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Annual Report 2008

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Preface



The year 2008 was a very exciting year for the Department of Clinical Physiology, Nuclear Medicine and PET, at Rigshospitalet, University of Copenhagen. We had a very high level of activity with almost 30.000 patient investigations in one year and more than 70 peer review papers. The financial balance was positive – as it has been for the previous 8 years - and we have had two relaxing visits: In summer to Tivoli and in winter the Christmas party after the Annual Research Day.

The highlight of 2008 was the official opening of the HRRT PET brain research tomograph donated by the John & Birthe Meyer Foundation. The opening 6th of May had an introduction of the scanner and its uses, followed by reception and visit to the PET unit and the new HRRT scanner. Birthe Meyer, Birgitte Meyer Brandt, Henrik Meyer from the John & Birthe Meyer Foundation delighted us with their presence as well as Director Søren Drost-Nissen from the Foundation. The software optimization by Merence Sibomani and Sune Keller has lead to an impressive speed and image resolution on the HRRT scanner.

2008 was a challenging year, as all the European hospitals had to take action, to overcome the acute isotope shortage of Tc-99m: the workhorse of nuclear medicine patient investigations. Tc-99m is produced naturally during decay of the radioisotope Molybdenum-99, which is generated as a bi-product of Uranium fission. All three European nuclear reactors that generate Mo-99m were shut during September. The Osiris reactor in Saclay, France and the BR2 reactor in Mol, Belgium were closed for scheduled maintenance and the high-flux reactor at Petten, the Netherlands was shut after a routine inspection revealed escape gas-bubbles in its cooling system. The isotope delivery was not normalized until after

Christmas. The isotope situation had to be overcome by harvesting Tc-99m twice a day from the usual Mo-99 source instead of just once a day. Patientstudies had to be done at weekends, some studies had to be replaced by ultrasound, MRI or CT. The Hevesy Lab. at RISØ National Laboratory was very helpful and produced F-18 fluorid for bone PET patient investigations and the Danish Medical Agency was extremely helpful and provided us with a license within very few days. The collaboration between clinicians, hospitals in Denmark, the providers of radiopharmaceuticals and the national and international authorities have been very positive and only few patients have experienced serious problems.

The greatest challenges in 2008 was when the Danish National Board of Health introduced “Kræftpakker” with national guidelines for extensive use of PET/CT for diagnostic work-ups of many cancer types – with the request of imaging within few days after remission. We have struggled to meet the challenges, and we have succeeded due to a very great effort from the staff. A warm thank you!

In 2008 Dr. Philip Hasbak was appointed as Nuclear Medicine Chief Physician with responsibility for nuclear cardiology. A warm welcome to Philip!

In October 2008 we celebrated the first Master Candidates from the new 5-year Bio-engineering degree at Bachelor and Master level from DTU and the University of Copenhagen, Faculty of Health Sciences. The candidates are now employed in research, medical industry and university hospitals.

Our PET/CT scanner no. 5 in the new Finsen Building II with Radiotherapy officially opened in December 2007. In 2008 the number of PET/CT scans have increased

for diagnostic investigations in cancer patients in staging, evaluation of treatment effects of surgery/radiotherapy/chemotherapy, relapse evaluation and planning of radiation therapy.

At the Cluster for Molecular Imaging the activity has been increasing in 2008 and Professor Andreas Kjær has initiated a Danish-Chinese research collaboration with the Shuguang Hospital, Shanghai. Andreas Kjær and the Danish Consul of Science and Innovation visited the Shuguang Hospital in September 2008 for discussions on research collaboration. In addition, Andreas Kjær is partner in a Danish-Chinese Center for Proteases and Cancer funded by the Danish National Research Foundation (Grundforskningsfonden). The Cluster researchers (“the Kjaer group”) have been very active at conferences eg. at the Academy of Molecular Imaging, where they won two awards at the Congress in Nice, September 2008.

The development in radiochemistry has been very positive. In 2008, ¹⁸F-choline, ¹⁸F-fluorid and ¹⁸F-PIB have been developed from RISØ and a long list of radiopharmaceuticals from our own department are now available for research in clinical procedures including ¹¹C-PIB.

In Nuclear Medicine the new SPECT/CT scanner Precedence Philips 16-slice was opened, so that we have 2 of a kind next to each other. The use of SPECT/CT has increased rapidly – due to the clear diagnostic power of this image combination.

In the Capital Region for all the Hospitals in greater Copenhagen area, we have strengthened the collaboration through the speciality council (Sundhedsfagligt Råd) and an Audit Report evaluating all the departments of Clinical Physiology and Nuclear Medicine in Copenhagen, gave us a very positive review.

From the Danish National Board of Health we were given permission to treat patients with neuroendocrine tumors with ^{177}Lu -Dota-tate; and the preparations for this were initiated in the summer of 2008.

As in previous years we welcomed many visiting guests and researchers, and many of us were invited speakers and teachers at Symposia, Workshops and Conferences in Denmark and abroad.

In 2008 we spent a lot of time on the purchase of new scanners in a collaborative effort including all the Danish Regions. It was a challenging experience and a special warm thank you to Søren Holm, who was leader of the PET purchasing group.

EMRC, the European Medical Research Councils, chaired by Professor Liselotte Højgaard, had a busy year with the White Paper "Present Status and future strategy for Medical Research in Europe". The document was disseminated widely and the next steps have been the Forward Look for

"Investigator-Driven Clinical Trials". Further, we have worked with the revision of the Animal Directive for medical research, where it is important that dignified research can be performed - without hindering the research possibilities.

We would like to offer a warm and sincere thank you to all staff members and external collaborators for their great effort in 2008. Everyone, from Department of Clinical Physiology, Nuclear Medicine and PET have made important contributions to patient studies, isotope production, research, development, education and collaboration. All these efforts result in better care for our patients and greater progress in research and development. A warm thank you to all collaborators from abroad and within the hospital. A special warm thank you to the Department of Radiation Therapy were Head of Clinic, Dr. Svend Aage Engelholm, has lead the project with preparations for a particle therapy facility at the hospital. We are proud of being helpful in that collaborative effort.

Thank you also to Ole Bergsten, MTA for a close collaboration on new equipment.

A warm thank you to everyone involved in the great achievements of the Department. We are looking forward to exciting new challenges in 2009 - for the benefit of patients, research and education!

Liselotte Højgaard & Linda M. Kragh





Mission and Objectives

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

General objectives Rigshospitalet:

- To be in the lead within highly specialized diagnostics treatment and nursing
- To carry out research and development at an advanced international level
- To educate staff in the health services on an highly specialized level
- To contribute with professional advice and exchange of knowledge and expertise with the surrounding world
- To be characterized by openness and human respect

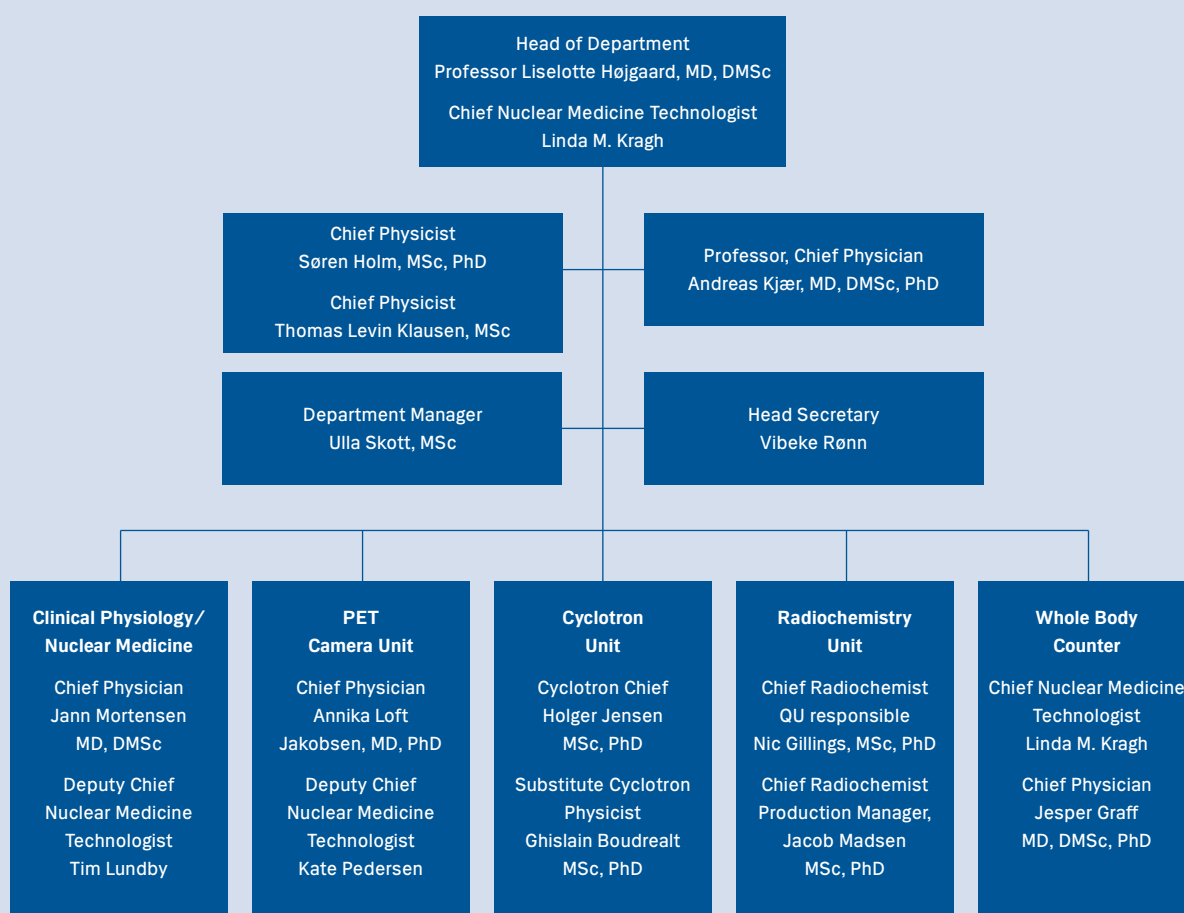
The objectives of The Department of Clinical Physiology, Nuclear Medicine and PET are:

- The optimal clinical physiology and nuclear medicine patient investigation
- Research at the highest international level in clinical physiology and nuclear medicine with special emphasis on molecular imaging, isotopes and radio-pharmaceuticals
- Pre- and postgraduate education for all relevant professionals within the expert field of the clinical, nationally and internationally
- The good patient experience and the wellbeing of the staff

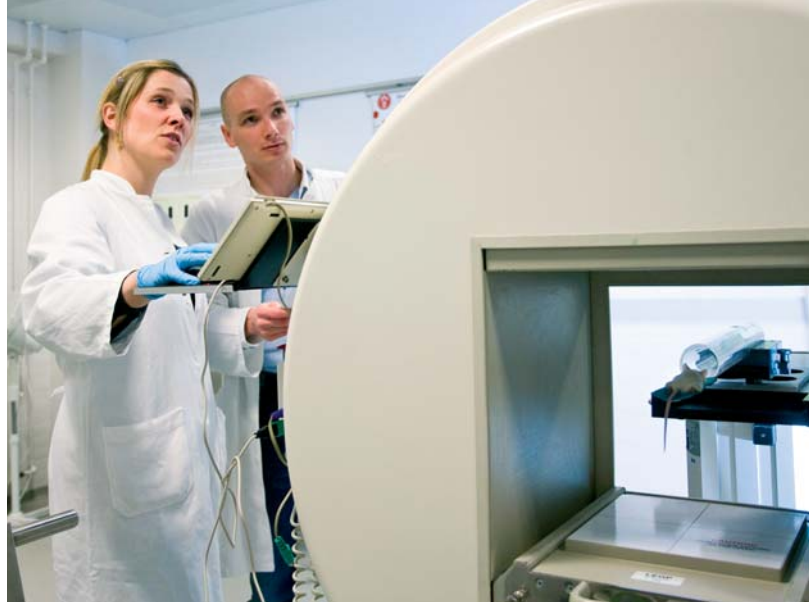
The staff has participated in a number of congresses, symposias, meetings and workshops with invited lectures, oral presentations, abstracts and posters. We have a comprehensive programme for all staff members at the department, and frequent visits from Danish and international research groups.

In 2008 more than 200 groups and individuals visited the department.

Organisation and Staff



Department of Clinical Physiology, Nuclear Medicine & PET is part of the Diagnostic Center, headed by Mogens Sandbjerg Hansen, Director, MD, DMSc and Karin Nørregaard, Vicedirector.



Physicians

Berthelsen, Anne Kiil, MD, Chief Physician, Borgwardt, Lise, MD, PhD, Senior Registrar, Christensen, Charlotte Birk, MD, Registrar, Christoffersen, Christina, Registrar, Cronberg, Carin, MD, Chief Physician, Dejanovic, Danijela, Registrar, Dümcke, Christine, MD, Registrar, Graff, Jesper, MD, DMSc, PhD, Chief Physician, Jakobsen, Annika Loft, MD, PhD, Chief Physician, Hasbak, Philip, MD, Chief Physician, Hesse, Birger, MD, DMSc, Chief Physician, Højgaard, Liselotte, MD, DMSc, Head of Department, Professor, Høyer, Alice Outzen Widding, MD, Consultant, Johnbeck, Camilla Bardram, MD, Registrar, Kjær, Andreas, MD, DMSc, PhD, MBA, Chief Physician, Professor, Krakauer, Martin, MD, Registrar, Kupers, Ron, MD, Associate Professor, Law, Ian, MD, DMSc, PhD, Chief Physician, Markova, Elena, MD, Chief Physician, Marner, Lisbeth, MD, Registrar, Mehlsen, Anne-Birgitte, MD, Staff Registrar, Mortensen, Jann, MD, DMSc, Chief Physician, Oturai, Peter, MD, DMSc, Chief Physician, Recke, Per von der, MD, Chief Physician, Skott, Ulla, MSc, Department manager

PhD students

Beck, Martin, Cand.scient., PhD Student, Binderup, Tina, MSc, Human Biologist, PhD Student, Chakera, Anette H., MD, PhD Student, Eckardt, Rozy, MD, PhD Student, Erritzøe, David, MD, PhD Student, NRU Researcher, Ettrup, Anders, Human Biologist, PhD Student, NRU Researcher, Frøkjær, Vibe, MD, PhD Student, NRU Researcher, Græbe, Martin, MD, PhD Student, Gutte, Henrik, MD, Research Fellow, PhD Student, Haahr, Mette, MD, PhD Student, NRU Researcher, Hansen, Martin, Cand.scient, PhD Student, Jensen, Mette Munk, Human Biologist, Research Fellow, Jensen, Torben Hougaard, Cand.scient, PhD Student, Jørgensen, Emilie Arnth, MSc, Human Biologist, PhD Student, Jørgensen, Jesper Tranekær, Human Biologist, Research Fellow, Kalbitzer, Jan, MD, PhD Student, NRU Researcher, Kornum, Birgitte, MSc, Human Biologist, PhD Student, NRU Researcher, Kristoffersen, Ulrik Sloth, MD, Research Fellow, PhD Student, Loring-Andersen, Julie, MD, Research Fellow, PhD Student, Marthin, June, MD, PhD Student, Nielsen, Kristina Rue, MD, PhD Student, Persson, Morten, MSc, Research Fellow, Pfeifer, Andreas, MD, Research Fellow, PhD Student, Skovgaard, Dorthe, MD, PhD Student, Tågil, Kristina, MD, PhD Student

Physicists, Chemists

Andersen, Peter Andreas, MSc, PhD, Physicist, Boudreal, Gislain, MSc, PhD, Substitute Cyclotron Physicist, Brandt-Larsen, Malene, PhD, Denholt, Charlotte Lund, MSc, PhD, Chemist, Gillings, Nicolas, MSc, PhD, Chief Radio Chemist, Holm, Søren, MSc, PhD, Chief Physicist, Jensen, Holger J., MSc, PhD, Cyclotron Chief Physicist, Jørgensen, Jesper, MSc, Physicist, Klausen, Thomas Levin, MSc, Chief Physicist, Madsen, Jacob, MSc, PhD, Chief Production Manager, Chemist, Nægren, Kjell, MSc, Research Radiochemist, Szabolcs, Lehel, MSc, PhD

Engineers, Technicians, Computer Scientists

Andersen, Flemming, MSc, PhD, Computer Scientist, Christensen, Jan Damgaard, Cyclotron Technician, Drennan, David, Cyclotron Technician, Chemist Dahan, Daniel, Cyclotron Technician, Dähnhardt, Andreas, Computer Assistant, Jensen, Bjørn Neumann, Electro Engineer, Keller, Sune Høglild, MSc, PhD, Computer Scientist, Sibomani, Merence, IT-expert, Weihrauch, Per, Cyclotron Technician

Nuclear Medicine Technologists, Radiographers and Nurses

Abrahamsson, Elisabeth, Radiographer, Christensen, Pia, Nuclear Medicine Technologist, Cortsen, Annette, Nuclear Medicine Technologist, Dall, Bente, Nuclear Medicine Technologist, Elkington, Sakeena, Nuclear Medicine Technologist, Federspiel, Marianne, Nuclear Medicine Technologist, Frederiksen, Mette Borggreen, Nuclear Medicine Technologist, Gudmundsson, Sven, Nuclear Medicine Technologist, Hansen, Anja Vallin, Nuclear Medicine Technologist, Hansen, Lasse, Nuclear Medicine Technologist, Heiberg, Therese, Nuclear Medicine Technologist, Hennings, Jannie, Nuclear Medicine Technologist, Hillebrandt, Henriette, Nuclear Medicine Technologist, Hovgaard, Beinta, Nuclear Medicine Technologist, Høybye, Lene, Nuclear Medicine Technologist, Jensen, Martin Ravn, Nuclear Medicine Technologist, Jørgensen, Hanne, Nuclear Medicine Technologist, Jørgensen, Mette Møller, Nuclear Medicine Technologist, Kahveci, Zuhail, Nuclear Medicine Technologist, Kernchen, Ulla, Staff Nurse, Knudsen, Camilla Sloth, Nuclear Medicine Technologist, Kragh, Linda M., Chief Nuclear Medicine Technologist, Kronvall, Johanna, Nuclear Medicine Technologist, Lindell, Elin, Nuclear Medicine Technologist, Linnet, Solveig, Nuclear Medicine Technologist, Lundby, Tim, Deputy Chief Nuclear Medicine Technologist, Myschetzky, Rebecca, Nuclear Medicine Technologist, Theil, Merete Søndersø, Nuclear Medicine Technologist, Nehme, Ghina, Nuclear Medicine Technologist, Nilausen, Mia, Nuclear Medicine Technologist, Osinska, Dorota, Nuclear Medicine Technologist, Pedersen, Birgitte, Nuclear Medicine Technologist, Pedersen, Kate, Deputy Chief Nuclear Medicine Technologist, Pejtersen, Maria H., Nuclear Medicine Technologist, Setterberg, Victoria, Nuclear Medicine Technologist, Stahr, Karin, Nuclear Medicine Technologist, Svalling, Susanne, Nuclear Medicine Technologist, Sørensen, Anne, Nuclear Medicine Technologist, Sørensen, Anne B., Nuclear Medicine Technologist, Sørensen, Beira, Nuclear Medicine Technologist, Sørensen, Louise Sørup, Nuclear Medicine Technologist, Thygesen, Poul, Nuclear Medicine Technologist, Ulrich, Eva, Nuclear Medicine Technologist, Wikke, Tina, Nuclear Medicine Technologist

Secretaries

Damborg, Anne-Marie, Quality Co-ordinator, Forstrøm, Ulla, Assistant Secretary, Hildebrand, Sanne, Medical Secretary, Jørgensen, Tina, Medical Secretary, Myltoft, Mette Gylling, Medical Secretary, Nielsen, Mariane, Service Assistant, Nielsen, Tina Vikmann, Medical Secretary, Runge, Gitte, PA to Professor, Medical Secretary, Rydahl, Maybritt, Medical Secretary, Rønn, Vibeke, Head Secretary, Semitoje, Gudrun, Medical Secretary, Stahlfest, Marianne, Medical Secretary Student

Students, Assistants

Andersen, Julie Bjerglund, MD Student, Scholar, Andreasen, Nis Bo, Student, Christensen, Anders N. MSc Student in Medicine and Technology Christensen, Christian Holm, Student, Christensen, Rune, MSc Student in Medicine and Technology, Dohn, Asmus Ougaard, Student, Fonslet, Jesper, Student, Holst, Karen, Assistant, Jensen, Charlotte Leerbech, Student, Jensen, Simon Bøgh, Student, Jørgensen, Troels, Cand.scient, Hospital Physicist Student, Kamstrup, Andreas, Student, Kjøller, Niels-Kristian, Student, Kobbernagel, Helene, MD Student, Nielsen, Carsten Haagen, Exchange Student, Molecular Imaging, Stanford, UO, Olesen, Oline, MSc Student in Medicine and Technology, Petersen, Stefan Alaric, Student Skytt, Nanna, MD, Student, Toft-Petersen, Rasmus, Student, Øberg, Mikkel, Student

Highlights of the year 2008

On the 6th of May the John and Birthe Meyer Foundation with Birthe Meyer, Gitte Meyer-Brandt and Henrik Meyer graced us with their presence for the opening of the HRRT PET brain scanner. We are the Foundation immensely grateful for this donation. IT-expert Merence Sibomani has worked with the improvement of the software for the HRRT PET scanner, resulting in a scanner with a very good resolution and extremely fast software.

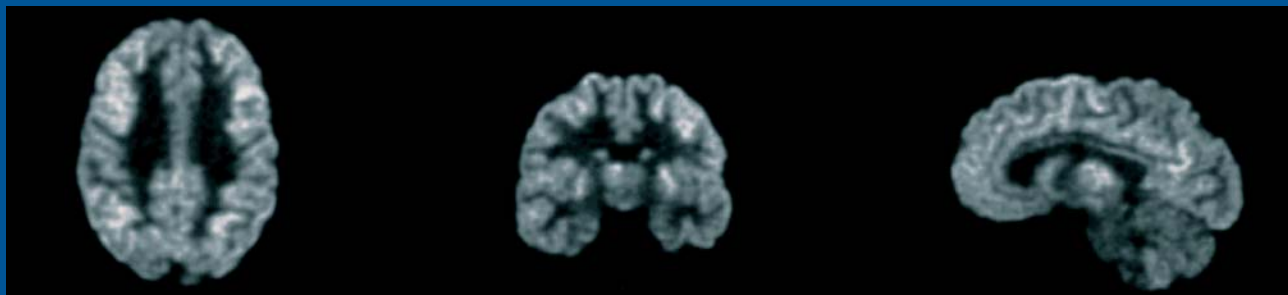
The new PET/CT 5 for clinical oncology patient investigations and our new rooms at the Finsen II were taken into use in 2008. It has become a building with nice waiting rooms for patients, modern facilities for the staff and new and efficient equipment.

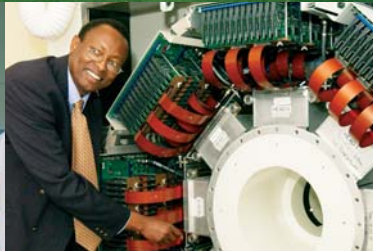
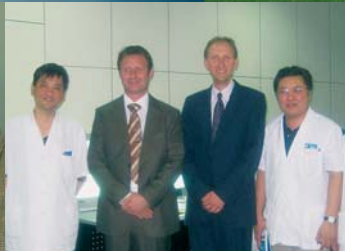
At EMRC the highlight of the year was the Concensus Conference about the “Forward Look on Investigator-driven clinical trials” at the Maison de la Region d’Alcase in Strasbourg where 200 high-level experts convened to improve the conditions for clinical research in Europe and in the rest of the world.

Our collaborators at the Department of Radiotherapy introduced Rapid Arc VMAT (Volumetric Modulated Arc Therapy) and the first patient investigation was done 9th of May 2008. We are privileged at the PET Unit to be at their service for PET/CT planned radiation therapy.

The Danish Political Research Council, with Professor Liselotte Højgaard being a member, published their Annual Report 2007 and launched it in the spring of 2008. The Annual Report had a special chapter on New ways for the Danish Medical Research.

Andreas Kjær has in collaboration with other researchers at Rigshospitalet and University of Aarhus received 16 mio. DKK from the Danish National Research Foundation.





Nuclear Medicine



Most of the patient examinations at the Department of Clinical Physiology and Nuclear Medicine are related to the diagnosis and monitoring of cancer patients. For this purpose we have seven gamma cameras for routine clinical imaging and human research studies, including three hybrid SPECT/CT cameras (two 16 slice Precedence scanners and a one slice Hawkeye scanner), one dual-head gamma camera and three single-head cameras, two of these were installed in 2008. Furthermore, we have two Jaeger body plethysmographs for lung function testing. In our animal facilities we have SPECT and PET and CT scanners as well.

The majority of the hybrid SPECT/CT scans comprise imaging of neuroendocrine tumours, pulmonary embolism and sentinel nodes.

The somatostatin receptor ligand ^{111}In Octreotide imaging is the most important endocrine nuclear medicine imaging modality and is being increasingly used for

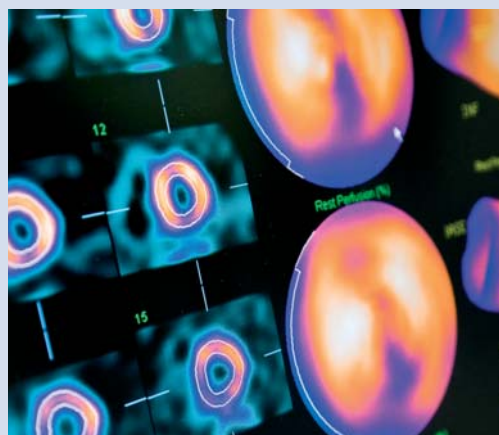
evaluation and monitoring of radionuclide therapy in patients with inoperable tumours. State-of-the-art 3-D physiologic and anatomical hybrid imaging using both perfusion and $^{81\text{m}}\text{Kr}$ ventilation SPECT together with pulmonary CT angiography has been applied for the diagnosis of pulmonary embolism. Other frequent indications for lung physiology measurements in children and adults are control after chemotherapy and transplantation or preoperative evaluation and radioaerosol mucociliary clearance examinations for the diagnosis of primary ciliary dyskinesia. The sentinel node technique is increasingly used, leading to optimized surgery of breast cancer, melanoma, oral cancer and other types of cancer. Radioisotope leakage monitoring procedures are used during isolated limb perfusion with melphalan and tumor necrosis alpha for recurrent melanoma and soft-tissue sarcoma.

The department has been much involved in production of comprehensive European

guidelines covering nuclear cardiology and sentinel node procedures.

Establishment of facilities for planned radionuclide therapy with ^{177}Lu -DOTATATE for patients with neuroendocrine tumours has been initiated.

Jann Mortensen & Peter Oturai



Pediatric Nuclear Medicine



Each year we perform 1.200 pediatric nuclear medicine investigations mainly for the large pediatric clinics at the hospital. It is a special focus area for our department to perform these investigations at the highest level of excellence, and at the same time make it a positive experience for both the child and the parents. The department is a member of the Pediatric Nuclear Medicine Network, the International Telemedicine Network for Second Opinion and Exchange of Ideas.

The department has been performing children PET scans as a focus area since 1999 and has now performed close to 1.000 children PET scans. Since our introduction of PET/CT in 2001 and the second PET/CT scanner in 2003, most of the whole body studies have been performed as PET/CT, though only a relevant number of high-resolution scans.

Our Pediatric Focus Group is still evolving systematizing informations, procedures

and the scanner performance etc. to continuously increase the quality of the pediatric examinations.

Our Pediatric Focus Group and the Children's Programme at Rigshospitalet planned and held the Pediatric Network Workshop at Rigshospitalet in 2008 to strengthen the cooperation concerning pediatric patients within the entire hospital and to increase quality of diagnostic, treatment and the experience of the hospitalization of the child. It was a great success with more than 175 participants and will be followed up by a Pediatric Symposium in 2009.

Our department has this year been member of the committee planning the development of the optimal solution for the children at Rigshospitalet and the committee for "Cancer diagnostic and treatment-packages" for children in the Capital Region, in order to perform the fastest high quality diagnostic work-up and treatment for children with cancer.

We are giving talks internationally as our Nuclear Medicine Technologist and Radiographer from the Pediatric Focus Group, Marianne Federspiel and Elisabeth Abrahamsson were at Great Ormond Street Hospital for Children, London, where they gave a successful talk on how to perform Pediatric PET/CT and SPECT/CT scans. We were also represented at the EAPNM 2008, Barcelona, "Multimodality Imaging of Pediatric Brain Tumors", where Lise Borgwardt was invited speaker.

Research in Pediatric Nuclear Medicine including PET is necessary, as we have an increasing amount of students in the field. We conduct research protocols in children with PET or PET/CT in lymphomas, sarcomas, epilepsy, Mb. Fabry, Brain-tumors and octreo-scans to monitor Langerhans histiocytosis. Further more MIBG SPECT/CT of children with neuroblastomas and SPECT/CT in general to further develop the pediatric area.

Lise Borgwardt

Cyclotron Unit



We have experienced a steady increase in the number of productions during the last few years. In 2008 we did 761 and 372 successful productions at our Scanditronix and CTI/Siemens cyclotrons respectively, corresponding to an increase of 31% relative to 2007. The increase was mainly in ^{18}F -FDG (42%) and ^{11}C -labelled radio-pharmaceuticals (27%).

Despite of both an increased number of productions and produced activity (as an example 35% more ^{18}F -FDG activity was produced in 2008) our releases of activity, via the monitored ventilation system, decreased in 2008. The figure shows the development since 2006 and it is seen that the release has been reduced by 38%. The positive development is mainly due to improvements of our filter systems and synthesis modules.

In 2008 we had only minor technical problems with the cyclotrons, but we had major problems with the supply of cooling water from the hospital. Due to an insufficient filtering of the water from the hospital, the heat exchangers for both cyclotrons were blocking. Consequently the cooling system for both cyclotrons were redesigned

and improved with efficient filters (5 μm), various probes for monitoring the heat transfer and the heat exchangers were replaced.

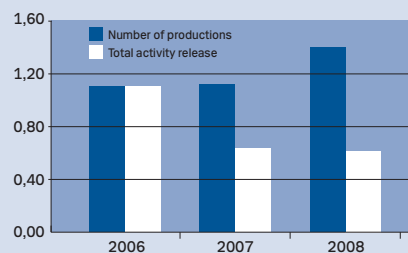
In 2007 a development for a new ^{11}C -methan target for our Scanditronix cyclotron was initiated in 2008, we started to use this target for routine productions. At target intilliest both higher and more specific activities could be achieved.

As a consequence of the increasing demands for ^{18}F -FDG we ordered an upgrade for the CTI/Siemens cyclotron with a second beam line and 3 new targets (^{18}F , ^{13}N and a solid target system). The upgrade is expected to be installed in early 2009. A second beam line makes dual beam irradiations possible (2x60 μA) and consequently we will be able to double our ^{18}F production capacity. The new target changer, is a special version of the standard CTI/Siemens target changer, which allows to irradiate various solid targets (target material electrodeposited at a circular gold disk as backing) for production of special isotopes like $^{62,64}\text{Cu}$, ^{77}Br , etc.

So far we will be the only user in the world except for at the University of Fukui in Japan, where the solid target system was developed together with CTI.

Holger J. Jensen

Productions and activity releases relative to 2006



Radiochemistry



Routine Production

In 2008 the demand for [¹⁸F]FDG increased considerably such that 2 productions were required on most days and a total of 369 batches were released. The Danish Medicines Agency have now approved an increase in batch size, which should allow for a reduction of the number of productions in 2009, whilst at the same time increasing the overall production capacity. A new beam-line for the CTI Eclipse cyclotron has been ordered, which will facilitate this process. Production of krypton generators continued according to the well-established delivery schedule on Mondays, Wednesdays and Fridays.

Research Production

Production of labelled neuroreceptor ligands for use in research projects by the Neurobiology Research Unit at Rigshospitalet continued in 2008 (see table). [¹¹C]PIB, the Alzheimer tracer, was used extensively in 2008, including a trial comparing the tracer with a fluorine-18 labelled analogue, which is produced at Risø DTU, National Laboratory for Sustainable Energy. As in previous years we continued to produce [¹¹C]DASB, [¹¹C]SB207145 and [¹¹C] Flumazenil for neuroreceptor studies and [¹³N] Ammonia for cardiac blood flow measurements and [¹⁵O]Water for cerebral blood flow measurements.

Radiopharmaceutical Development

Collaboration with The Neurobiology Research Unit, Rigshospitalet and the Department of Medicinal Chemistry at the Danish University of Pharmaceutical Sciences under CIMBI (Centre for Integrated Brain Imaging) continued in 2008. The main focus is on the development of serotonin agonist ligands for PET. A post-doc in synthetic organic chemist and a Ph.D. student are working on this project mainly at the Danish University of Pharma-

ceutical Sciences. A promising lead compound, [¹¹C]Cimbi-5 was evaluated in 2008 and several analogues will be developed and tested in 2009. In collaboration with Neurosearch A/S the alpha-7 nicotinic acetylcholine receptor ligand [¹¹C]NS12857 was synthesised and initial in vivo evaluation was performed.

[¹⁸F]FALGEA, a labelled peptide for imaging the epidermal growth factor tyrosine kinase receptor (EGFR) was developed in the department in collaboration with the Department of Radiation Biology at Rigshospitalet and The Department of Natural Sciences, University of Copenhagen and evaluation in a rat tumour model commenced in 2008 and will continue in 2009.

Several tracers were produced in 2008 for animal PET studies at the Cluster of Molecular Imaging at The Panum Institute. The cell proliferation tracer, [¹⁸F]FLT, was synthesised and is currently being validated for human use. An application will be sent to The Danish Medicines Agency in 2009.

From Risø DTU we obtained ⁶⁴CuCl₂, which was used in the synthesis of the hypoxia tracer ⁶⁴Cu-ATSM, potentially useful for radiotherapy planning. The amino acid analogue cis-4-[¹⁸F]fluoro-L-proline was synthesised and used for assessment of exercise-induced changes in collagen formation in rat skeletal muscle and tendon.

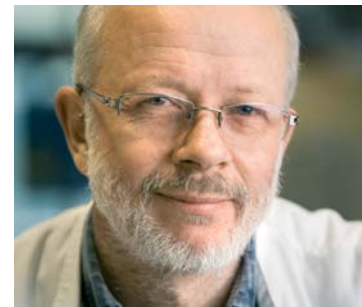
A potential therapeutic drug was labelled with carbon-11 ([¹¹C]TT1) and tested in vivo in collaboration with the biotechnology company Topotarget. Other similar compounds will be tested. Synthesis of the peptide ⁶⁸Ga-DOTA-TOC, an analogue of octreotide, was established. ⁶⁸Ga-DOTA-TOC will be used for imaging studies of somatostatin receptors in neuroendocrine tumors. PET tracers are also currently under development for measurement of processes such as apoptosis and angiogenesis.

Nic Gillings and Jacob Madsen

Radiopharmaceutical	Batches released for human use			
	2005	2006	2007	2008
[¹⁸ F]FDG	235	256	268	369
^{81m} Kr Generator	approx. 800	694	869	885
[¹⁸ F]Altanserin	40	42	36	18
[¹¹ C]DASB	17	47	49	11
[¹¹ C]SB207145	-	3	20	44
[¹¹ C]PIB	-	-	-	39
[¹¹ C]Flumazenil	-	-	1	2
[¹³ N]Ammonia	75	97	67	23
[¹⁵ O]Water	195	176	62	146
Radiopharmaceutical	Batches produced for animal/ invitro studies			
	2005	2006	2007	2008
[¹⁸ F]FLT	-	-	-	15
Cis-4-[¹⁸ F]fluoro-proline	-	-	-	6
⁶⁴ Cu-ATSM	-	-	10	10
[¹⁸ F]FALGEA	-	-	-	5
[¹¹ C]Cimbi-5	-	-	-	11

Summary of radiopharmaceutical productions in 2008

PET and PET/CT Scanners



During 2008, the installed equipment base of the PET and Cyclotron Unit counted two stand-alone PET scanners and three combined PET/CT scanners in the hospital itself. We are also involved in the experimental work with PET and CT at Cluster for Molecular Imaging at the Faculty of Health Sciences at the University of Copenhagen.

The oldest PET scanner still in use for patients is a GE Advance, installed in 1993 as the first of its kind in Europe. It has proven to be an extraordinarily well-designed and stable device, which can still make clinical images of adequate high quality. From a technical point, however, it has long passed the "end-of-life" limit set by the manufacturer, and it may eventually become difficult to maintain. During 2008 it has performed a large number of brain scans, clinical routines as well as receptor research studies. The ammonia heart perfusion studies were made here, but only very few whole-body PET scans. Currently, longitudinal projects that were started on the GE Advance are being finished here to avoid the potential influence on the results by a change in scanner.

New brain projects in general are initiated on our dedicated brain scanner, the HRRT (for High Resolution Research Tomograph). Originally intended - as the name indicates - mainly for re-search, the HRRT has now also become a clinically useful instrument. Designed in cooperation by several research groups in Europe and USA, and built by CTI in Knoxville, Tennessee (a company now owned by Siemens) the HRRT project has a 10-year long history that finally resulted in the building of one series of 18 instruments; the Copenhagen installation is among the last of these, but nevertheless at the front in application. Technically, the HRRT has a record high

number of detector crystal elements (119.808). The enormous amount of data these detectors create has always been a major challenge, but the continuous improvement in computer performance has now reached a level where image reconstruction time is comparable to the acquisition time. The images provide a resolution of 2-3 mm in the full field of view by standard reconstruction methods, but using improved reconstruction software (PSF-based) this can be reduced to 1.5-2 mm. The local implementation of these methods was made by Merence Sibomana (consultant) and Sune Keller (postdoc) who also (with support from Siemens) are organizing the collaboration and meetings of the HRRT user community world-wide.

The important task of patient motion supervision and correction is being addressed in a ph.d. project by Oline Vinter Olesen who graduated in 2008 with a masters thesis made on the HRRT.

The majority of studies in the PET department continue to be FDG whole-body scans for cancer diagnosis, staging, planning and follow-up. These scans are normally performed with the use of combined PET and CT. Our first PET/CT scanner is a GE Discovery LS, where the PET is a slightly updated version of the Advance PET scanner. The Discovery LS was installed in the autumn of 2001 as the second PET/CT in Europe. In the combined PET/CT examination, the CT scan is used both as a full diagnostic quality CT (including contrast media) and for attenuation correction of the PET images.

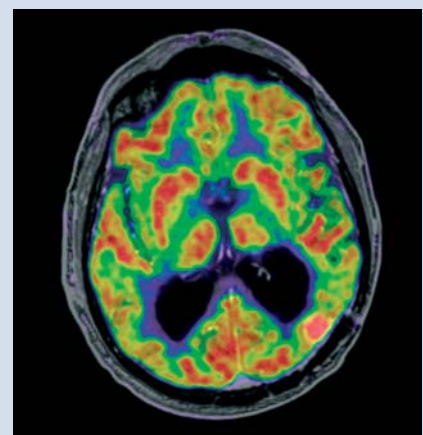
Our second PET/CT, installed in 2005, is a Siemens Biograph with 16-slice CT. It is run in a unique well-functioning collaboration with the Department of Radiotherapy, and it is extensively used for therapy planning.

A third PET/CT scanner was installed in November 2007 in the new extension of the Finsen building. It has a CT scanner with 40 slices and the PET axial field of view is extended (in round figures) from 15 to 20 cm. This apparently minor change increases the overall sensitivity by 78% that can be used to obtain (a combination of) lower doses, faster scans and improved images.

In the Cluster for Molecular Imaging, we maintain the old GE 4096 PET scanner (suitable for larger animals, e.g., pigs), and research scanners for PET and CT of small animals. The PET is a Focus 120 with resolution well below 2 mm, and the CT is a MicroCAT II, with an ultimate 15 μ resolution.

Much effort has been spent in planning and performing a large-scale national tender for PET/CT, with the intension of acquiring a total of 13 scanners for a nationwide upgrade in the field of cancer diagnostics. One of these scanners, a Siemens Biograph with 64-slice CT is scheduled for installation in our department during the spring of 2009.

Søren Holm



PET/CT scanning



Positron emission tomography and its usefulness in oncology are well established. With the introduction of the combined PET/CT scanners, a new world has opened with exciting possibilities.

We perform the CT scans of PET/CT as high quality diagnostic scans using oral and intravenous contrast media. When reading the scans, we describe the PET and the CT scans separately before reading the fused images and giving a final, combined conclusion taking both examinations into account. This provides the clinician with a more precise PET result, a better CT result, and also a more useful conclusion. The CT result improves in quality because the PET result can help depicting the small tumours that could easily have been overlooked even by a trained radiologist's eye. Finally, the combined PET/CT conclusion is superior to both scan results alone. Furthermore, the patient is spared from an extra CT examination at The Department of Radiology as well as an extra radiation dose.

We cooperate closely with The Department of radiotherapy on the use of PET/CT for treatment planning of cancer and we do more than 700 PET/CT scans for radiotherapy every year. The advantages are numerous: the anatomical localisation and the metabolic activity of the tumour are defined, and the tissue heterogeneity can then be taken into account when choosing radiation technique and energy, and only one scan is necessary. Two of our PET/CT scanners have the possibility of performing PET/CT scans for radiotherapy planning. The nuclear medicine specialist delineates the viable tumors depicted by PET on the fused PET/CT images after interpretation together with the radiologist. The regions are exported to the radiation dose planning system together with the CT scan, and the information is incorporated in the treatment planning. Research in this field is necessary, and we have conducted trials with nasopharyngeal and cervical cancer and malignant lymphoma with encouraging results. PET/CT for radiotherapy planning is now used routinely for patients with cervical, head & neck, lung-, oesophageal-, cardia-, rectum- and anal cancer as well as malignant lymphoma and mesothelioma.

We have just started a new study using 4D-PET/CT for radiotherapy planning for lung cancer. It is surprising how much the tumour changes morphology during respiration, and we are eagerly awaiting the results!

Working with PET/CT every day, we are convinced of the usefulness of PET/CT in clinical work as well as in clinical research. However, the introduction of any kind of new modality requires clinical trials to verify the usefulness of the method.

Annika Loft Jakobsen & Anne Kiil Berthelsen



Patient Investigations

CNS and peripheral nervous system

Regional cerebral bloodflow, rest, ¹⁵ O-H ₂ O	16
Regional cerebral bloodflow, physiological, ¹⁵ O-H ₂ O	81
Regional cerebral metabolism, ¹⁸ F-FDG	198
Regional cerebral metabolism, ¹⁸ F-Altanserin	12
Regional cerebral receptor, stat., ¹¹ C-DASB	12
Regional cerebral receptor, stat., ¹¹ C-SB	44
Regional cerebral receptor, stat. ¹¹ C-PIB	36
Regional cerebral receptor, dyn. ¹⁸ F-AH110690	6
Regional cerebral receptor, dyn., ¹¹ C-FMZ	2
Total	407

Respiratory organs

Lung function test, whole body plethysmography	1.188
Lung function test, whole body plethysmography w/reversibility	109
Lung function test, spirometry, WLHLB +WL1LB	1.007
Lung function test, spirometry w/reversibility	84
Lung function test, spirometry, physiological provocation	1
Lung function test, diffusioncapacity (CO)	2.341
Lung function test, peak flow w/reversibility	1
Lung perfusion scintigraphy, ^{99m} Tc-MAA	188
Lung perfusion scintigraphy, regional, ^{99m} Tc-MAA	66
Lung perfusion scintigraphy, Spect, ^{99m} Tc-MAA	84
Lung ventilation scintigraphy, Spect, ⁸¹ Kr-gas	69
Lung ventilation scintigraphy, ^{99m} Tc-DTPA	1
Lung ventilation scintigraphy, ^{81m} Kr-gas	181
Lung ventilation scintigraphy, regional, ^{81m} Kr-gas	118
Mucociliary clearance, ^{99m} Tc-venticolloid	34
Total	5.472

Heart and cardiovascular system

Isotope cardiography, first pass, ^{99m} Tc-HSA	71
Isotope cardiography, LVEF, ^{99m} Tc-HSA	1.427
Isotope cardiography, LVEF + vol., ^{99m} Tc-HSA	6
Myocardial perf. scintigr. gated, ^{99m} Tc-MIBI, pharmacol. stress, dipy.	35
Myocardial perf. scintigr. gated, ^{99m} Tc-MIBI, pharmacol. stress, dobut.	8
Myocardial perf. scintigr. gated, ^{99m} Tc-MIBI, pharmacol. stress, adeno.	132
Myocardial perf. scintigr. gated, ^{99m} Tc-MIBI, physiological stress	53
Myocardial perf. scintigr. gated, ^{99m} Tc-MIBI, NTG	203
Myocardial perf. scintigr. gated, ^{99m} Tc, MIBI	11
PET myocardial perfusion, ¹³ N-NH ₃	11
PET myocardial perfusion, ¹³ N-NH ₃ , pharmacol. stress, dipy.	11
PET myocardial perfusion, ¹³ N-NH ₃ , cold press, phys. stress	2
Exercise electrocardiography	16
Total	1.986

Peripheral vessels

Isolated limb perfusion leakage monitoring, chemotherapy	14
Total	14

Gastrin intestinal tract, including liver, biliary tract and pancreas

Bleeding scintigraphy (abdomen), ^{99m} Tc-erythrocyt	1
Biliary tract scintigraphy, ^{99m} Tc-Mebrofenin	16
Meckels diverticulum scintigraphy, ^{99m} Tc-pertechnetat	1
Total	18

Kidneys and urinary tract

Glomerular filtration, ⁵¹ Cr-EDTA, several samples	201
Glomerular filtration, ⁵¹ Cr-EDTA, one sample	3.729
Renal scintigraphy, ^{99m} Tc-DMSA	10
Renography, ^{99m} Tc-MAG ₃ , diurese	14
Renography, ^{99m} Tc-MAG ₃ , Dual head	1
Renography, ^{99m} Tc-MAG ₃	1.804
Renography, ^{99m} Tc-MAG ₃ , ACE-inhibitor	138
Renography, ^{99m} Tc-DTPA	12
Total	5.909

Bone and joint

Bone scintigraphy, ^{99m} Tc-HDP, regional, static	132
Bone scintigraphy, ^{99m} Tc-HDP, whole body, static	940
Bone scintigraphy, ^{99m} Tc-HDP, SPECT	18
Bone scintigraphy, ¹⁸ F-florid, whole body, static	2
Total	1.092

Endocrine organs

Thyreoide scintigraphy, ^{99m} Tc-pertechnetat	425
Thyreoide scintigraphy, ¹²³ I-jodid	2
Iodine absorption gl. thyreoide ¹³¹ I-jodid	1
Parathyreoide scintigraphy, ^{99m} Tc-MIBI, SPECT + CT	64
Tumorscintigraphy, ¹²³ I-jodid	47
Wholebody scintigraphy, diagnostic ¹²³ I-jodid	25
Adrenal marrow scintigraphy, ¹²³ I-MIBG	101
Whole body scintigraphy after ¹³¹ I-therapy	101
Total	766

Blood and lymph system

Erythrocyt volume, ^{99m} Tc-ery	15
Plasma volume, ¹²⁵ I, S-albumin	13
Lymph scintigraphy, extremities, ^{99m} Tc-HSA, stases	1
Lymph scintigraphy, extremities, ^{99m} Tc-nanocolloid, stases	1
Sentinal node, tumor drainage, ^{99m} Tc-nanocolloid	45
Sentinal node scintigr. tumor drainage, mamma c., ^{99m} Tc-nanocolloid	16
Sentinal node scintigr. tumor drainage, malign. mel., ^{99m} Tc-nanocolloid	125
Sentinal node scintigr. tumor drainage, penile c., ^{99m} Tc-nanocolloid	10
Sentinal node scintigr. tumor drainage, vulva c., ^{99m} Tc-nanocolloid	6
Peritumoral injection of ^{99m} Tc-nanocolloid for sentinel node operation	533
Spleen scintigraphy, ^{99m} Tc-erythrocyte, heated	4
Total	769

In vitro analysis

Plasma thyroglobulin	983
Total	983

Other diagnostic procedures

Aprotinin scintigraphy, ^{99m} Tc-aprotinin	12
Tumor scintigraphy, ¹¹¹ In-Octreotide	237
PET tumor scanning, ¹⁸ F-FDG	3.135
PET infection scanning, ¹⁸ F-FDG	83
PET tumor scintigraphy, ¹⁸ F-Cholin	4
White blood cell scintigraphy, ^{99m} Tc	1
White blood cell scintigraphy, ¹¹¹ In	147
Whole body, ⁵⁹ Fe in meal	54
Whole body, contamination measurement	40
Image fusion (PET, SPECT, MRI, CT or planar), PET and KF-section	3.488
Diagnostic CT, PET	2.689
Diagnostic CT, KF	8
CT scanning, perfusion	24
CT-therapy scanning	595
Description of external PET and PET/CT investigations	49
Digitilization PET images	21
First pass ¹⁸ F-FDG tumor scans	2
Total	10.589

Radiotherapy

Treatment with ¹³¹ I, benign thyroid	51
Investigation without specification	8
Isotope treatment with Zevalin ⁹⁰ Ytrium	1
Supplementary/repeted imaging, PET and KF-section	1.008
Total	1.068

Total number of patient investigations: 29.073

Animal Studies

Rats	¹¹ C chemotherapeuticum	10
	¹⁸ F-proline before	60
	¹⁸ F-proline after	60
	⁶⁴ Cu-ATSM	10
	⁹⁹ Techetium nanoparticles	2
	¹¹¹ Indium IC2 antibody	5
Mice	¹⁸ F-FDG	264
	¹⁸ F-FLT	118
	⁶⁴ Cu-ATSM	100
	⁶⁴ Cu-Dotatate	20
Pigs	¹¹ C PIB	4
	¹¹ C PIB validation	6
Dogs	⁶⁴ CU sarcom	6

Total number of animal studies: 665

Finance

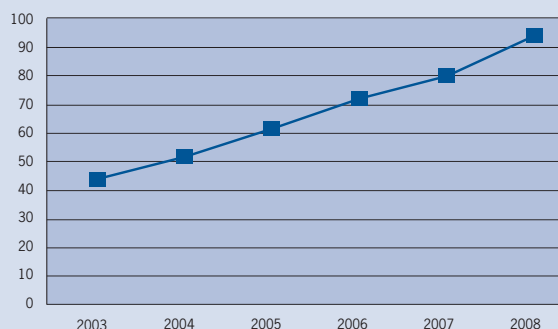
BALANCE 2008

Expenditure

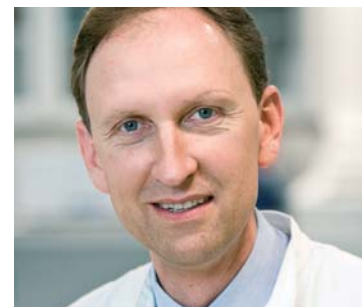
Running costs	DKK	17.6 million
Staff	DKK	33.1 million
In total	DKK	50.7 million

Receipts	DKK	17.2 million
Net sum	DKK	33.5 million

TURNOVER 2003-2008



Research



The department has an extensive research programme and works in collaboration with several national and international partners. Our research focuses on the development of new tracers for PET and nuclear medicine, on clinical evaluation of new diagnostic methods, and on the use of methods from clinical physiology and nuclear medicine to study pathophysiology. At present, special attention is given to translational research in the area of molecular imaging and we conduct extensive research based on the principles behind molecular imaging. Current areas of major research are detailed below.

Development of new tracers

A series of projects aimed at development of new, specific tracers for non-invasive tissue characterization to be used for the diagnosis of different cancer types as well as for planning and monitoring of therapy are currently underway. These projects, most of which are translational in nature, are carried out in collaboration with other departments and laboratories, since they are dependent on expertise in molecular biology, chemistry, radiochemistry, cancer biology and imaging. In collaboration with a pharmaceutical company and supported by the Danish National Advanced Technology Foundation, a molecular imaging platform for testing of new anti-cancer drugs is being developed.

Clinical PET and PET/CT

A series of prospective protocols are being used to evaluate the diagnostic and prognostic value of PET and PET/CT in different forms of cancer in children and adults. The use of PET/CT for the planning of radiation therapy (IMRT) and the use of respiratory gating are also being evaluated.

Pediatric nuclear medicine investigations

The department conducts many pediatric investigations. Several research protocols with the use of PET and SPECT are carried out in cooperation with clinical departments, particularly oncology.

Neuro PET

With the use of PET/CT, including HRRT, studies on brain tumors are undertaken. In addition, imaging of dementia with new tracers is currently studied. In cooperation with Neurobiology Research Unit and Centre for Integrated Molecular Brain Imaging, neuro receptor ligands have been developed and used for research in neurobiology. The focus has mainly been on the serotonergic system.

Atherosclerosis

With the use of PET/CT, methods non-invasive imaging of atherosclerosis and prediction of vulnerability of atherosclerotic plaques are undertaken in different groups of patients.

Nuclear cardiology

With the use of PET, coronary flow regulation is studied in connection with gene-therapy and pharmacological interventions in a variety of disease stages. With the use of SPECT /CT the development of ischaemic heart diseases is studied in selected groups of patients.

Lung studies

Research is being conducted into mucociliary clearance of the nose and lungs; Lung function testing and lung scintigraphy in different patient groups, eg. lung transplantation; The value of combined use of SPECT/CT for diagnosing pulmonary embolism. Animal experiments investigating

deposition characteristics are other examples of current lung research.

Radionuclide treatment

Localized radiation therapy using specific ligands binding to certain cancer forms is currently being implemented. The department takes part in research within this area by testing new ligands and producing relevant isotopes. Cancers that are currently being targeted include certain types of lymphoma, ovarian cancer and neuroendocrine tumors. Treatment will in part be based on imaging using new tracers for molecular profiling.

Whole body Counting

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

Andreas Kjær

Cluster for Molecular Imaging

The move towards individualized, tailored therapy has led to an increasing need for diagnosing disease at the cellular and molecular level. Most of the molecular biology methods used today need tissue sampling for in vitro analysis. In contrast, molecular imaging diagnostics at the cellular and molecular level is performed non-invasively in the living, intact organism. With PET it is possible to label a whole new group of biomolecules with radioactive isotopes to be used for visualization of, for example, metabolism, receptors and gene expression. Especially within cancer biology – but not limited to this – these techniques are expected to lead to a breakthrough in the diagnosis and treatment of disease. Of the different methods for molecular imaging only those techniques based on nuclear medicine are of a true translational nature; in other words methods developed in animal models may directly be transferred to and used in humans. Tailored therapy requires a thorough characterization of tissue, for example tumour and metastases. Ideally this characterization could be achieved non-invasively using PET.

Our current molecular imaging research programme is aimed at using molecular biology and imaging techniques in both

animals and humans to develop, evaluate and deploy non-invasive molecular imaging for human tissue characterization. This would enable the planning of individualized, tailored therapy.

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

Main steps involved in tracer development and use

- Selection of key processes involved in the pathophysiology of the disease
- Definition of relevant molecular targets of the key processes Design of specific ligands
- Radioactive labeling of ligands
- Test of imaging ligands in animal models
- Use of imaging data for therapy planning (e.g. IMRT or radionuclide therapy) and monitoring of response
- Use for diagnosing, therapy planning and monitoring in patients

Through the formation of the Cluster for Molecular Imaging at the Faculty of Health Sciences, University of Copenhagen (headed by Professor Andreas Kjær) it has been

possible to establish a core facility at the Panum Institute for molecular imaging in animals with PET, SPECT and CT. This has improved our translational capacity since we are now able to test new tracers in animal models prior to clinical use.

Furthermore, we are the molecular imaging partner of the European Advanced Translational Research Infrastructure in Medicine (EATRIS) under the European Union's 7th Framework Programme.

Currently the main focus of the translational research is non-invasive tissue characterization in cancer and cardiovascular diseases models to study pathophysiology and to develop the diagnostic tools for selection, planning and monitoring of tailored therapy.

Some tissue characteristics currently targeted for imaging

- Hypoxia
- Angiogenesis
- Apoptosis
- Cell proliferation
- Glycolytic activity
- Receptor expression

Andreas Kjær



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As in previous annual reports we have chosen to list scientific papers, and not the many abstracts and proceedings from the department.

Scientific Collaboration

Professor Andreas Kjær is partner in the “Danish-Chinese Center for Proteases and Cancer” funded by the Danish National Research Foundation.

A group of Danish scientist from Aarhus University (headed by Senior Lecturer Peter Andreasen, the Institute of Molecular Biology) and Rigshospitalet (among which Professor Andreas Kjær is one) has established a collaboration with a group of Chinese scientists to strengthen cancer research, leading to tailored treatments for cancer patients. The collaboration has emerged a large donation from the Danish National Research Foundation of 16 mio. DKK for three years to establish this virtual scientific center.

Professor Andreas Kjær has been appointed by the Ministry of Foreign Affairs in Denmark to participate in the Danish-Chinese “Partnership for joint benefit”. The Danish Government has launched an Asian strategy; an action programme for a strengthened and concerted effort in China. The focus areas are climate, energy and environment, science, innovation and education. In September 2008 Andreas Kjær and the Danish Consul of Science and Innovation in China was invited to Shuguang Hospital in Shanghai for discussions on research collaborations.

In April 2008 Professor Andreas Kjær was invited to give a lecture on “Molecular Imaging of Neuroendocrine Tumors” at the Memorial Sloan-Kettering Cancer Center in New York. The visit was part of a Neuroendocrine Tumor Research Exchange program between the Nordic Countries and the US, also visiting Yale University, New Haven and Massachusetts General Hospital in Boston.



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Center for integrated
molecular brain imaging

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

In cooperation with the Neurobiology Research Unit, Professor Gitte Moos Knudsen and Professor Olaf B. Paulson, a series of neuroreceptor ligands are developed and used for research in neurobiology. The focus has mainly been on the serotonergic system. In 2005 Gitte Moos Knudsen received a grant from the Lundbeck Foundation and established CIMBI; “Center for Integrated Molecular Brain Imaging”, where we are proud to collaborate on the PET studies.



MSc in Medicine and Technology

In cooperation with the Technical University of Denmark (DTU) and the University of Copenhagen (KU), the department represented by Professor Liselotte Højgaard has been involved in planning the new MSc programme in Medicine and Technology, which was implemented on September 1th, 2003 as a five-year bioengineering degree at Bachelor and Master's level. The first Masters graduated in 2008 with a big party celebrating the first candidates at DTU on September 19th, 2008.

Since the launch of the programme in 2003 more than 200 students have applied for the 60 available places each year. You can read more about the course at www.medicin-ing.dk

MSc in Medicine and Technology

Today's healthcare sector is facing complex problems at the crossroads between medicine and technology that can only be solved by teams of doctors, engineers, physicists, nuclear medicine technologists, nurses, radiographers, computer scientists and chemists. The Medicine and Technology programme equips the student with broad health-related knowledge together with classical technical engineering expertise. Medicine and Technology engineers will be able to occupy positions in hospitals, research institutions and the medical industry in general.



Grants and Awards

From the John and Birthe Meyer Foundation 20.5 mio DKK for an HRRT dedicated brain PET scanner.

Søren Holm has received the Prize of Honour 2008 from the Danish Society of Clinical Physiology and Nuclear Medicine.

Ian Law has received 25.000 DKK from the "Physicians Insurance Society of 1891" and 30.000 DKK from the "Grants of Højmosegård". Both grants have been given for the research project "Functional characterization of Brain Tumors".

Ron Kupers has received a grant of 1.2 mio. DKK from the "Danish National Research Council" for the project "Cognition and crossmodal plasticity in the human brain following visual loss".

Tina Binderup, MSc Human Biology, PhD student, received a Young Investigator Award for her presentation at the World Molecular Imaging Conference, Nice, France in September 2008.

Anne Mette Fisker Hag, MSc Human Biology, received a Young Investigator Award for her presentation at the World Molecular Imaging Conference, Nice, France in September 2008.

Education



The Department of Clinical Physiology, Nuclear Medicine & PET participates in the pregraduate medical education at the Faculty of Health Sciences, University of Copenhagen within the fields of human biology, clinical physiology and nuclear medicine, theoretical physiology, and medical engineering. The department participates in the OSVAL programmes for medical students and the education of nuclear medicine technologists.

Regarding postgraduate education, the department contributes to the specialist education of doctors in clinical physiology and nuclear medicine in Denmark. Thus, the Oncology-, Cardiology-, Lung-, and Endocrinology-pathophysiology courses dedicated for the specialist education are all held at our department and arranged by chief physicians in the department. A high

number of PhD students are associated to the research activities in the department. All staff members participate in the department's educational activities. The Nuclear Medicine Technologists have participated in our dedicated CT courses, which include 80 lectures and tutorials. This allows our staff to be in charge of the PET/CT and SPECT/CT scanners also for the CT part. Their CT competence is officially acknowledged by the Danish National Agency for Radiation Protection.

The department performs extensive training programmes to staffs from other Nuclear Medicine and Radiological Departments in Denmark and the Nordic countries. Study visits to our facilities of physicians and nuclear medicine technologists for periods of weeks up to 6 months have been arranged.

Chief physician Peter Oturai is responsible for the postgraduate education of physicians in the department.

Clinical associate professor Jann Mortensen is responsible for the pregraduate education of medical students.

Peter Oturai & Jann Mortensen



Nuclear Medicine Technologists



The Nuclear Medicine Technologists take care of the daily radiopharmacy production and manage the daily clinical patient investigations in both nuclear medicine and PET. More over they also participate in research and development projects. They have co-responsibility for several projects and are involved in data management, quality assurance, patient and animal studies. The research results are disseminated through oral presentations and posters at both Danish and international meetings and symposia for technologists. We collaborate with CVU Øresund on research, training and development.

A numerous part of the department's Nuclear Medicine Technologists participated in the European Association of Nuclear Medicine Congress in Munich in October 2008. At the technologists' educational session Bente Dall gave a presentation on "A comparison of three different methods for measuring whole body radiation exposure", and the same presentation was also presented for the "Danish National Agency for Radiation Protection".

Our Nuclear Medicine Technologists are frequently asked to provide courses and give lectures either in Denmark, Scandinavia or at the PET/CT course in Vienna. In 2008 Nuclear Medicine Technologist Hanne Jørgensen was our representative teacher at EANM's PET/CT in Vienna and she gave lectures to radiographers and technologists at the diploma course in nuclear medicine at Metropolitan University College. Radiographer Elisabeth Abrahamsson was invited speaker at the ESTRO-meeting in Gothenburg presenting "Therapy PET/CT scanning, the nursing point of view". Nuclear Medicine Technologist Marianne Federspiel and Radiographer Elisabeth Abrahamsson were invited to give a lecture "Pediatric PET/CT and

SPECT/CT" at Great Ormond Street Hospital for Children in London.

Deputy Chief Nuclear Medicine Technologist Kate Pedersen, being a member of the EANM Technologist Committee, participated in the planning of the EANM courses in Vienna and gave lectures there as well. She was also invited speaker at the Turku PET Symposium 2008. Chief Nuclear Medicine Technologist Tim Lundy was in Rotterdam at the Erasmus University learning to treat patients with radiopharmaceuticals (Lu-177 Dotatate).

Education

The Nuclear Medicine Technologists have throughout the year participated in supplementary training and our technologists and radiographers were teachers at courses. Eight Nuclear Medicine Technologists participated in our own dedicated CT course, giving competence to perform PET/CT and SPECT/CT scanings. The course is officially recognized by the Danish National Agency for Radiation Protection.

Our Nuclear Medicine Technologists have participated in supplementary training: 2 participated in courses on radiotherapy planning, 2 participated in the the final GMP

courses, 3 took their bachelor diploma, 1 is taking her Master education, 1 Deputy Chief Nuclear Medicine Technologist has started his Master education.

The Danish Government has established a new framework for some health professional educations to be more interdisciplinary and modular split, including the education for Nuclear Medicine Technologists. 25 of these students have had 14 training modules during the autumn of 2008 at our Department and 3 have completed their BA, defending it in 2009.

Our Nuclear Medicine Technologists are a very dynamic, competent and responsible group with an important role for the continuous development of the clinic. They have all been involved in the rebuilding of the PET section and the implementation of 2 new scanners.

Research plays a very important role in our Department and many Nuclear Medicine Technologists and Radiographer participate in this field, regardless the research often takes place after daily work. Furthermore, they kindly gather up when the waiting list for patient investigations result in extended working hours in evenings and weekends.

Linda M. Kragh



Equipment

Equipment	Product	Purchase year
Gamma cameras	GE Millenium VG, Hawkeye, lowdose CT	2001
	Philips ADAC Thyrus	2001
	Philips ADAC Skylight	2002
	Mie-Scintaron	2004
	Mediso N-TH45-D	2004
SPECT/CT camera	Philips, Precedence 16-slice	2006
	Philips, Precedence 16-slice	2008
PET scanners	GE Advance	1993
	HRRT Siemens/CTI	2007
PET/CT scanners	GE Discovery LS	2001
	Siemens Biograph Sensation 16 (hirez)	2005
	Siemens Biograph TruV 40-slice CT	2007
Lung function	Jaeger Masterscreen w/bodybox	2005
	Jaeger PFT pro w/bodybox	2007
Whole body counter	WBC w/Nal counting chamber	1977
	WBC w/plast counting chamber	1978
Cyclotron	Scanditronix 32 Mev	1990
	RDS Eclipse cylotron, CTI	2005
NMR	Varian spectrometer 400 MHz	1993
Cluster for Molecular Imaging	SPECT Provivo, ADAC mobile	1990
	PET scanner GE 4096	1991
	SPECT Mediso Nucline X-Ring/R	2004
	Siemens Micro-PET Focus 120	2006
	Micro-CT Siemens Micro-CAT II	2006
	Phosper Imager Perkin Elmer cyclotrone	2007

The John & Birthe Meyer Foundation has donated all equipment in the PET and Cyclotron Unit.

Rigshospitalet is accredited by the Joint Commission International, an international American accreditation board.

We have worked on standards and politics, standard operation procedures, our quality handbook, patient informations and documentation. It has been an extensive task, and it has contributed to a positive improvement of the quality for the department.



Organization Accredited
by Joint Commission International

Other Activities

Anne Kiil Berthelsen, Chief Physician is a member of the "British Institute of Radiology" and a member of the Danish Lymphoma Group (DLG).

Lise Borgwardt, Senior Registrar is a member of the Tumorboard for "Pediatric Solid Tumors" at Copenhagen University Hospital, Rigshospitalet. External member of the guideline group for Pediatric PET under EANM and Chair of the "Pediatric Network Group" at Rigshospitalet and Chair of the "Pediatric Focus Group" at the Department of Clinical Physiology and Nuclear Medicine & the PET and Cyclotron Unit.

Christina Winkler Dümcke, Senior Registrar is a member of the course committee at the Danish Society of Clinical Physiology and Nuclear Medicine.

Nic Gillings, Chief Radio Chemist is a member of the management committee of the EU COST Action B12 programme: "Radiotracers for in vivo assessment of biological function".

Jesper Graff, Chief Physician is representative in "Vurderings- og Ansættelsesudvalget" in Clinical Physiology & Nuclear Medicine under the Danish Society of Clinical Physiology and Nuclear Medicine.

Birger Hesse, Chief Physician is a member of the "European Council of Nuclear Cardiology" (ECNC) and Chair of The Medical Research Library at Rigshospitalet. Member of the "Cardiovascular Committee, EANM" and Head of "Corelab for myocardialscintigraphy". Editorial board in Eur J Nucl Med & Molec Imag, Curr Med Imag Rev, Eur Ass Nucl Med Cardiovascular Com and Eur Council Nucl Cardiol Board. Member of the Advisory Committee of International Conference on Nuclear Cardiology 2009.

Søren Holm, Chief Physicist is President of the Danish Society for Medical Physics (DSMF), member of the Educational Board of DSMF and a delegate for the DSMF at the "European Federation of Organizations in Medical Physics" (EFOMP). Member of an IAEA advisory group concerned with QA/QC and image artefacts affecting quantitation in PET/CT. Member of "Sundhedsfagligt Råd i Klinisk fysiologi og Nuklearmedicin" in the Capital Region, the Specialty Advisory Committee (SFR) in Clinical Physiology & Nuclear Medicine. External lecturer at Copenhagen University.

Professor Liselotte Højgaard, Head of Department, is Chair of the Standing Committee of the European Medical Research Councils (EMRC), at the European Science Foundation, Strasbourg and member of the Science Advisory Board, the

European Science foundation. Member of the "Danish Council for Research Policy". Chair of the Council for "Medical Museion" (Museum of the History of Medicine in Copenhagen). She represents the University of Copenhagen and Rigshospitalet in the programme, MSc in Medicine and Technology in cooperation with The Technical University of Denmark (DTU). Member of ATV "The Danish Academy of Technical Sciences".

Annika Loft Jakobsen, Chief Physician is a member of the "European Organisation for Research and Treatment of Cancer" (EORTC), the Functional Imaging Group and "The British Institute of Radiology". Member of the EANM, AML, BIR and Oncoradiological Society and chair of the Diagnostic Imaging Group under Danish Lymphoma Group (DLG) and member of the guideline group for Pharyngeal/Laryngeal Cancer.

Professor, Andreas Kjær, Chief Physician is the President of the "Scandinavian Society of Clinical Physiology & Nuclear Medicine" (SSCP-NM). Past-president of the board of "Selskabet for Teoretisk og Anvendt Terapi" (the Society for Theoretical & Applied Therapy). Member of "Forskningsrådets formandskab" (The Research Council) at Rigshospitalet. Member of the Scientific Committee of the Danish Cancer Society. He is leader of the project "Molecular Imaging for Testing of New Drugs" funded by the Danish National Advanced Technology Foundation. Steering Committee member and partner of EATRIS (the European Advanced Translational Research Infrastructure in Medicine) under the EU 7FP. Head of the Graduate School for Molecular Imaging and head of Cluster for Molecular Imaging at the Faculty of Health Sciences, University of Copenhagen.

Linda M. Kragh, Chief Nuclear Medicine Technologist, is a member of "Sundhedsfagligt Råd i Klinisk fysiologi og Nuklearmedicin" in the Capital Region, the Specialty Advisory Committee (SFR) in Clinical Physiology and Nuclear Medicine", member of "Uddannelsesrådet for Bioanalytikeruddannelsen i Storkøbenhavn" in the Capital Region (the speciality council for the education of laboratory technologists) and member of the "Danish Society for Clinical Physiology and Nuclear Medicine".

Ian Law, Chief Physician is a member of the Board of the Medical Society and member of the Referencegroup MTV regarding dementia under the National Health Service. Member of the Research Council at Copenhagen University Hospital, Rigshospitalet. He is responsible for the "Brain imaging" and "Oncology" specialist course for nuclear medicine physicians and member of the guideline group for Sarcoma.

Jann Mortensen, Clinical Associate Professor, Chief physician is a member of the board of "Dansk Endokrinologisk Selskab" (Danish Society of Endocrinology) and the steering committee of "Dansk Lungecancer Gruppe" (Danish Lung Cancer Group). Member of the sub-committees for "Dansk Diagnostisk Lungecancer Gruppe" (Danish Diagnostic Lung Cancer Group) and "Lungecancer Screeningsgruppen" (Screening of Lung Cancer Group). Member of the supplementary training committee of the Danish Society of Clinical Physiology and Nuclear Medicine and substitute for the board of the Danish Society of Clinical Physiology and Nuclear Medicine. Member of the National Working Group for planning clinical guidelines for Lung Cancer workup and the Regional Working Group for implementation of clinical guidelines for Breast Cancer workup. He is responsible for the specialist course in "Clinical Respiratory Physiology" for nuclear medicine physicians and respiratory physicians. Section editor of The Clinical Respiratory Journal.

Kjell Å Någren, Senior chemist is a member of the EANM Neuroimaging Committee.

Peter Oturai, Chief Physician, is responsible for the postgraduate education. He is a member of the board and Vice President of the "Danish Society for Clinical Physiology and Nuclear Medicine (DSKFNM)". A representative for DSKFNM in the "Danish Medical Society" (Dansk Medicinsk Selskab). Danish delegate, representing DSKFNM, in the "European Association of Nuclear Medicine", in the "European Union of Medical Specialists" (UEMS), and in the "World Federation of Nuclear Medicine and Biology". Member of the "UEMS/European Board of Nuclear Medicine - Accreditation of Nuclear Medicine Training Centres Committee". He has been a member of the "National Board of Health working group" defining Clinical Physiology and Nuclear Medicine in Denmark.

Kate Pedersen, Nuclear Medicine Technologist is a member of the Technologist Committee under EANM and member of "Udvalget for Ledende og Afdelingsbioanalytikere i Region Hovedstaden under Dbio".

Andreas Pfeifer, is a member of the "European Endocrine Tumor Society" and the "Danish Society of Clinical Physiology and Nuclear Medicine".

European Medical Research Councils

The European Medical Research Councils (EMRC) is the membership organization of all the European medical research councils – for the EU member states, and for all the other European countries also.

Set up in 1971, the EMRC evolved into Standing Committee of the ESF in 1975. It covers broad range of disciplines and the Committee's objectives range from promoting interactions between the biological, biomedical and clinical research communities to developing European scientific strategies and stimulating collaboration in emerging and interdisciplinary research areas.

In pursuing these objectives, the EMRC seeks to ensure that its strategy takes into account the variety of sources of funding available across Europe.

The chair of the Committee for the European Medical Research Councils is Professor Liselotte Højgaard from the Rigshospitalet, University of Copenhagen, Denmark.

The Standing Committee is composed of delegates with a high scientific profile nominated by their ESF Member Organisations involved in biomedical sciences, together with observers from the European Commission, Standing Committee for Life, Earth and Environmental Sciences (LESC): Canada, WHO-Europe, Israel, New Zealand and USA.

In 2008 EMRC disseminated the White Paper, "Present Status and Future Strategy for Medical Research in Europe". The White Paper has been quoted widely in the scientific literature. The highlight of 2008 was the annual meeting in London hosted by MRC at The Royal College of Medicine with visitors from the MRC in India and China, and a mini Conference about gender issues with endorsement of our statement about equal right for performing research in medicine.

The document was disseminated and the next step has been the Forward Look on "Investigator-Driven Clinical Trials". Further, we have worked very hard with the revision of the EU Animal Directive for Medical Research, where it is important that dignified research protecting animals for scientific purposes, can be performed without hindering the research possibilities, - for the benefit of health and wellbeing of the European citizens.



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Rigshospitalet, University of Copenhagen

Rigshospitalet, University of Copenhagen, was founded by King Frederik V in 1757. At present it has 1.200 beds, 8.000 employees and a budget of approximately 0.6 bio €. The research production is more than 1.400 publications per year, including approximately 80 higher academic degrees (PhD and doctoral of medical science). Rigshospitalet is part of The Capital Region of Copenhagen. www.rigshospitalet.dk

University of Copenhagen

University of Copenhagen, Faculty of Health Sciences was founded in 1479.
The University is member of The International Alliance of Research Universities.
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Rigshospitalet



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