Radiofysikdagar 2011

Ystad Saltsjöbad

14-15/11

Svensk Förening för Radiofysik

www.radiofysik.org

Program Radiofysikdagar 2011

Ystad Saltsjöbad, Skåne, Sverige

kl	**Måndag 14/11**
8.00-12.00	Kurs: Observatörsexperiment
10.00-12.00	Cheffysikermöte
12.00-13.30	Lunch
13.30-13.45	Välkommen Stefan Johnsson (Svensk Förening för Radiofysik)
	Session 1 – moderator: Anders Montelius, Uppsala
13.45-14.30	**Kurt Lidén-pristagare** Kerstin Ledenius (Göteborg) *Optimization of Paediatric CT Examinations*
14.30-14.45	Sara Asplund, J Vikgren, A Svalkvist, Å A Johnsson, M Boijsen, A Flinck, V Fisichella, Å Wiksell, J Ivarsson, H Rystedt, L G Månsson, S Kheddache and M Båth (Göteborg) *Observer performance studies on chest tomosynthesis at Sahlgrenska University Hospital: detectability of pulmonary nodules and observer learning effects*
14.45-15.00	Mattias Nickel and S Johnsson (Kalmar) *Experiences from risk assessment in diagnostic nuclear medicine*
15.00-15.15	Magnus Dustler, I Andersson, D Förnvik and A Tingberg (Malmö) *The effect of breast positioning on breast compression in mammography: a pressure distribution perspective*
15.15-15.30	**Bästa examensarbete 1** Patrik Brodin (Lund/Köpenhamn) *Radiobiological optimization including consideration of secondary cancer risk: A treatment modality comparison study for pediatric medulloblastoma.*
15.30-16.00	Kaffe
16.00-17.00	**Årsmöte** Svenska Sjukhusfysikerförbundet
	Spa, mingel, fördrink, etc.
19.30-	Middag

kl	**Tisdag 15/11**
	Session 2 – moderator: Tommy Knöös, Lund-Malmö
8.45-9.00	**Bästa examensarbete 2** Henrik Rydén (Göteborg/Freiburg) *Implementation and validation of robust Dixon methods for abdominal imaging at 3T.*
9.00-9.20	Sören Mattson (Malmö) *Current activities within ICRP regarding radiation protection in medicine*
9.20-9.40	Anders Sandell (Lund) *Cyklotroner och isotopproduktion - idag och i morgon*
9.40-10.00	Hunor Benedek (Lund) *Dosplansoptimering – vilken är den "bästa" planen?*
10.00-10.30	Kaffe
	Session 3 – moderator: Stefan Johnsson, Svensk Förening för Radiofysik
10.30-11.15	**Holger Sköldborn-pristagare** Tuvfe Nyholm (Umeå) *The role of MRI in radiotherapy – at present and tomorrow*
11.15-11.30	Stefan Johnsson, E Johansson, M Milrad, C Ceberg, F Nordström, S Wetterstedt and S Bäck (Kalmar, Lund, Malmö) *A national platform for comparison of independent dose calculations in radiotherapy – an on-line solution for iPAD and Android tablets*
	Rapport från nationella arbetsgrupper
11.30-11.45	Sigrid Leide Svegborn (Malmö) *Kvalitetskontroller på nuklearmedicinsk utrustning*
11.45-12.00	Jörgen Olofsson (Umeå) /Magnus Gustafsson (Göteborg) *Kvalitetssäkring av moderna strålbehandlingstekniker, spec. IMRT/VMAT*
12.00-13.30	Lunch
13.30-14.00	**Årsmöte** Svensk Förening för Radiofysik
	Session 4 – moderator: Stefan Johnsson, Svensk Förening för Radiofysik
14.00-14.45	**Kalle Viktorlöf-föreläsare** Leif Moberg (SSM)
14.45-15.00	Charlotte Lundh, T Mai, Å Cederblad and M Båth (Göteborg) *Real time visualization of dose rates in interventional radiology*
15.00-15.15	**Bästa examensarbete 3** Tobias Larsson (Lund/Köpenhamn) *Accuracy of MLC-tracking for inversely optimized arc therapy treatments of varying complexity for two MLCs.*
15.15-15.30	Avslutning

Optimization of Paediatric CT Examinations

K Ledenius[1]

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The absorbed dose to paediatric patients is important bearing in mind the increased risk of radiation-induced cancer due to exposure to X-rays at young ages. Questions have also been raised of whether a CT examination of the paediatric brain might lead to a reduction in cognitive function. Considering the difference in anatomy and thus in X-ray attenuation, children have a special need in CT image quality and require separate scanning protocols and thus separate optimization from adults.

The work performed at the Sahlgrenska Academy resulting in the thesis "Optimization of paediatric CT examinations" was in cooperation with the staff on the department of paediatric radiology and clinical physiology at the Queen Silvia Children´s Hospital in Gothenburg. The overall aim was to find an optimization approach to minimize the absorbed dose to paediatric patients undergoing CT examinations, while maintaining the diagnostic image quality and taking into account observer variability.

In a first study, the effect of reducing the tube current on the diagnostic image quality was evaluated for paediatric cerebral CT examinations using the non-parametric statistical method of inter-scale concordance. The observer variability was evaluated by means of Svensson's method in a second study. The approaches in these two studies were then combined in a third study to optimize the noise index in abdominal paediatric CT examinations. The aim of the fourth study was to estimate the variability in the results when using inter-scale concordance. A post-processing 2D adaptive filter, claiming to enable reductions in radiation exposure, was investigated in the third study, and in a separate fifth study.

For the cerebral CT examinations reductions in radiation exposure were possible for patients 1 to 10 years old. It was possible to further reduce the radiation exposure for shunt-treated patients. Noise index 11 was sufficient for a routine abdominal examination for patients aged 6 to 10 years, noise index 12 was considered sufficient for patients aged 11 to 15 years. The variability in results when using inter-scale concordance was less than 20 % between two studies regarding routine cerebral CT examinations. The post-processing filter enabled reductions in radiation exposure up to 15 %.

Observer performance studies on chest tomosynthesis at Sahlgrenska University Hospital: detectability of pulmonary nodules and observer learning effects

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In chest tomosynthesis a number of low dose projections, acquired within a limited angular range, are used to reconstruct an arbitrary number of section images of the patient. Thereby, the overlaying anatomy is largely reduced, allowing for better detectability than for ordinary radiographs. Since the projection images are collected at a very low dose level, the total radiation dose from a tomosynthesis examination is comparable to that from an ordinary radiographic examination.

Since December 2006, chest tomosynthesis has been used at our hospital. This presentation aims at describing three detection studies that have been performed during the initial years of use.

The first study was a comparison between tomosynthesis and radiography for detection of pulmonary nodules using experienced thoracic radiologists as observers. The observers had approximately 6 months of experience of tomosynthesis at the start of the first study. It was found that the detectability was significantly higher for tomosynthesis than for radiography. The sensitivity was increased especially for small nodules.

Since the observers had limited experience of tomosynthesis in the first study, the aim of the second study was to investigate the effect of additional clinical experience on their performance. The same cases were analyzed again after an additional year of experience of tomosynthesis. No significant improvement in detectability was found, which suggests that experienced radiologists can take advantage of the new technique after only a short period of experience.

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In the third study, the effect of learning with feedback was investigated for observers with varying degrees of experience of chest tomosynthesis. The detectability of pulmonary nodules was measured before and after a learning session, at which the observers were given feedback on their performance of a new set of tomosynthesis cases. The results showed that only observers inexperienced in tomosynthesis significantly improved after the learning session.

The results of the studies show that chest tomosynthesis is a valuable tool for detection of pulmonary nodules at a low cost in radiation dose, and indicate that it is possible to quickly take advantage of the technique – either after a short period of clinical experience or after learning with feedback.

Experiences from risk assessment in diagnostic nuclear medicine

M Nickel[*1], S Johnsson[1]

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Risk assessment, i.e. a systematic process of identifying and quantifying the probability of harmful effects, can be an effective tool for quality and patient safety assurance in health care.

A risk assessment was made for the process of diagnostic nuclear medicine and the risk associated with the unintentional exposure to ionizing radiation. The risk assessment was based on a method recommended by the National Board of Health and Welfare for use in patient safety work (*Riskanalys- och Händelseanalys*, Socialstyrelsen 2009, ISBN 978-91-86301-28-6).

The method utilizes scoring of two quantities: *severity* and *probability*. In addition, a third quantity, *detectability*, was included in accordance with other methods for risk assessment. For every identified risk, each quantity was given 1-4 points in accordance with the provided guides for scoring. The total risk score for each risk was then calculated as the product of the individual scores. It is recommended by the method that every risk with a total score of 8 or more always should be analyzed further.

Risks were identified throughout the entire process: handling of prescriptions, manufacturing of radiopharmaceuticals, administration of radiopharmaceuticals to patients and diagnostic imaging. Although several risks were identified, and despite a third quantity was included, no risk resulted in a total risk score greater than 4.

The main conclusion from this work is that it is not obvious how the risks associated with unintentional radiation exposure (in the dose range expected in diagnostic nuclear medicine) should be related to the quantity *severity*. While the scoring in health care generally relates to deterministic effects (i.e. death, disability and discomfort as a direct consequence), the main effects associated with exposure to low doses of radiation are stochastic (i.e. the *risk* of cancer induction). How should we compare a healthcare-associated infection to a 0.1% risk of cancer later in life?

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The Effect of Breast Positioning on Breast Compression in Mammography: a Pressure Distribution Perspective

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Standard procedure at mammography is to compress the breast in order to improve image quality, better separate superimposed tissue components and to reduce patient dose.

Traditionally, compression guidelines have been based on applied force, rather than actual thickness reduction, even though structures such as the pectoral muscle are stiffer than breast tissue and if compressed along with it, as in the MLO (Medio Lateral Oblique)-projection, might absorb much of the applied force. It can be hypothesized that excluding some parts of the pectoral muscle will lessen this effect.

This study investigated the difference in compression of breasts before and after they were repositioned to exclude 1 cm of the juxtathoracic part. Six women were included in this initial study, with more to be included before presentation. The distribution of compression pressure was measured using thin FSR (Force Sensing Resistor) pressure sensors attached to the compression paddle. Breast thickness and compression force was measured by the mammographic device. Pressure data was visually displayed in colour on the mammographic images to be able to relate it to breast anatomy.

In all six cases the breast was thinner and had a higher mean pressure distributed over a larger area after repositioning, though both before and after repositioning there was a significant concentration of force in a narrow band along the juxtathoracic edge of the breast. This indicates that the inclusion of the pectoral muscle and other juxtathoracic structures in the MLO-projection substantially affects pressure distribution and prevents compression of the breast. These results suggest that the positioning in the MLO-projection could be discussed in order to find a balance between effective compression and tissue inclusion.

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Radiobiological optimization including consideration of secondary cancer risk: A treatment modality comparison study for pediatric medulloblastoma

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The purpose of this Master's thesis study was to estimate and compare normal tissue toxicity and secondary cancer (SC) risks from 3D conformal radiotherapy (3D CRT), arc radiotherapy (ART) and intensity-modulated proton therapy (IMPT) for treatment of pediatric medulloblastoma (MB). The purpose was also to investigate the possibility of optimizing radiotherapy treatment with the aim of reducing normal tissue toxicity as well as the risk of SC.

Treatment plans of craniospinal irradiation (CSI) were generated with 3D CRT, ART as of the RapidArc implementation and spot-scanned IMPT. The patient material consisted of treatment records including CT- and MRI-scans of four males and six females aged 4 to 15 years old. Risks of SC or normal tissue toxicity induction were estimated and compared between techniques. The RapidArc plans were then re-optimized with the aim of limiting the dose to the organs contributing to the risk of SCs, the risk estimates were then re-analyzed.

The risks of normal tissue toxicity as well as SC were substantially lower for IMPT compared to the photon techniques. The risk of developing a solid SC from ART was higher than for 3D CRT but could be reduced with re-optimization. However, a later re-analysis of these results showed a slightly worsened coverage of the spinal target volume for the re-optimized plans, which has to be considered.

Having shown in this study that the estimated long-term risks of SCs and non-malignant toxicities can be substantially manipulated by tailoring the radiation dose distribution, we continued our investigation by trying to solve the question of how to compare different complications in an objective manner. Although it is clear that IMPT appears to be the best solution for these patients, without the ability to directly compare risks of various types of complications, the choice between the two photon techniques, which are what is practically available today, is not an obvious one.

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Implementation and validation of robust Dixon methods for abdominal imaging at 3T

M. Sc. Thesis in Medical Physics

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UNIVERSITY OF GOTHENBURG

UNIVERSITÄTS FREIBURG KLINIKUM

Sammanfattning på svenska

Fett uppträder ofta med hög intensitet på T1-viktade MR-bilder på grund dess korta T1-relaxationstid. Till följd av detta kan fett dölja patologisk information i bilderna och försvåra en medicinsk utvärdering. Separerade fett- och vattenbilder har flera användningsområden såsom attenueringskorrektion för kombinerad PET/MR, segmentering av visceralt och subkutant fett, och kvantifiering.

Det finns flera tekniker för att separera fett och vatten med MR-kameror, där Dixonbaserade metoder hör till de mest använda. En nackdel med Dixonmetoder är dess känslighet för B_0-inhomogeniteter, som är ett betydande problem, särskilt vid höga fältstyrkor.

I det här arbetet har tre avancerade Dionxmetoder (POP, ASR och GC) utvärderats vid 3T. Både rekonstruktionsparametrar och skannprotokoll har optimerats. För att jämföra metoderna kvantitativt har en ny metod föreslagits, där det subkutana fettratiot i de separerade bilderna jämförs med fettratiot uppmätt med MR-spektroskopi. Även mängden felregistrerade pixlar (swaps) har jämförts mellan metoderna. För att genomföra implementeringen och utvärderingen av metoderna har ett grafiskt användargränssnitt utvecklats i MATLAB.

Syftet med arbetet var att implementera en metod som gav pålitliga fettkvantifieringsresultat. Metoden med bäst resultat kommer att användas i en kommande studie på överviktiga barn.

Samtliga metoder visade bra resultat under optimala förhållanden, men skillnader mellan metoderna var mycket tydliga då mät- och rekonstruktionsparametrar ändrades. Metoderna varierade kraftigt i rekonstruktionstid. Bilderna rekonstruerade med ASR-metoden visade god överensstämmelse med fettratiomätningarna, inga felregistrerade pixlar under optimala förhållanden, samt en snabb rekonstruktionstid. Därför rekommenderas ASR-metoden för den kommande studien.

Current activities within ICRP regarding radiation protection in medicine

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The International Commission on Radiological Protection is an independent, international organisation with more than two hundred volunteer members from approximately thirty countries across six continents. Since 1928, ICRP has developed, maintained, and elaborated the International System of Radiological Protection used world-wide as the common basis for radiological protection standards, legislation, guidelines, programmes, and practice. ICRP has published more than one hundred reports on all aspects of radiological protection. The ICRP is organized in a Main Commission and five Committees. Most of the work is done in the Committees and their Task Groups: *Committee 1:* Radiation Effects. *Committee 2:* Doses from Radiation Exposures. *Committee 3:* Protection in Medicine. *Committee 4:* Application of ICRP Recommendations. *Committee 5:* Protection of the Environment.
Committee 3 is concerned with protection of persons and unborn children when ionising radiation is used for medical diagnosis, therapy, or for biomedical research. The committee is also responsible for the assessment of the medical consequences of accidental exposures. It has currently 16 members and a number of observers (from WHO, IEC, EC, IARC, ICRU, ILO, ISO). Committee 4 is concerned with providing advice on the application of the recommended system of protection in all its facets for occupational and public exposure.
The talk will describe the recent work carried out by the Committee 3 (12 publications in the period 2000-2010), the most recent publication ("Education and training in radiological protection for diagnostic and interventional procedures"), describe work in progress ("Radiological protection in paediatric diagnostic and interventional radiology", "Avoiding adverse radiation effects to doctors and patients in fluoroscopically guided procedures - practical guidelines", and "Patient and staff radiation protection in cardiology") and finally reflect the discussion about documents to be considered for the coming years. Input to this discussion will be highly appreciated.

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Dosplanoptimering – vilken är den ”bästa” planen

Hunor Benedek, M.Sc. [*1] , Kristoffer Petersson, M.Sc.[2]Tommy Knöös, Ph.D.[1,2], Crister Ceberg, Ph.D.[1,2], Per Nilsson, Ph.D.[1,2], [1] och Per Engström, Ph.D.

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Introduktion

Den tekniska utvecklingen inom radioterapin har varit enorm de senaste decennierna. Inte minst pga ökad datorkraft men även genom nya banbrytande innovationer. Det finns idag flera olika intensitetsmodulerade radioterapitekniker; med statiska fält (IMRT), med rotationsteknik (IMAT) och med spiralteknik (tomoterapi, TOMO). För kliniker med flera olika modaliteter är det viktigt att optimera resurserna så att de nya teknikerna används på bästa sätt och ger patienten den individuellt bästa möjliga behandlingen. För att göra detta möjligt behövs verktyg för utvärdering av olika behandlingstekniker eller olika dosplaner för en patient, och resultatet av utvärderingen ska inte vara subjektivt pga utvärderingen eller användaren.

Syfte

Syftet med föredraget är att diskutera hur de nya moderna behandlingsteknikerna kan användas så effektivt som möjligt, dvs vilka patienter har mest nytta av IMRT, IMAT eller TOMO. Olika metoder att hitta den bästa planen presenteras också, bl a Pareto front-baserade metoder. Patientens dosplan ska till slut levereras på ett säkert sätt. Hur säkerställer man detta?

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The role of MRI in radiotherapy – at present and tomorrow

T Nyholm

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With an MR scanner it is possible to acquire images with superior soft-tissue contrast in comparison with CT. It is also possible to measure physiological tissue properties like diffusion, perfusion, blood vessel permeability, and even to perform 3D spectroscopy measurements searching for different metabolites. Because of these fantastic possibilities with the MR technique, it is natural to look into ways of using the information within the area of radiotherapy. In Umeå we have hosted a dedicated MRI scanner within our radiotherapy department for 6 years. During this time we have identified problems that need to be solved, and also in some cases found solutions.

In the presentation I will describe different research projects from Umeå related to implementation of MRI in the clinical routine, both as part of the standard workflow and for treatment follow-up.

A national platform for comparison of independent dose calculations in radiotherapy – an on-line solution for iPAD and Android tablets

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Despite the large number of patients treated with radiotherapy in Sweden, formal risk analyses are seldom made, and the safety requirements for administrating advanced radiotherapy remain unclear. A national database with statistical tools for evaluation would constitute a platform for comprehensive risk analysis of advanced radiotherapy, which is a pre-requisite in order to guarantee a high level of patient safety when introducing new treatment techniques. In an earlier retrospective study, we showed that tools within the field of statistical process control can be an effective way to identify processes with an increased risk of hazard (*Nordström et al. Control chart analysis of data from a multi-center monitor unit verification study. Submitted to Radiotherapy and Oncology, 2011)*. The aim of this project is to build and evaluate a flexible and mobile platform where results from independent dose calculations at different radiotherapy clinics are collected, evaluated and compared on-line. Within in this work we have created a national database and developed intuitive and user-friendly applications for both iPAD and Android tablets where data can be both entered and analysed in a graphical form. The tablets communicate with the database by either wireless network or 3G. Several different Swedish clinics are currently evaluating the system and they represent a wide selection regarding different independent dose calculations methods, record-and-verify systems, treatment planning systems and QA programmes in order to evaluate the prospect of using the system on a national level. Preliminary results show that the system can be used effectively and intuitively by medical physicist during their daily routine work. Since data from every calculation are collected and not only calculations where an error was found, we believe the system is well suited for early detection of trends and potential hazards in different processes within the field of radiotherapy.

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Nationell arbetsgrupp inom nuklearmedicin:

Kvalitetskontroller på nuklearmedicinsk utrustning

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I våras startade en ny arbetsgrupp i föreningens regi där uppdraget är att ta fram riktlinjer för vilka kvalitetskontroller som behöver genomföras för att säkerställa tillräcklig prestanda på nuklearmedicinsk utrustning.

Arbetsgruppen bildades som en följd av resultatet från en nationell enkät utförd 2010 inom EQUALIS kvalitetssäkringsprogram (”Extern kvalitetssäkring av undersökningar inom hälso- och sjukvården”). Denna studie visade nämligen att de kvalitetskontroller som utförs på de c:a 33 sjukhus i Sverige som är utrustade med nuklearmedicinsk apparatur (aktivitetsmätare, gammakamera, SPECT, SPECT/CT, PET och PET/CT) skiljer sig markant. Detta gäller både vilka kontroller som görs, när de görs, hur de görs och vem som gör dem. Även åtgärdshantering vid brister i kvaliteten skiljer stort. En genomgång av de internationella riktlinjer och råd som finns visar på en viss förvirring och att det är i princip upp till varje avdelning/fysiker/ingenjör att själv avgöra vilket kontrollprogram som ska följas.

Syftet med denna arbetsgrupp är att ta fram riktlinjer för vilka kvalitetskontroller som behöver genomföras för att säkerställa tillräcklig prestanda på nuklearmedicinsk utrustning i Sverige. Riktlinjerna kommer även innefatta, med vilken lägsta frekvens angivna kvalitetskontroller bör genomföras samt gränsvärden för när utrustningen bör tas ur bruk. Resultatet sammanställs i form av två rapporter; en mer övergripande rapport med syfte, bakgrund etc. samt en mer kortfattad och handfast lathund för praktisk användning ute på sjukhusen. Båda rapporterna kommer att publiceras på SFfR’s hemsida.

Deltagare i arbetsgruppen är: Henrik Båvenäs (Västerås), Sigrid Leide Svegborn (Malmö), Sofia Åström (Luleå), Sven-Åke Starck (Jönköping), Ulrika Lindgren (Sundsvall) och Ulrika Svanholm (Stockholm).
Koordinatorer är: Agnetha Gustafsson (Linköping) och Cathrine Jonsson (Stockholm).

Hitintills har vi haft en fysisk träff - en heldag i Stockholm, samt två telefonmöte. Dessutom har delar av arbetsgruppen träffats på Nuklearmedicinskt vårmöt i Lund i maj och nu på EANM:s konferens i Birmingham för en månad sedan.

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Kvalitetssäkring av moderna strålbehandlingstekniker, spec. IMRT/VMAT

Jörgen Olofsson, Umeå

Den specifika kvalitetssäkring som idag utförs för varje intensitetsmodulerad strålbehandlingsplan är tids- och resurskrävande och kanske heller inte optimal avseende vare sig patientsäkerhet eller resursoptimering. Det finns ett flertal internationella rekommendationer inom området, men ingen konsensus om en optimal QA-process sett ur ett riskperspektiv.

Den nationella arbetsgruppen för kvalitetssäkring av avancerad strålbehandling, i synnerhet IMRT och VMAT, har målsättningen att (1) Kartlägga hur kvalitetssäkringen av IMRT/VMAT utförs i praktiken runt om i Sverige idag. (2) Gå igenom befintliga internationella rekommendationer för kvalitetskontroller vid strålbehandling med IMRT/VMAT. (3) Reflektera över om, hur och varför olika kvalitetssäkringskoncept som tillämpas inom industrin kan användas för avancerad strålbehandling. (4) Föreslå praktiska riktlinjer för kvalitetssäkring av moderna strålbehandlingstekniker (IMRT/VMAT). Resultatet sammanställs, preliminärt, i form av två rapporter; en mer övergripande rapport med syfte, bakgrund etc samt en mer kortfattad och handfast lathund för praktisk användning ute på sjukhusen.

Real time visualization of dose rates in interventional radiology

C Lundh[*1], T Mai[2] , Å Cederblad[1] and M Båth[1, 2]

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Today the conventional method of dose monitoring occupational radiation exposure is to do a monthly read out of the accumulated dose. Recently, a real-time system for visualization of radiation dose rates - DoseAware - has been developed. DoseAware consists of dosimeters that detect the radiation dose rates for each individual and continuously send this information to a base station, where it is visualized on a display as a colour-coded bar diagram.

The aim of this study was to investigate if the DoseAware System could change the working method for interventional radiology personnel from a radiation protection point of view making them more aware of the radiation they are being exposed to, and furthermore if the personal doses could be lowered.

The study was performed at the interventional cardiology department at Halmstad Hospital during one+one months. During the first data collection period no real time feedback of dose rates was available to the staff (3 cardiologists and 10 nurses). During the second data collection period the staff was able to see their current radiation exposure on a monitor while they were working. The dose information from about 160 procedures from the two data collection periods were analyzed and compared. After the data collection periods, focus-group interviews were conducted to gain knowledge from the staff's experiences.

The results showed that the radiation protection awareness of the staff could be positively affected by the real time visualization of dose rates. The reduction of collective dose for all staff members were about 30% ($p=0.05$) when using the DoseAware system. The median KAP-value per procedure and also the median personal dose per procedure were lowered for some of the operators. However, the different operators' behavior varied a lot and the inter-operator variability by far exceeded the intra-operator variability making it difficult to draw conclusions in the limited data. In addition, focus group interviews with all staff involved showed that the possibilities for feedback were highly appreciated and were deliberatively used by staff members to revise their methods in order to avoid high radiation exposure.

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Accuracy of MLC-tracking for inversely optimized arc therapy treatments of varying complexity for two MLCs

Purpose: To determine the geometric accuracy of MLC-tracking using a circular field and to investigate the dosimetric accuracy for inversely optimized arc delivery to a moving target for two different MLCs and for varying plan complexity.

Materials and methods: To determine the geometric accuracy, a marker was placed on a motion platform moving sinusoidally in the SI direction, with 2.0 cm peak to peak motion and 6 s cycle time while the MLC was set to shape a circular field. The geometric accuracy during tracking, i.e. the difference between the marker and the center of the MLC, was calculated based on EPID images. To investigate the dosimetric accuracy, plans were made in Eclipse™ treatment planning system using the RapidArc® treatment technique for two lung cancer patients with a prescribed dose of 2 Gy per fraction. A gantry rotation span of 225° to 135° was used. Four sets of increasingly stringent planning dose objectives (PO) were applied in planning for delivery on a Novalis TX™ linear accelerator (equipped with a High definition MLC (HDMLC)) and on a Varian 2300ix linear accelerator (with the Millennium 120 MLC (M-MLC)), for two collimator angles (CA); 45° and 88°. For each patient, one plan was created with CA45 and with an optimization constraint limiting the distance to adjacent leaves. Plans were also created in a clinical version of Eclipse for the PO#1 and PO#2 sets. The number of MU ranged from 334 to 751 for all plans. The plans were delivered to a Delta4® dosimetric device placed on a motion platform using the same motion pattern as above. Position monitoring was done using the ExacTrac® optical system. Measurements were made with and without MLC-tracking, and with and without motion. Measurements with a stationary target were used as reference in gamma evaluation, with gamma criteria of 2% and 2 mm. The calculated dose distributions were also used as reference, with gamma criteria of 3% and 3 mm.

Results: The geometric accuracy with MLC-tracking was 0.316 mm (RMS) and 0.346 mm for the HDMLC and the M-MLC respectively. For all RapidArc plans measured, the MLC-tracking method considerably increased the gamma index pass rate for delivery to a moving target compared to delivery with no motion compensation (using the measured dose on a static phantom a reference). The pass rate was also improved for CA 88° compared to 45°. A correlation was seen between reduced average adjacent leaf distance (weighted against the dose weight for the corresponding control point) and improved gamma index pass rate.

Conclusion: It is possible to use MLC-tracking during RapidArc® delivery to compensate for the target motion simulated in this study. The gamma index pass rate was increased using MLC-tracking, but the effect decreased for more complex plans. Aligning the leaves with the target motion substantially increased the gamma index pass rate for both MLCs, regardless of the plan complexity. The distance to adjacent MLC leaves seems to be an important factor in predicting MLC-tracking performance.

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