

RT alone (median 66 Gy/33 fr.). RT-induced cardiac complications were evaluated retrospectively using Common Terminology Criteria of Adverse Events v3.0.

**Results:** The median follow-up for surviving patients was 85 months. The overall and cause specific survival rates were 59% and 79%, respectively. Ninety-three patients were analyzed for evaluation for cardiac complications. Cardiac complications ( $\geq G3$ ) were observed in 10 patients (10%): pleural effusion in 1 (1%), cardiac ischemia in 5 (5%) and arrhythmia in 4 (4%). Among 5 patients with cardiac ischemia, 2 died in acute myocardial infarction and 3 needed the stent placement. Among 4 patients with arrhythmia, 2 died in heart failure and 2 needed the pacemaker implantation. Four of 13 patients (31%) with cardiovascular diseases before RT experienced deterioration of the disease.

**Conclusions:** Cardiac complications ( $\geq G3$ ) were observed in 10% of patients treated by RT alone for stage I esophageal cancer: pleural effusion in 1%, cardiac ischemia in 5% and arrhythmia in 4%. We think our data can be used for comparison with the data of cardiac complications after CRT for esophageal cancer patients.

### 930 POSTER Comparative dosimetric study of dynamic conformal arc (DCA), conformal beam (CB) and intensity-modulated radiosurgery (IMRS) for childhood cerebral arteriovenous malformations (cAVM) treatment

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**Purpose:** To investigate the dosimetric differences among DCA, CB and IMRS techniques for cAVM treatment in children.

**Methods and Materials:** Between 03/05 and 11/06 we have treated six children with cAVM younger than 18 years (range: 6–18 years). First symptoms were: hemorrhage in 5 patients and neurologic deficit in 1 patient. cAVM volume ranged from 0.15 to 7.22 cc (mean = 2.26 cc). Spetzler-Martin grade was as follows: Grade 2, n = 1 and Grade 3, n = 5. AVM score ranged from 0.175 to 1.62. Three patients (50%) had other treatment before radiosurgery: 2 embolization and 1 partial surgery. Prescribed dose at the peripheral isodose (81–92%) ranged from 16.7 to 19 Gy (mean = 17.6 Gy).

We calculated DCA, CB and IMRS plans for each patient. The following dosimetric parameters were analysed for all plans: conformity index (CI), heterogeneity index (HI), normal brain tissue complication probability (NTCP), obliteration probability (OP), success probability (SP), normal brain dose-volume histograms and probability of a second cancer incidence (PSC).

**Results:** IMRS was superior to DCA and CB for homogeneity and conformity, IMRS was discreetly worse for NTCP than DCA and CB (5.9%, 5.3%, 5.4% respectively), and so for SP (58.9%, 59.4% and 59.4%). Equal OP was obtained for each plan on each patient (range 70.8–77.5%), since OP only depends on the minimal dose on the lesion. Percentage of normal brain volume receiving low doses was higher in IMRS than in DCA and CB approaches respectively but without clear influence in PSC. Dosimetric parameters always fulfilled the RTOG recommendations.

**Conclusions:** IMRS treatment improves target conformity and homogeneity, but increases the volume of normal tissue exposed to low doses of radiation. No important differences were found between DCA and CB techniques.

### 931 POSTER Cost-effectiveness of particle therapy: current evidence and future needs

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**Background:** Due to the ever-expanding health care expenses, knowledge about the cost-effectiveness of treatments is continuously gaining importance. In spite of the fact that radiotherapy (RT) is a rather cheap treatment modality, increasing complexity will inevitably translate in higher costs. This is certainly so for proton and light ion therapy. In order to find current evidence on cost-effectiveness of particle therapy we systematically searched the literature.

**Methods:** Twelve databases were searched systematically with a pre-defined search strategy. No limit was applied to language or study design.

**Results:** Out of 773 identified papers, only 13 papers were dealing with the economic aspects of particle therapy. Seven papers described aspects of the workload, staffing levels, setting up and operating costs of a proton therapy facility. Only three papers reported on "cost-effectiveness", all on proton therapy, and performed by the same Swedish research group (Karolinska Institute, Stockholm). An economic evaluation model

for childhood medulloblastoma, a cost-effectiveness analysis model for breast cancer and a cost-utility analysis based on a Markov model for breast cancer, prostate cancer, head & neck cancer and medulloblastoma was reported. The results of this latter study indicated that the average cost per QALY gaining for the four types of cancer assessed was about € 10,130. If the value of a QALY was set to € 50,000 (benchmarked varies highly between countries: € 20,000–100,000), proton treatment may be cost-effective. However, due to a high level of uncertainty because of a lack of data and many assumptions, these results should be interpreted with caution.

The content of the remaining three papers was miscellaneous.

**Conclusion:** So far, literature data on cost-effectiveness of proton therapy is limited, and is lacking for carbon ions. Further research into cost effectiveness of particle therapy is needed. In order to obtain valid results and decrease uncertainty, a large amount of data on costs and effects are needed. To achieve this goal, a multidisciplinary international collaboration is required.

### 932 POSTER Reliability of the linear-quadratic formula for evaluating biological equivalence between single-fraction and hypofractionated radiation doses: an in vitro study

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**Background:** No appropriate model exists to estimate how single doses of radiation as used in gammaknife radiosurgery biologically correspond to hypofractionated doses as used in cyberknife and other stereotactic radiotherapy. The linear-quadratic (LQ) model is often used for convenience, but should be applied to 8- or more-fraction radiotherapy. In this study, we compared biological effects of single-high and hypofractionated doses in single cells and spheroids, and examined the reliability of the LQ model.

**Material and Methods:** V79 and EMT6 single cells received single doses of 2–12 Gy, and 2 and 3 fractions of 4 and 5 Gy each given at 4 h intervals to allow full repair of sublethal damage. Surviving fractions were determined by a colony assay. Single and fractionated doses to actually reduce cell survival to the same level were determined. From surviving fractions after single doses, the  $\alpha/\beta$  ratio was obtained, and using the ratio and the LQ formula, equivalent single doses for the hypofractionated doses were calculated. The calculated doses were then compared with actually determined equivalent single doses for the hypofractionated doses. V79 spheroids (approximately 0.8 mm) received single doses of 5–26 Gy and 2–5 fractions of 5–12 Gy given at 2–4 h intervals. After irradiation, spheroids were dissociated into single cells and cell survival was determined by a colony assay. Equivalent single doses for the hypofractionated doses were calculated as done with single cells, and then they were compared with actually determined equivalent single doses for the hypofractionated doses.

**Results:** The  $\alpha/\beta$  ratio was 5.1 for V79 single cells and 0.23 for EMT6. In both cell lines, equivalent single doses for hypofractionated doses calculated from the LQ formula were approximately 12%–15% lower than the actually measured biologically-equivalent single doses. In V79 spheroids, the former doses were approximately 20%–24% lower than the latter doses. Thus, the LQ model calculation underestimated the equivalent dose in both single cells and spheroids.

**Conclusion:** It is not appropriate to use the LQ formula for estimation of equivalent single and hypofractionated doses. The use of the LQ model may underestimate the effect of hypofractionated radiation.

### 933 POSTER Quality Management System and organization of services in radiotherapy as a result of implementation of European Union directives and other international documents to the Polish law based on the experience of Great Poland Cancer Centre

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**Background:** There are many reasons for the implementation of the Quality Management System in radiotherapy: lawful regulations, safety of patients and staff, progressive computerization of the process of treatment, technological development, implementation of sophisticated techniques, increasing awareness of the society, the possibility of free selection of treatment centre all over Europe etc.

Aims of this work were (a) the evaluation of the level of influence of EU law and recommendations of European and International organizations on the development of Polish law establishing conditions for safe use of ionizing

radiation in medicine, (b) the elaboration of the model, standards and recommendations for Quality Management System (QMS) in radiotherapy based on the experience of Great Poland Cancer Centre.

**Materials and Methods:** The comparison analysis of EU and Polish acts of law issued in years 1980–2006. For the elaboration of QMS in radiotherapy, the universal industrial ISO norm 9001:2000, referring to quality management system was used. Recommendations of this norm were completed with detailed quality standards based on authors' work experience, the review of articles on quality assurance and quality control standards for radiotherapy published between 1984–2006 and the review of current recommendations and guidelines of American, International, European and National bodies (societies, agencies etc). for quality assurance in radiotherapy.

**Results:** As a result of the comparison analysis of selected documents: (I) the level of transposition of EU law into the Polish law was verified and several phases of implementation were observed. (II) The original model of QMS in radiotherapy with the package of 352 quality standards in radiotherapy: organizational, physical-technical and clinical, documentation for QMS and detailed instruction for implementation of QMS in hospitals were elaborated.

**Conclusions:** The national mandatory regulations regarding quality management in radiotherapy were elaborated mostly due to: continuing transposition of EU law into the Polish law and the irradiation accident in Bialystok in 2001. The elaborated QMS in radiotherapy, can be used in any institution using ionizing radiation for medical procedures, and its implementation, as it was done in Great Poland Cancer Centre could be the first step for the improvement of the organization of work in radiotherapy due to (i) the improvement of safety conditions, (ii) optimization of treatment through the identification of processes and the relation between them, and identification of resources essential for the correct realization of these processes, (iii) decrease of the risk of radiation accidents and incidents, (iv) establishment of clear organizational structures in the hospital.

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POSTER

#### Cone beam CT (CBCT) for breast-planning: reliability and quality

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**Introduction:** Cone Beam CT (CBCT) can be used for Target delineation and planning, image guided radiotherapy and adaptive treatment planning. Systematic and ad random errors can be avoided. But, soft tissue contrast is inferior compared to a classic CT scan (CCT).

**Purpose:** 1. Is breast-planning on a CBCT reliable? 2. Has respiration a significant impact on soft tissue contrast?

**Methods and Materials:** 1. When implementing CBCT in clinic, 10 patients had both a CCT and a CBCT. We compared 13 plans: photon tangential breast plans (n=3); photon and electron parasternal plans (n=10). Comparison was done by measurement of differences in MU and in equivalent path length (EPL) (= corresponding length in a density equal to water). Planning was based on a Pencil Beam Algorithm. 2. During simulation, the movement of the sternum was quantified by the Varian RPM system (n=62). The EPL was measured on a parasternal plan. We tested the hypothesis of a correlation between large amplitudes in movement of the sternal bone due to respiration and large differences in EPL.

**Results:** 1. EPL is significantly shorter for CBCT compared to CCT ( $p < 0.0001$ ), which means that the density of the CBCT is consistently less than for the CT scan. For breast planning with photons, this results in a statistically significant ( $p = 0.002$ ), but clinically acceptable (<2%) difference in MU between CBCT and CCT. For electrons, larger differences were seen. 2. We found no correlation between respiration movement and EPL.

**Conclusions:** 1. We can conclude that CBCT is a reliable tool for breast planning with photons. For electrons, it appears to be less reliable. 2. Soft tissue contrast on CBCT might be influenced by respiration movement, but with the method used, we could not detect a correlation.

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POSTER

#### IGRT with helical tomotherapy – experiences of the first 8 months in Heidelberg

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**Background:** Helical tomotherapy was introduced into clinical routine at the department of radiation oncology in the University hospital of Heidelberg in July 2006. This report is intended to describe the experience of the first 123 patients treated with this new for of intensity modulated image guided radiotherapy. Patient selection, time effort, handling of daily image guidance with megavoltage CT and quality of radiation plans shall be assessed.

**Materials and Methods:** Between July 2006 and February 2007 123 patients were treated with helical tomotherapy in the University hospital of Heidelberg. This very heterogeneous group of patients was composed of

the following tumor entities: head-and-neck tumors (n=24), prostate cancer (n=19), gastrointestinal tumors (n=20), breast cancer (n=13), multiple metastases (n=11), spinal reirradiation (n=7), thoracic tumors (other than lung) (n=6), radiosurgery (n=5), malignant pleural mesothelioma (n=5), sarcoma (n=4), lung cancer (n=3), whole abdominal irradiation for ovarian cancer (n=3), skin malignancies (n=2), craniospinal axis treatment (n=1). In 98% of the fractions a pretreatment megavoltage ct scan was performed. After matching with the kilovoltage planning ct scan corrections for translations and roll were done.

**Results:** Helical tomotherapy was able to treat very small, very big or multiple targets. Image-guidance with MV-CT allowed precise position correction and hereby safe treatment application even if patients could not be properly immobilized due to obesity, pain, claustrophobia or neurological impairment. For the described tumor entities average time on table was 24.6 minutes, average treatment time 10.6 minutes. Excellent dose distributions with homogeneous target coverage and sparing of organs at risk could be achieved for all the described tumors.

**Conclusions:** Helical tomotherapy and daily image-guidance with megavoltage ct could be introduced fast and successfully into daily clinical routine. This method is suited to treat standard IMRT cases or patients with very big and complex shaped targets.

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POSTER

#### Tomotherapy for prostate cancer – comparison of dose distribution with linac-based IMRT planning and inter- and intra-fraction prostate motions

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**Background:** With tomotherapy, intensity-modulated radiation therapy (IMRT) and image-guided radiotherapy can be performed readily. In the present study, we compared dose distribution of tomotherapy planning for prostate cancer with linac-based planning and evaluated prostate motion between daily fractions and during treatment.

**Patients and Methods:** We made linac-based IMRT planning for 15 MV X rays using Pinnacle3 and tomotherapy planning in 13 patients. We then compared dose distribution and dose-volume histogram for PTV, rectum, bladder and femoral heads between the two plans. We measured interfraction prostate motions from distance between a couch position adjusted based on bony structures and that adjusted based on prostate contour in 21 patients (701 fractions). All patients were fixed using a body frame which was fixed to the couch during treatment. Interfraction prostate motions were measured from both the position at the first fraction and the average position. We took megavoltage (MV) CT also after treatment for initial 5 fractions of treatment, and we evaluated intrafraction prostate motions by comparing MVCT images before and after treatment in 21 patients (105 fractions).

**Results:** Dose distributions of tomotherapy plans were superior to linac-based IMRT plans for many constructions (PTV, rectum and femoral heads). Average (+ SD) interfraction prostate motions were  $0.7 \pm 0.6$  mm in right-left (RL) direction,  $1.6 \pm 1.6$  mm in superior-inferior (SI) direction and  $2.3 \pm 1.9$  mm in anterior-posterior (AP) direction from the prostate position at the first fraction. They were  $0.6 \pm 0.6$  mm in RL direction,  $1.3 \pm 1.2$  mm in SI direction and  $1.6 \pm 1.5$  mm in AP direction from the average position. Intrafraction prostate motions were  $0.3 \pm 0.6$  mm in RL direction,  $0.2 \pm 0.6$  mm in SI direction and  $1.4 \pm 1.8$  mm in AP direction.

**Conclusions:** IMRT planning using tomotherapy seems to more readily produce an optimal plan than linac-based IMRT planning. Interfraction prostate motions were largest in AP direction and smallest in RL direction. Intrafraction prostate motions were largest in AP direction and relatively small in both RL and SI directions. Based on this study, we are planning to reduce internal margins in both RL and SI directions in order to reduce adverse effects on the rectum and bladder.

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POSTER

#### A study on the optimization of beam direction and virtual organ delineation to minimize radiation pneumonitis in the intensity modulated radiotherapy of lung cancer

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**Background:** This study introduces an intensity modulated radiotherapy (IMRT) process in lung cancer patients and evaluates the utility of intensity