cameras	Philips ADAC Skylight	2002
	Mediso Nucline X-Ring-R/HR	2009
SPECT/CT cameras	GE Infinia Hawkeye	2004
	Siemens SymbiaT2	2006
	Philips, Precedence 16-slice CT	2006
	Philips, Precedence 16-slice CT	2008
	GE Discovery 670	2010
	Siemens Symbia 16-slice CT	2011
PET scanner	HRRT Siemens/CTI	2007
PET/CT scanner	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
	Siemens mCT-S (64)	2016

Equipment	Product	Purchase year
PET/MR scanner	Siemens mMR	2011
	GE SPINlab MR Hyperpolarizer	2014
Lung function	Jaeger Masterscreen w/bodybox	2005
	Jæger Masterscreen w/bodybox	2007
	Jaeger PFT pro w/bodybox	2007/13
DXA scanner	GE Lunar Prodigy	2004
	GE Lunar Prodigy	2005
	GE Lunar Prodigy	2011
	GE Lunar iDXA	2014
Whole body counter	WBC w/NaI counting chamber	1977
	WBC w/plast counting chamber	1978
Cyclotrons	Scanditronix 32 MeV	1991
	RDS Eclipse cyclotron, CTI	2005
At Cluster for Molecular Imaging, Panum	Provivo/ ADAC mobile gamma camera	1990
	Siemens Micro-PET Focus 120	2006
	Siemens preclinical CT 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
	Mediso nanoScan SPECT/CT	2015



Academic and other activities

Andreas Kjær, Professor, Consultant, ERC advanced grantee, is 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 and President of the Scandinavian Society of Clinical Physiology and Nuclear Medicine (SSCPNM). Member of the National Cancer Institute (NCI) white paper writing group on use of hyperpolarized ^{13}C MR, advisory board member of the Avatar Cancer Program, CPMC (Sutter Health), San Francisco. Editor-in-Chief of Diagnostics (Basel). Editorial board member of Journal of Nuclear Medicine (JNM) and European Journal of Nuclear Medicine & Molecular Imaging (EJNMMI). Leader of projects for development of theranostics for aggressive cancer and for project of hyperPET, funded by the Innovation Fund Denmark. Coordinator of an H2020 project on click-chemistry for PET. National Director of EATRIS (the European Advanced Translational Research Infrastructure in Medicine), Head of the Cluster for Molecular Imaging and Director of the PhD Program for Medical & Molecular Imaging at the Faculty of Health and Medical Sciences, University of Copenhagen. Co-chair of the Lundbeck Foundation Clinical Research Fellowship Program (US-DK). Member of the Academy of Technical Sciences (ATV).

Anne Kiil Berthelsen, Consultant, is member of the International Lymphoma Radiation Oncology Group, Steering Committee (ILROG), "European Organisation for Research and Treatment of Cancer Lymphoma Group " (EORTC), the Danish Society of Radiology, the Danish and the Nordic Society of Gynaecological Oncology, British institute of Radiology (BIR), Billeddiagnostisk udvalg Ukendt Primærtumor (DAHANCA), National PET/CT Group, the Danish Society of Clinical Oncology, the Danish Society of Magnetic Imaging and Diagnostic Imaging Group under Danish Lymphoma Group, ERS European Society of Radiology.

Anne-Mette N. Wittekind, MSc. Pharm., Deputy Qualified Person, is member of Dansk Standard.

Annika Loft Jakobsen, Consultant, is involved in a various number of clinical research protocols, teaching at national and international courses pre- and postgraduate for medical doctors, technologists, radiographers and nurses and is invited speaker at national and international meetings and congresses. She is supervisor for several PhD students and responsible for the specialist course in oncology for nuclear medicine physicians. She is a member of the "European Organisation for Research and Treatment of Cancer" (EORTC). Member of the Oncology Committee of EANM, and member of BIR, Danish Society of Oncologial 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. Board member of DGCG (Danish Gynecological Cancer Group) and DCCG (Danish Colorectal Cancer Group).

Egill Rostrup, MSc, MD, DMSc, Consultant, Member of the editorial board of the Journal of Cerebral Blood Flow and Metabolism, Steering committee of the Healthy Aging Clinical Neuroproject at Glostrup, and the The Lundbeck Foundation, Center for Clinical Intervention and Neuropsychiatric Schizophrenia Research.

Elisabeth Albrecht-Beste, Clinical Associate Professor, Consultant, is board member of Danish Society of Radiology, chair of post-graduate radiology courses in Denmark, chair of postgraduate education committee of Danish Society of Radiology, chair of the Regional Advisory Board in postgraduate education in radiology and member of the Danish Society of Oncoradiology.

Helle Hjorth Johannesen, Consultant, is member of Danish Society of Radiology, President of Danish Society of Oncoradiology, member of Danish Society of Medical Magnetic Resonans Imaging and Danish Society for Good Clinical Practice.

Helle Juhl Simonsen, Research MRT, Biomedical Laboratory Scientist, is board member and treasurer in the International Society for Magnetic Resonance in Medicine (ISMRM)/Nordic Chapter. Member of the Local Chapters Committee, Awards and Nominations Committee and Abstract Committee in International Society for Magnetic Resonance in Medicine (ISMRM)/Section for MR Technologist (SMRT), Member of the Members and Services Committee in European Society for Magnetic Resonance in Medicine and Biology (ESMEMB).

Henrik B.W. Larsson, MD, DMSc , Consultant, Head of Functional Imaging Unit. Professor in Clinical and Comparative Physiology, Institute of Clinical Medicine, The Faculty of Health and Medical Science, University of Copenhagen, Denmark, Representing Professor (ordførende professor) in Clinical Physiology and Nuclear Medicine, Institute of Clinical Medicine, The Faculty of Health and Medical Science, University of Copenhagen, Denmark, Professor in Medical Magnetic Resonance Imaging, Norwegian University of Science and Technology, Norway, Responsible for specialist course in tracer kinetic theory, math and statistic for nuclear medicine physicians. Responsible for specialist course in functional imaging (MRI, PET-MRI, UL) for nuclear medicine physicians, Management board of EU COST Action (BM1103): "Arterial Spin Labelling in Dementia", Steering committee of the 7 Tesla project, Copenhagen, Denmark.

Ian Law, Professor, Consultant, is Chair of the Neuroimaging Comittee, European Association of Nuclear Medicine (EANM), Member of the "PET Response Assessment in Neurooncology (RANO) working group" under the European Association of Nuclear Medicine (EANM), European Association of Neurooncology (EANO), and Society of Neurooncology (SNO). Member of the Danish Neurooncology group (DNOG). Member of the working group for "Clinical Guidelines for the Treatment of Brain Metastases", Danish Neurosurgical Society (DNKS), responsible for the specialist training course in the central nervous system for nuclear medicine physicians.

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

Jann Mortensen, Clinical Associate Professor, Consultant, is member of "Den Regionale Videnskabsetiske Komité F for Hovedstaden" (Regional Ethics Committee). He is responsible for the specialist course in "Clinical Respiratory Physiology" for Nuclear Medicine physicians and Respiratory Physicians, he is the responsible physician for Nuclear Medicine in the Faroe Islands, 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 steering committee and the quality subcommittee for creating Danish reference values for lung function, and member of the steering committee of the Danish ESDL spirometry course.

Johan Löfgren, Consultant, teaches at specialist courses for oncologists and is a member of the Diagnostic Imaging Group under Danish Lymphoma Group. He is involved in clinical research protocols with special focus on PET/MRI and is an invited speaker at national and international meetings and congresses.

Kim Francis Andersen, Consultant, is member of the Board of Danish Sarcoma Group (DSG). He is involved in various clinical research protocols. He teaches at specialist courses for medical doctors and is supervisor for students at the Medicine and Technology program (Biomedical Engineering), Technical University of Denmark (DTU). He is an external reviewer at the Czech Science Foundation in the field of sarcomas.

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 Clinicial Physiology and Nuclear Medicine in the Capital Region), member 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 Uddannelsesudvalget på Radiografuddannelsen at Metropol (the Speciality Council for the Education of Radiographers at Metropol).

Lise Borgwardt, Consultant, is Scientific Committee member of the EANM, Vice Chair of the Paediatric Committee under EANM, member of the Paediatric Imaging Harmonization Group, member of the Tumourboard for Paediatric Solid Tumours at Rigshospitalet, Chair of the Paediatric 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. She is involved in clinical research protocols, supervisor for PhD students, teaching at national and international

Academic and other activities

courses pre- and postgraduate for medical doctors, and is invited speaker at national and international meetings and congresses.

Lisbeth Marner, MD, PhD, DMSc, Staff specialist, is a member of European Society for Paedicatric Oncology (SIOPE) Imaging group; responsible for specialist course in tracer kinetic theory, math and statistic for nuclear medicine physicians; responsible for a large imaging study in children with CNS cancer, teaches at several PhD courses as well as pregraduate courses for Medicine and Technology Bioengineers, is a member of the Danish CNS Interest Group and is accountant for the Young Nuclear Medicine Club (YNK).

Liselotte Højgaard, Professor, Head of Department. Chairman of the Board of the Danish National Research Foundation. She is Member of Conseil d'Administration, INSERM, Institut National de la Santé et de la Recherche Médicale, Frankrig. Chair of EU Science Advisory Board in Health Research. Member of the Board, Konsistoriet, the Karolinska Institute. 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 ATV "The Danish Academy of Technical Sciences", member of the Olav Thon Foundation, Science Advisory Board, member of the Board of the Crown Prince Frederik and Crown Princess Mary's Foundation and member of the Board of Arvid Nilssons Foundation and Tagea Brandt's prize.

Louise Alslev, Staff Specialist, is responsible for the planning of educational visits for physicians at the PET Section at Rigshospitalet. She teaches at a PhD course at the Faculty of Health and Medical Sciences, University of Copenhagen and at the Bachelor´s Degree Program in Radiography at the Metropolitan University College. Employee representative for the junior doctors at the Centre of Diagnostic Investigation, Rigshospitalet. Member of Yngre Læger-rådet (Counsel of Junior Doctors) at Rigshospitalet.

Malene Fischer, Associate Professor of Research, Consultant, is supervisor for several PhD students and involved in both pre- and postgraduate teaching. Course Director of "Introduction to Clinical Medical Imaging" at the Medicine and Technology Bioengineer program, member of the European Association of Nuclear Medicine (EANM) and the Danish Society of Clinical Physiology and Nuclear Medicine (DSKFNM). Affiliated to the Centre of Excellence for Personalized Medicine of Infectious Complications in Immune Deficiency (PERSIMUNE) and the steering committee of MATCH (Managing of Post-Transplant Infections in Collaborating Hospitals). Elected member of the board of representatives, the Association of Consultants in Denmark.

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

Marianne Federspiel, Nuclear Medicine Technologist, Senior Consultant to the EANM Technologists Committee.

Marie Øbro Fosbøl, PhD Student, President of Society of Young Nuclear Medicine Physicians (YNK, member of the board of Danish Society of Clinical Physiology and Nuclear Medicine (DSKFNM) and member of the course committee in clinical physiology and nuclear medicine.

Nic Gillings, MPhil, PhD, Chief Radiochemist, Qualified Person (QP) is a member of the EANM Radiopharmacy Committee, member of the Society of Radiopharmaceutical Sciences and member of the Royal Society of Chemistry. He also acts as coordinator for the joint supplier audit program for all manufacturers of PET radiopharmaceuticals in Denmark and Southern Sweden.

Otto Mølby Henriksen, Consultant, PhD, is member of the DRG Committee in Danish Society for Clinical Physiology and Nuclear Medicine (DSKFNM). Supervisor of one research year student and co-supervisor of one PhD student.

Peter Hovind, Consultant, participates in several clinical research protocols. He is the President of the Danish Society of Clinical Physiology and Nuclear Medicine. At present, he is also the Head of the specialist courses in Clinical Physiology and Nuclear Medicine under the Danish Health and Medicines Authority, where he is responsible for the theoretical part of the specialist training in Clinical Physiology and Nuclear Medicine in Denmark. He is the Head of the Doctors Clinical Physiology and Nuclear Medicine Training Committee of the Danish Society for Clinical Physiology and Nuclear Medicine and a member of the board of the Danish Endocrine Society (DES) and the Niels A. Lassen Foundation. He is co-editor for the Danish Medical Journal in the medical imaging section. He is responsible for the postgraduate education in the Glostrup Section of the department.

Peter Oturai, Consultant, is responsible for the postgraduate education of physicians in the department. He is Danish delegate, representing Danish Society for Clinical Physiology and Nuclear Medicine (DSKFNM), in the European Union of Medical Specialists (UEMS) and deputy delegate in the European Association of Nuclear Medicine (EANM). He has been representing DSKFNM in the Danish Health and Medicines Authority's committee for speciality planning of Clinical Physiology and Nuclear Medicine (CPNM). He is member of the Danish Thyroid Cancer Guideline Group (DATHYRCA), member of the Doctors CPNM Training Committee and member of the CME and Educational Committee – both affiliated to DSKFNM. He is responsible for the specialist course in Endocrine Pathophysiology for CPNM physicians in Denmark.

Rasmus Sejersten Ripa, Staff Specialist, is supervisor for several PhD students. Member of the Danish Health Authority's Committee for Heart Disease. He is co-editor of BMC Cardiovascular Disorders and member of American Society of Nuclear Cardiology.

Robin de Nijs, MSc, PDEng, PhD, Specialist Medical Physicist, is member of EANM's Network of Excellence for Brain Imaging, member of the Danish Society for Medical Physics and lecturer at EFOMP's School for Medical Physics Experts and Copenhagen University.

Søren Holm, Senior Physicist, is a member of the EANM Physics Committee and the newly founded EANM Radiation Protection committee, and has represented EANM in meetings with IAEA and HERCA (Heads of European Radiation Competent Authorities). He is a delegate for DSMF to the European and International organisations for Medical Physics (EFOMP and IOMP), board member of the Nordic Society for Radiation Protection (NSFS), member of one IAEA advisory group concerned with QA/QC and image artefacts affecting SPECT/CT and another IAEA advisory group regarding staffing in medical physics, 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 University of Copenhagen.

Thomas Levin Klausen, Chief Physicist, MSc, Specialist Medical Physicist, Chair of Danish Society for Medical Physics Educational Council, member of the Danish Society for Medical Physics (DSMF) and the Danish Society of Clinical Physiology and Nuclear Medicine (DSKFNM). Responsible Physicist for Nuclear Medicine in the Faroe Islands.

Ulrik B. Andersen, Consultant, Co-supervisor for PhD students in the department. Member of European Society of Hypertension and acknowledged hypertension specialist by this society. Responsible for the specialist course in cardiovascular circulation for nuclear medicine physicians in Denmark. Member of the Danish Society of Clinical Physiology and Nuclear medicine, Danish Society of Cardiology and Danish Society of Diagnostic Ultrasound.

Studies 2016

CNS and peripheral nervous system	
Regional cerebral blood flow, DIAMOX, ^{15}O-H_2O	12
Regional cerebral metabolism, ^{18}F-FDG	1,029
Regional cerebral receptor, ^{11}C-PIB	168
Regional cerebral receptor, ^{18}F-FET	465
Regional cerebral blood flow, ^{99m}Tc- HMPAO, pharm.prov.	13
Regional cerebral blood flow, ^{99m}Tc- HMPAO	51
Regional Dopamine Transporter (DAT) receptor imaging, ^{123}I-FP-CIT	271
Regional cerebral receptor, ^{11}C different tracers human (NRU)	78
Regional cerebral receptor, ^{11}C differenct tracers animal (NRU)	49
Regional cerebral receptor, ^{18}F-Florbetapir	19
Regional cerebral receptor, ^{18}F-FLT	11
Regional cerebral receptor, ^{68}Ga-Dotatoc	28
CT-scanning of cerebrum	212
MR-scanning of cerebrum	2,764
Total	**5,170**

Respiratory organs	
Lung function test, whole body plethysmography	2,074
Lung function test, whole body plethysmography w/reversibility	55
Lung function test, spirometry,	2,230
Lung function test, spirometry w/reversibility	214
Lung function test, diffusion capacity (CO)	4,079
Lung function test, spirometry with phys.prov.	5
Max. insp. abd exspir. muscle pressure	54
Lung perfusion scintigraphy, ^{99m}Tc-MAA	1
Lung perfusion scintigraphy, regional, ^{99m}Tc-MAA	9
Lung perfusion scintigraphy, SPECT, ^{99m}Tc-MAA	386
Lung ventilation scintigraphy, ^{81m}Kr-gas	19
Lung ventilation scintigraphy, regional, ^{81m}Kr-gas	113
Lung ventilation scintigraphy, SPECT, ^{81m}Kr-gas	341
Lung ventilation scintigraphy, SPECT ^{99m}Tc-Technegas	57
Mucociliary clearance, ^{99m}Tc-Venticolloid	8
CT thorax PET/CT breathhold	23
Total	**9,668**

Heart and cardiovascular system	
Isotope cardiography, LVEF, ^{99m}Tc-HSA	1,460
Myocardial perf. scintigr. gated, ^{99m}Tc-MIBI, pharmacol. stress, adeno.	195
Myocardial perf. scintigr. gated, ^{99m}Tc-MIBI, psysiological. stress	2
Myocardial perf. scintigr. gated, ^{99m}Tc-MIBI,	165
Myocardial ^{123}I- MIBG, sympaticus activity	70
Myocardial calcium score	611
Tilt table test	273
Analysis of heart rate variability	295
PET myocardial metabolism, ^{18}F-FDG	96
PET myocardial perfusion, ^{82}Rb	651
PET myocardial perfusion, ^{82}Rb, pharmacological stress, adeno	628
CT cardiac angiography	70
Total	**4,516**

Peripheral vessels	
Systolic blood pressure, fingers	2
Systolic blood pressure, ancle and toes	407
Systolic blood pressure, ancle-brachial index after treadmill	87
24 hours blood pressure measurement	262
Doppler ultrasound of carotid arteries	4,113
Doppler ultrasound of abdominal vessels	470
Isolated limb perfusion leakage monitoring, 99mTc-erythrocyt	6
Total	**5,347**

Gastrin intestinal tract, liver, biliary tract and pancreas	
Salivary gland scintigraphy ^{99m}Tc-Pertechnetat	22
Biliary tract scintigraphy, ^{99m}Tc-Mebrofenin	90
Bleeding scintigraphy (abdomen) ^{99m}Tc-erytrocytter	**4**
Bleeding scintigraphy (abdomen) ^{99m}Tc-HSA	**1**
Doppler ultrasound of splanchnic blood flow	**430**
Glucose tolerance test	**10**
Total	**557**

Kidneys and urinary tract	
Glomerular filtration, ^{51}Cr-EDTA, several samples	89
Glomerular filtration, ^{51}Cr-EDTA, one sample	3,593
Renal scintigraphy, ^{99m}Tc-DMSA	25
Renography, ^{99m}Tc-MAG , diuresis	41
Renography, ^{99m}Tc-MAG 3, graft	2
Renography, ^{99m}Tc-MAG 3, ACE-inhibitor	22
Renography, ^{99m}Tc-MAG 3	2,256
Renography, ^{99m}Tc-MAG 3, dual head	8
Renography, ^{99m}Tc-DTPA	**34**
Renography, ^{99m}Tc-DTPA, ACE-inhibitor	**221**
Doppler ultrasound of renal blood flow	**430**
Ultrasound kidneys	**411**
CT kidneys	**87**
CT bladder	**87**
Total	**1,270**

Bone and joint	
Bone scintigraphy, ^{99m}Tc-HDP, regional, static	70
Bone scintigraphy, ^{99m}Tc-HDP, 2 phased	8
Bone scintigraphy, ^{99m}Tc-HDP, whole body, static	755
Bone scintigraphy, ^{99m}Tc-HDP, SPECT	724
Bone scintigraphy, ^{18}F-fluorid, whole body, static	3
Osteodens. dual X-ray absorptiometri (DXA), columna lumb.	4,725
Osteodens. dual X-ray absorptiometri (DXA), lat.spine	445
Osteodens. dual X-ray absorptiometri (DXA), radius	144
Osteodensitometri, dual X-ray absorptiometri collum fem.	9,252
DXA, body composition	633
MR scanning columna cervicalis	2
MR scanning wrist	34
Total	**16,795**

Endocrine organs	
Thyroid scintigraphy, ^{99m}Tc-Pertechnetat	1,048
Thyroid scintigraphy, ^{123}I-Iodide	28
Thyroid, ultrasound	1,091
Thyroid scintigraphy, ^{99m}Tc-Pertechnetat, SPECT	1
Thyroid, fine needle aspiration biopsy	53
Iodine uptake test, ^{131}I-Iodide	26
Parathyroid scintigraphy, ^{99m}Tc-Stamisis	11
Parathyroid scintigraphy, ^{99m}Tc-Stamisis, SPECT	36
Tumourscintigraphy, ^{123}I-Iodide	1
Tumourscintigraphy, ^{123}I-Iodide, rh-TSH	13
Adrenal marrow scintigraphy, ^{123}I-MIBG	43
Scintigraphy after ^{177}Lu- Dotatate therapy	132
Synacthen test	107
Total	**2,590**

Blood and lymph system	
Erythrocyt volume, ^{99m}Tc-erythrocytter	57
Plasma volume, ^{125}I-HSA	57
Lymph scintigraphy, extremities, ^{99m}Tc-HSA, leakage	1
Sentinel node scintigr. tumour drainage, ^{99m}Tc-Nanocolloid	14
Sentinel node scintigr. tumour drainage, c. mammae, ^{99m}Tc-Nanocolloid	34
Sentinel node scintigr. tumour drainage, mel. malign., ^{99m}Tc-Nanocolloid	158
Sentinel node scintigr. tumour drainage, c. penis, ^{99m}Tc-Nanocolloid	22
Sentinel node scintigr. tumour drainage, c. vulvae, ^{99m}Tc-Nanocolloid	33
Sentinel node scintigr. tumour drainage, head/neck SPECT, ^{99m}Tc-Nanocolloid	93
Sentinel node, peroperative with gamma probe, ^{99m}Tc-Nanocolloid	1
Peritumoural injection of ^{99m}Tc-Nanocolloid for sentinel node	631
Spleen scintigraphy, ^{99m}Tc-erythrocyte, heated	3
Total	**1,104**

Other diagnostic procedures	
Aprotinin scintigraphy, ^{99m}Tc-Aprotinin	2
Tumourscintigraphy ^{111}In-Octroetid	1
PET tumour scanning, ^{18}F-FDG	5,226
PET scanning, ^{18}F-FDG	219
PET infection scanning, ^{18}F-FDG	163
PET tumour scanning, ^{68}Ga-DOTATOC	681
White blood cell scintigraphy, ^{99m}Tc-white blood cell	13
White blood cell scintigraphy, ^{99m}Tc-white blood cell, SPECT	21
White blood cell scintigraphy, ^{111}In-white blood cell	2
White blood cell scintigraphy, ^{99m}Tc-leucoscan, SPECT	1

Assessment of blood samples	18
Whole body, contamination measurement	104
Image fusion (PET, SPECT, MRI, CT or planar)	10,689
CT head/neck SPECT/CT	241
CT wb SPET/CT	534
CT thorax SPECT/CT	485
CT pelvis SPECT/CT	55
CT abdomen SPECT/CT	264
CT lower extremities SPECT/CT	7
CT wb PET/CT (KF)	1,361
CT wb PET/CT (PET)	5,368
MR wb PET/MR	107
CT lover extremities PET/CT	15
Ultrasound, various	15
Second opinions external	1,112
Extra tumour delineation	148
Other investigations	189
Supplementary/repeated imaging	2,713
Total	**29,754**

Radiotherapy	
Treatment with ^{131}I, benign thyroid	81
Isotope treatment with ^{177}Lu-Dotatate	121
Isotope treatment with ^{223}Ra-Dichlorid	213
Total	**415**

In vitro analyses	
Affinity studies	4.067
Flow cytometry analyses	9.987
Gene expression analyses	10,838
Immunohistochemistry	1,005
Plasma and protein analyses	1,344
Total	**27,241**

Animal studies

Mice	
^{11}C-Tetrazine	26
^{18}F-ASIS	39
^{18}F-Apopep	6
^{18}F-FDG	215
^{18}F-FET	145
^{18}F-FLT	254
^{52}Mn-liposome	90
^{64}Cu	5
^{64}Cu-ASIS	36
^{64}Cu-DOTA-AE105	20
^{64}Cu-liposome	543
^{64}Cu-liposome targeted	96
^{64}Cu-X	6
^{68}Ga-NOTA-AE105	20
^{68}Ga-RGD	48
^{89}Zr-Heceptin	167
^{99m}Tc-DMSA	16
^{111}In-Tetrazine	62
^{124}I-liposome	40
^{134}Ce-AE105	5
^{134}CE-ATN291	5
^{140}ND-AE105	5
^{140}ND-ATN291	5
^{177}Lu-ASIS-ionphore	33
^{177}Lu-ASIS-SPECT	14
^{177}Lu-DOTATATE	2
^{177}Lu-X	2
Optical imaging, bioluminescence	1,095
Fluorescence imaging, ICG-Glu-Glu-AE105	24
MR-scans	1,145
MR-scans DWI	245
Radiotherapy, externally	321
Radiotherapy, ^{177}Lu-DOTATATE	7
Radiotherapy, ^{177}Lu-X	7
Radiotherapy, ^{177}Lu-ASIS	206
Radiotherapy, alpha emitters	36
CT-scans	178
CT-scans for image fusion	1,167

Rats	
^{18}F-FDG	102
^{64}Cu-liposomes	144
^{82}Rubidium	77
Optical imaging, bioluminescence	85
MR-scans	60
MR-scans DWI	2
MR-spectroscopy	8
Radiotherapy, externally	6
CT-scans for image fusion	258

Dogs	
^{18}F-ASIS/^{13}C-pyruvate	1
^{18}F-FDG/^{13}C-pyruvate	13
^{64}Cu-liposome	3
^{68}Ga-RGD/^{13}C-pyruvate	2
MR-scans for image fusion	16
CT-scans for image fusion	3

Rabbits	
^{18}F-Apopep	1
^{68}Ga-RGD	44

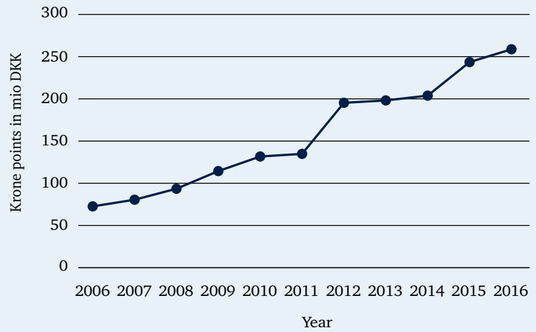
Pigs	
^{18}F-FDG	3

Total	**7,164**

Total number of studies **111,591**

Finance

Turnover



The increase in activities measured in krone point* rose from 72,6 mio DKK in 2006 to 258,7 mio DKK in 2016.

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

Balance 2016

Expenditure (DKK mio)	94
Receipts	17

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Theses

Suetta C. Doctoral thesis. Plasticity and function of human skeletal muscle in relation to disuse and rehabilitation: Influence of ageing and surgery, Defended on the 20th of May 2016, University of Copenhagen.

Andersen JB. PhD thesis. Neonatal Imaging of Cerebral Blood Flow with Positron Emission Tomography and Arterial Spin Labeling Magnetic Resonance. Defended on the 18th of May 2016. University of Copenhagen.

la Cour JL. PhD thesis. Radiation Induced Atherosclerosis – A Possible Side Effect of Radioiodine Therapy. Defended on the 5th of February 2016. University of Copenhagen.

da Cunha-Bang S. PhD thesis. Multimodal Neuroimaging of Aggression in Violent Offenders. Defended on the 8th of July 2016. University of Copenhagen.

Johnbeck CB. PhD thesis. Positron emission tomography for neuroendocrine tumors. Defended on the 20th of May 2016, University of Copenhagen.

Mc Mahon B. PhD thesis. Seasonal changes in cerebral serotonin transporter binding in individuals with or resilient to Seasonal Affective Disorder. Defended on the 1th of April 2016. University of Copenhagen.

Nielsen CH. PhD thesis. Stratification of patients for targeted EGFR therapy and monitoring of therapy response by measurement of serum biomarkers and PET imaging. Defended on the 1st of April 2016, University of Copenhagen.

Stenbæk DS. PhD thesis. Sex steroid hormone manipulations and serotonergic neurotransmission in relation to verbal affective memory recall, simple reaction time, and mental distress. Defended on the 14th of January 2016. University of Copenhagen.

Tønnesen R. PhD thesis. Vitamin D status in young adults in Denmark – Implications for bone mineral density, renin angiotensin-system & sympathetic nervous system. Defended on the 29th of September 2016. University of Copenhagen.

Zornhagen KW. PhD thesis. Hypoxia imaging in dogs with PET and correlation with key molecular hypoxia markers. Defended on the 22nd of January 2016, University of Copenhagen.

Patents

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Research

Andreas Kjær

Research and development is a key activity and focus area of our department. We have over the years build, and continuously strengthened, a comprehensive research program with focus on developing innovative solutions to solve unmet needs in patients. We constantly adjust our research program to be clinically relevant and timely. Our research program is built on established strong in-house competencies combined with strategic collaborations with leading international and national research groups with complementary expertise. Our research program focuses in particular 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. Current major research areas are briefly described below

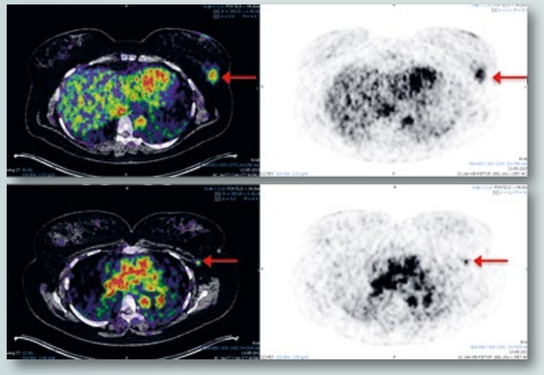
New tracers

An array of projects that are aimed at development of new PET and SPECT tracers for non-invasive tissue characterization, phenotyping, are currently undertaken. Within cancer, but not limited to this, these novel tracers are to be used for diagnosing, staging, risk stratification and therapy planning and monitoring. Two recent examples of tracers that were both taken first-in-humans by us during 2016 are ^{68}Ga-NOTA-AE105 and ^{68}Ga-NODAGA-RGD$_2$. The first tracer, ^{68}Ga-NOTA-AE105, is a marker of cancer aggressiveness and metastatic potential (the invasive phenotype). The second tracer, ^{68}Ga-NODAGA-RGD$_2$, is visualizing neoangiogenesis, which is the target for anti-angiogenesis drugs such as bevazizumab (Avastin®). As part of our research program, we developed a comprehensive platform for validation of new tracers including cell laboratory, molecular biology (proteomics and genomics), histology and biomarker laboratory. We currently have several other promising new PET tracers in our developmental pipeline and expect several of these to be translated into clinical use within the next years.

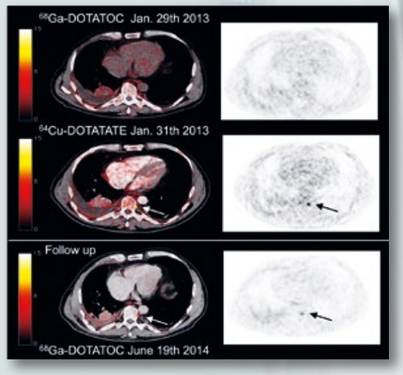
PET/MRI

As one of the first departments that had a hybrid PET/MRI scanner installed, we have continuously expanded our research program on PET/MRI with particular attention on the added value of combining PET and MRI. We currently undertake a substantial number of clinical trials with the purpose to fully unfold the potential of PET/MRI by combining molecular imaging with PET and multiparametric MRI. In addition, we develop new methods for PET/MRI. The goal is to improve tissue characterization and response monitoring ability in cancer treatment, paediatric studies, brain studies and atherosclerotic plaque characterization. Focus of MRI includes the use of diffusion weighted images (DWI)/apparent diffusion coefficient (ADC) and magnetic resonance spectroscopy

Research



◂
Figure showing first-in-humans uPAR-PET/CT in breast cancer patient using the PET tracer ^{68}Ga-NOTA-AE105. In addition to the primary tumour being clearly visualized, an axillary metastasis was shown. Traditional work-up with chest X-ray and ultrasonography did not visualize any metastases. Pathology confirmed that the uPAR positive lymph node contained metastatic breast cancer tissue (from Skovgaard et al. J Nucl Med 2016)



▸
Figure showing head-to-head comparison of our in-house developed somatostatin receptor imaging ligand ^{64}Cu-DOTATATE with ^{68}Ga-DOTATOC. In this patient the higher sensitivity of ^{64}Cu-DOTATATE is demonstrated as a bone metastasis is clearly seen on ^{64}Cu-DOTATATE-PET (middle panel) but not on ^{68}Ga-DOTATOC-PET (upper panel). At follow-up 18 months later the metastasis could also be seen on ^{68}Ga-DOTATOC-PET (from Bardram et al. J Nucl Med 2016).

(MRS). With access also to preclinical PET and MRI, we are capable of working translational when developing and evaluating new methods. As an example, the use of PET/MRI for radiation therapy planning and response monitoring is being evaluated both preclinically and clinically.

Hyperpolarized ^{13}C-MRSI

We were the first to install a dynamic nuclear polarized (DNP) for hyperpolarization of ^{13}C-labeled compounds next to a PET/MRI scanner. Accordingly, we have given particular attention to development of and research in the combination of hyperpolarized ^{13}C-MRS and PET and the added value of combining the modalities, a technique we named *hyperPET*. We have so far studied the use of hyperPET in tissue characterization in cancer, cardiovascular disease and inflammation/infection. Using ^{13}C-pyruvate we have further studied the Warburg effect directly and how it is not always is reflected in glucose utilization and thereby FDG uptake. Currently, we combine ^{13}C-pyruvate with non-FDG PET tracers as well as implement other ^{13}C-compounds for MRSI. So far, our results seem to support that hyperPET may be superior in cancer phenotyping and response monitoring and therefore has the potential to become a useful clinical modality. Also in the field of hyperPET our approach is translational.

Clinical PET/CT in oncology

We continuously carry out a large number of prospective protocols for evaluation of the diagnostic and prognostic value of PET/CT with various tracers, including the ones developed in-house, 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 also now include PET/MRI to study the added value compared to PET/CT.

Paediatric nuclear medicine investigations

At the department we undertake many paediatric investigations. Numerous research protocols with the use of PET and SPECT are carried out in cooperation with clinical departments, particularly within oncology and function of the hepato-biliary system. The use of PET/MRI in children to save radiation dose is also the subject of several investigations.

Neuro PET

With the use of PET/MR, PET/CT including HRRT PET, studies on brain tumours are undertaken. Studies of brain perfusion using PET or DCE-CT are also performed. In addition, attention is given to imaging of dementia using various new tracers. Brain tumours are in particular studied with the amino acid tracer FET but also with novel in-house developed tracers as uPAR-targeting ligands. 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.

Functional MR

Studies on functional brain MR are undertaken in close collaboration with clinical departments including neurology and psychiatry. Special attention is given to development of new methods for functional MRI and clinical application of new functional and molecular MR methods. Methods are targeted at obtaining information on tissue physiology, organ perfusion and molecular biology.

Research

Atherosclerosis
To be able to visualize non-invasively atherosclerosis and predict vulnerability of atherosclerotic plaques, studies using PET/MRI and PET/CT are undertaken. Patient groups at risk are studied and special focus is on the value of new specific PET tracers, e.g. for the study of macrophage activation and atherosclerosis-induced cell proliferation in the bone marrow and spleen. The ambition is to develop an image-based algorithm for identification of patients at risk that will benefit from surgery. As we were the first to publish data showing advantage of PET/MRI over PET/CT for carotid artery imaging we have continued to develop vascular imaging using PET/MRI with special focus on new PET tracers.

Nuclear cardiology
The ability to measure absolute myocardial perfusion and myocardial flow reserve by means of ^{82}Rb PET is exploited to study the regulation of these parameters in various cardiovascular diseases and the predictive value of the measures, e.g. final infarct size. Also the influence of interventions including gene therapy, pharmacological treatment and exercise may be closely monitored using ^{82}Rb PET. In addition, with the use of ^{123}I-MIBG the cardiac sympathetic innervation and activity may be measured. 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 and hepatitis 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, its viability and regeneration. Several of the studies are performed using PET/MRI to obtain additional information.

Lung studies
Numerous studies using lung function testing and lung scintigraphy in different patient groups, e.g. lung transplantation and endobronchial stenting for emphysema, are undertaken. Accordingly, we recently demonstrated the value of combined use of SPECT/CT for diagnosing pulmonary embolism. 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. Finally, the department is participating in a large study colleting data for a lung function test reference database.

Studies of muscle function
Applying methods from clinical physiology and nuclear medicine as well as molecular analyses, muscle function, bone density and body composition are studied. The current focus is on the effect of exercise, immobilization and aging. In addition, data are collected on the same parameters from a population-based study. These data will serve as a reference database and elucidate markers to predict ageing-related disease.

Inflammation, infection and rejection
Non-invasive imaging of inflammation and infection is currently being undertaken in several studies at the department. Also studies on the best way to visualize and evaluate rejection reactions are performed. In some studies, the added value of MR-derived parameters of PET/MR is studied. The department is partner in the PERSIMUNE program, personalized medicine of infection complications in immune deficiency. Finally, on a translational basis development of new PET ligands for immune response monitoring is currently being pursued.

Radionuclide treatment and theranostics
Targeted radionuclide therapy using beta- or alpha-emitting specific ligands binding to certain cancer characteristics has been undertaken for many years at the department. The department takes part in research within this area by testing new ligands and producing relevant isotopes. In particular, we also in-house develop new theranostics based on promising imaging ligands labeled with beta or alpha emitting radionuclides. Cancers that are currently being targeted clinically include neuroendocrine tumours, prostate cancer 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.

Image guided surgery
The concept of intraoperative guidance using either radioactive or optical imaging ligands is increasingly used for surgery. In close collaboration with clinical departments we have recently developed one of our most promising PET ligands targeting uPAR into an optical probe. This probe will be used for intraoperative delineation of cancer to ensure negative margins while leaving normal tissue intact. The technology, which will be used in pair with preoperative PET imaging of the same target, is particularly promising in concert with robotic surgery.

Whole body counting
Whole body counting is used for precise measurements of body composition in a series of collaborative studies. Also, studies on the absorption of certain minerals from the gastrointestinal tract are undertaken.

Cluster for Molecular Imaging

Andreas Kjær

Implementation of precision medicine, i.e. tailoring therapy to the disease characteristics of each patient, has led to a need for diagnosing at the molecular level. Traditional molecular biology methods use tissue sampling for in vitro analysis. In contrast, molecular imaging allows for whole-body non-invasive studies at the molecular level in intact organisms. A further advantage of image based techniques is circumvention of sampling error, i.e. that a biopsy is not representative of the whole disease due to heterogeneity. It is possible to label almost any molecule with radioactive isotopes suitable for PET imaging and such molecular imaging PET ligands may then be used for visualization of tumour specific receptors and tissue characteristics, e.g. tumour aggressiveness or angiogenesis. Especially within cancer biology, but not limited to this, the technique is expected to lead to a break-through in diagnosing and treatment. Among available molecular imaging methods, the nuclear medicine based technologies and in particular PET, have the greatest translational potential as they can be directly transferred from animal models to use in humans. Also, due to the unsurpassed high sensitivity, often they can be micro-dosed. Finally, successful imaging ligands may be developed into radionuclide therapy, such imaging-therapy pairs are known as theranostics.

Our molecular imaging and theranostics research program is aimed at, 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 complex process that involves many steps from definition of target to final use of the tracer in patients. The major steps involved in PET tracer development and translation into patients are depicted in the figure 1.

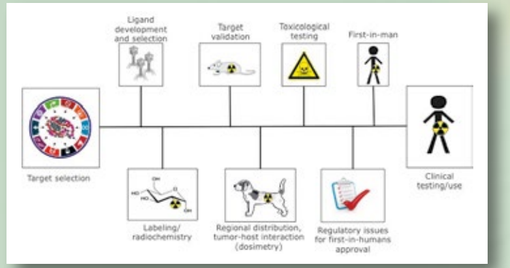


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Figure 1. The major steps involved in PET tracer development: following selection of the key-process involved in pathophysiology of a disease, a relevant molecular target is defined. Thereafter, a specific ligand is developed and labeled with a suitable radionuclide for imaging. Target validation (specificity) is then tested in relevant animal models and biodistribution studied for calculation of radiation dosimetry. Successful, lead candidates are then rigorously tested for possible toxicity according to European guidelines. Following approval by the health authorities a first-in-humans phase I clinical trial may then be initiated. If successful, phase II studies of clinical utility are then pursued. Imaging ligands may also be used as a starting point for new targeted therapies, in particular radionuclide based therapies.

▸

Figure 2. PET/MR imaging of human patient-derived (PDX) HER2 positive breast cancer implanted orthotopically into the brain of a mouse to be used as a model of breast cancer brain metastasis. For PET imaging, an in-house developed HER2 targeting tracer was used. The model can e.g. be used to evaluate whether new breast cancer therapies are also efficient in brain metastases (image provided by Carsten H. Nielsen)

▸

Figure 3. Myocardial scintigraphy (^{99m}Tc-MIBI SPECT/CT) before (left panels) and after (right panels) induction of myocardial infarction in rats. One application of the model is testing the ability of new PET tracers to identify area at risk and predict final infarct size (Image provided by Andreas Clemmensen).

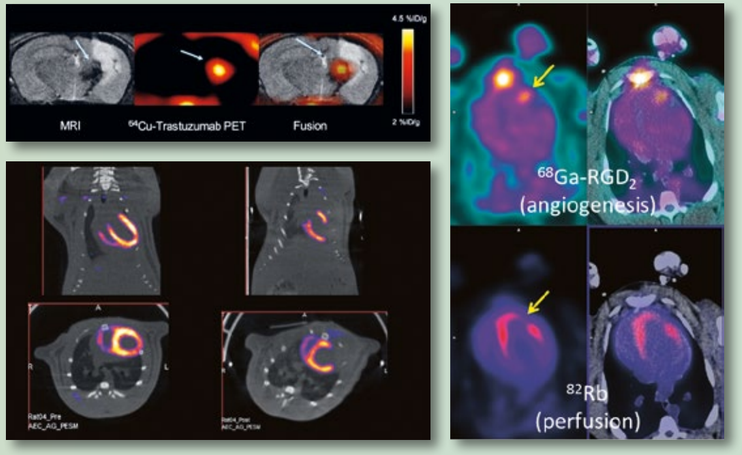

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Figure 4. Post myocardial infarction angiogenesis in a minipig model. By using an in-house developed angiogenesis PET tracer (^{68}Ga-NODAGA-RGD$_2$) and the PET myocardial perfusion tracer ^{82}Rb, it was possible to visualize increased angiogenesis in the area of infarction (yellow arrows; image modified from Rasmussen et al. Diagnostics (Basel) 2016)

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 specialized facility at the Panum Institute for molecular imaging in animals with PET, SPECT, CT, MRI and optical 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 of our pipeline in pre-clinical testing that already are 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 tumours as well as metastatic cancer models using human cancer cell lines. Most recently, we also implemented the use of patient-derived tumours (PDX) for orthotopic implantation to even better mimic the conditions in cancer patients (Figure 2).

Furthermore, we have also introduced and developed animal models of cardiovascular diseases including atherosclerosis, myocardial infarction and takotsubo (Figure 3). For studies of atherosclerosis also mini pigs and rabbits are used (Figure 4).

Over the last 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 tumours in mice, early use of promising PET tracers in companion dogs with spontaneous tumours scheduled for cancer therapy. The latter allows for testing in "full-size" as well as evaluation of tumour-stroma interaction due to the syngeneic tumour environment. In this way we bridge between xenograft models and first-in-human studies. The relative value and pros and cons of the different models are shown below in figure 5.

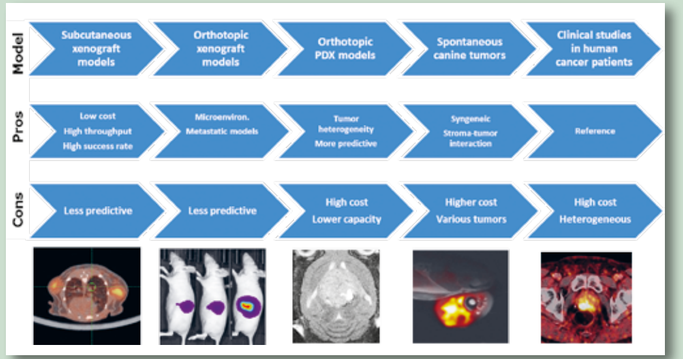


Figure 5. Comparison of the different in vivo models used by us in the development and testing of new PET tracers and targeted radionuclide therapies

At Cluster for Molecular Imaging we always seek to match our clinical methods to be able to develop new techniques for use in patients. Accordingly, we recently added SPECT/CT capabilities to our existing PET/MRI/MRS capabilities. SPECT/CT will in particular be used to visualize ^{177}Lu-labeled radionuclide therapy ligands to investigate biodistribution and binding to tumours. In addition, we recently obtained approval for animal experiments using alpha-emitting therapy. Also preclinical studies in the field of hyperpolarized ^{13}C-MRS and hyperPET are performed in collaboration with DTU. Finally, also optical imaging has gained translational potential as it can be used intraoperatively for delineation of tumours and in particular when robotic surgery is performed (Figure 6).

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, we also perform studies within molecular imaging of inflammation and metabolism, e.g. activation of brown adipose tissue.

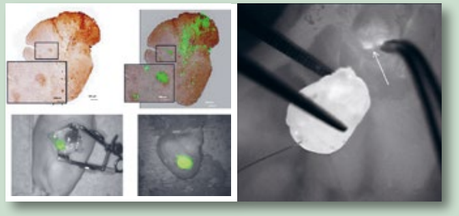
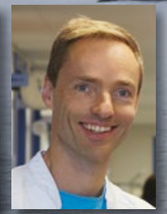


Figure 6. Optical imaging of uPAR using our in-house developed ICG:AE105 in orthotopic human xenograft mouse tumour model. Upper panels: Close correlation ex vivo between immunohistochemistry (left) and fluorescence of ICG:AE105 (middle); Lower panels: uPAR optical signal in orthotopic human pancreatic cancer (left) and glioblastoma (middle). The image at right shows how the ligand is used to see whether all tumour tissue is resected – tumour tissue (bright) left behind at arrow (Images provided by Karina Juhl and Anders Christensen)

Some tissue characteristics currently targeted for imaging:

- Cancer specific receptors (numerous projects, e.g. SST, HER2, EGFRvIII)
- Glycolytic activity (PET and hyperpolarized MRSI)
- Cell proliferation
- Amino acid transport
- Hypoxia
- Apoptosis
- Necrosis
- Angiogenesis
- Invasive cancer phenotype
- Atherosclerotic plaque vulnerability
- Immune-response

Collaboration with Landssygehuset, Faroe Islands



Jann Mortensen and Thomas Levin Klausen

The Faroe Islands population of 50,000 is served by 2 smaller hospitals in Klaksvík and Tvøroyri and the larger National Hospital of the Faroe Islands, Landssjúkrahúsið in Tórshavn.

The National hospital has a staff of 850 and 180 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 in clinical physiology and nuclear medicine with our department at Rigshospitalet.

The Department of Clinical Physiology and Nuclear Medicine in Tórshavn performed around 360 scintigraphies of lungs, bones, thyroid, kidneys, sentinel nodes and renography in 2016 on the department´s 2-headed Skylight camera. Around 400 lung functions test were performed with the Jaeger whole body plethysmograph and nearly 500 routine and research DXA studies were performed with The Norland DXA 840 scanner.

Second opinion on scintigraphies and lung function measurements is provided via a direct telemedicine connection. The responsible physician and phycisist for Nuclear Medicine in Tórshavn is Consultant, DMSc Jann Mortensen and Physicist Thomas Levin Klausen.

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.

The focus of the research program is neurobiology, physiology and pathophsiology, molecular imaging and neuroreceptor ligands with focus on the serotonergic system.

https://cimbi.dk/

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 masters graduated in 2008. 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.

A warm thank you to Professor Jørgen Arendt Jensen, Associate Professor Kaj-Åge Henneberg, Professor Jens E. Wilhjelm, DTU and Professor Tine Alkjær Eriksen, University of Copenhagen for their great effort and our fine collaboration both on education and research.

UNIVERSITY OF COPENHAGEN

DTU

Danish National Research Foundation

Danmarks Grundforskningsfond
Danish National Research Foundation

Professor Liselotte Højgaard
Chairman of the Board of the Danish National Research Foundation

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 Foundation could celebrate the first successful 25 years November 2016. The Center of Excellence (DoE) program is the main funding mechanism together with the Niels Bohr professorships. Since 1991 the Foundation has commited itself to support Danish Research with more than 6 billion DKK (= 800 mio €).

The Center of Excellence is the primary funding mechanism and the Foundation's 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-staging application process. The objective of the CoE program is to strengthen Danish research by providing the best possible working conditions and organizational 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.

In 2013 DNRF was evaluated by an international panel leader by Dr Wilhelm Krull, Secretary General of Die Volkswagen Stiftung. The outcome was very positive and showed that the DNRF's Centers of Excellence are on level with the very best researchers in the world. 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.

Professor Liselotte Højgaard is Chair of the Board of the Danish National Research Foundation.

The board members at the end of 2016: Professor Liselotte Højgaard, Professor Eivind Hiis Hauge, Professor Eero Vuorio, Professor, Dr. Bart De Moor, Professor Christina Moberg, Professor Morten Overgaard Ravn, Professor Minik Rosing, Professor Jesper Ryberg and Professor Anne Scott Sørensen.

Professor Søren-Peter Olesen is Director of DNRF, and Steen Marcus is Vice Director. A warm thank you to all staff members and directors for an excellent collaboration.

▸
Liselotte Højgaard and Søren-Peter Olesen

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)
- 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

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