significant or systematic difference between techniques for the volumes of tissue receiving 50% and 30% of the dose.

Conclusions: Clinically acceptable plans can be created with all three techniques. The use of DCA and HA appear to reduce planning time for spherical targets but not for irregular shapes. It is yet to be established if either arc-based technique will reduce planning and treatment times. HybridArc leads to significantly higher MU, which has implications for scatter dose. Further investigation into treatment times and deliverability of the planned dose distributions is required to determine the optimal technique.

EP-1465
The benefit of IMPT in treatment of left-sided breast cancer patients in deep inspiration breath hold
M. Rasi¹, O.H. Odland², L. Bolstad Hysing², G.M. Engeseth¹, J. Petersen⁴, E. Blix³, B. Offersen³, M.P. Muren⁹
¹University Hospital of Northern Norway, Radiation therapy department, Tromsø, Norway
²Haukeland University Hospital, Department of Oncology and Medical Physics, Bergen, Norway
³Haukeland University Hospital, Department of Oncology and Radiation Therapy, Bergen, Norway
⁴Aarhus University Hospital, Department of Medical Physics, Aarhus, Denmark
⁵University Hospital of North Norway, Department of Oncology and Radiation Therapy, Tromsø, Norway
⁶Aarhus University Hospital, Department of Oncology, Aarhus, Denmark

Purpose/Objective: Conventional photon radiotherapy (RT) has successfully been applied in treatment of, both early, and locally advanced breast cancer. However, there are still concerns related to the long-term side-effects of low doses to nearby normal tissue, both with respect to e.g. ischemic heart disease (Darby et al, NEJM 2013) as well as secondary cancer induction in e.g. the lungs (Grantzau et al, R&O 2014). The doses to heart and lungs should therefore be kept as low as possible without compromising the target volume dose. The physical properties of protons make them attractive also for breast irradiation, however the benefit of protons in the context of gated treatment delivery has not been fully explored yet. In this study we have therefore compared doses to the whole heart, the left anterior descending coronary artery (LAD) and the left lung for left-sided breast cancer patients treated with Deep Inspiration Breath Hold (DIBH) RT using either protons or photons.

Materials and Methods: The study was performed on five left-sided breast cancer patients originally treated to 50 Gy in 2 Gy fractions, with conventional photon RT in DIBH. Intensity-modulated proton therapy (IMPT) plans were created for all the patients based on the DIBH CT-series using the original (breast-only) target volumes. All plans were initially optimized using following criteria: 95% of the prescribed dose to PTV, heart V25 < 5%, LAD V10 < 5% and lung V20 < 15%. After achieving these goals, the IMPT plans were optimized further in order to minimise the dose to organs at risk (OARs) while maintaining the 95% dose criteria to PTV (or D2 > 95%, i.e. at least 98% percent of the PTV should be covered by 95% of the prescribed dose). The mean dose (Dmean) for heart and LAD, the V20 for lung as well as the conformity index (CI=V95/PTV) were assessed.

Results: All OAR dose/volume-parameters investigated were lower with IMPT compared to CRT for all five patients (Table 1). In particular the doses to the heart and LAD were significantly reduced. The PTV conformity was at least 0.98 for all IMPT plans, while it was generally lower and more patient-dependent for the CRT plans.

Conclusions: For left-sided breast cancer patients treated with DIBH RT to the breast, the use of IMPT was found to yield improved PTV conformity and better sparing of heart, LAD and lung compared to conventional photon-based RT.

EP-1466
The effect of mean dose or voxel-wise calculation in prediction of radiation-induced secondary cancers
A.M. Madkhali¹, C. Timlin², T. Sio³, R.C. Miller⁴, M. Partridge⁵
¹CRUK/MRC Oxford Institute for Radiation Oncology - University of Oxford & Colige of Medicine - King Saud University, Department of Oncology, Oxford, United Kingdom
²Particle Therapy Cancer Research Institute - University of Oxford, Department of Physics, Oxford, United Kingdom
³Mayo Clinic, Radiation Oncology, Rochester MN, USA
⁴Mayo Clinic, Radiation Oncology, Jacksonville, FL, USA
⁵CRUK/MRC Oxford Institute for Radiation Oncology - University of Oxford, Department of Oncology, Oxford, United Kingdom

Purpose/Objective: More than half of cancer patients receive radiotherapy for radical or palliative purposes. Increasing survival rates in cancer patients make it important...
to study late side-effects, including secondary radiation-induced cancers. Although a number of predictive models exist, the absolute accuracy of these models in the radiotherapy dose range is limited partly due to scarcity of data and partly by extrapolation beyond historical data bounds. One of the challenges faced with applying models to the highly spatially varying dose distributions produced in modern radiotherapy is dose heterogeneity within organs at risk. The aim of this work is to investigate the difference between using mean dose (MD) and high-resolution voxel-by-voxel dose (VbV) maps for calculating malignant induction probability (MIP).

**Materials and Methods:** A 3D conformal radiotherapy (3DCRT) and actively scanned proton plans were used for an adult patient and a teenage patient with medulloblastoma. MIP is calculated for each patient using the linear-quadratic (LQ), linear (LIN) and linear-no-threshold (LNT) models with in-house developed code. MIPs calculated using the mean dose to the organs as well as voxel-by-voxel dose are compared for individual organs and the whole body.

**Results:** Whole body MIPMD for the adult patient ranged between 0.337 and 0.929, while MIPVbV ranged between 0.078 and 0.834 (teenage) for proton plans. For 3DCRT plans and an average factor of 3.1 (adult) and 2.3 (adult) and 1.7 (adult) and 1.6 (teenage) for both the LQ and LIN models, significant differences in MIP can be seen. Organ-specific MIPs vary over a wide range (Figure 1), although MIPMD is higher than MIPVbV by an average factor of 1.7 (adult) and 1.6 (teenage) for both the LQ and LIN models for 3DCRT plans and an average factor of 3.1 (adult) and 2.3 (teenage) for proton plans. Use of MD gives consistently higher MIP estimates than VbV calculation in areas of dose heterogeneity (note reversal of this trend in the brain, which has a uniform high dose).

**Conclusions:** Results demonstrate large systematic differences between the risk estimates produced using either mean dose or voxel-by-voxel calculation. Although the relative relation between MIPPhoton and MIPProton remains broadly constant, using mean dose in heterogeneous dose distributions potentially overestimates MIP and, by association, secondary cancer risk.

**EP-1467**

**Meta-analysis of radiosensitivity and fractionation sensitivity of human tumours**

C.M. Van Leeuwen1, A.L. Oei2, N.A.P. Franken1, L.J.A. Stalpers1, J. Crezee1, A. Be1, H.P. Kok1
1Academic Medical Center, Radiation Oncology, Amsterdam, The Netherlands
2Academic Medical Center, Laboratory for Experimental Oncology and Radiobiology (LEXOR) - Center for Experimental Molecular Medicine - Department of Radiation Oncology, Amsterdam, The Netherlands

**Purpose/Objective:** The linear quadratic (LQ) model is the basis of many radiobiological predictions. Its main parameters α and β represent the tissues’ radiosensitivity, whereas the ratio α/β represents the fractionation sensitivity.

Generic values are often used for biological modelling (e.g. $\alpha/\beta = 10\text{Gy}$), which may not be appropriate for all tumours. Many studies estimate the LQ-parameters from clinical data, but heterogeneity in patient populations and analysis methods leads to disagreement between their results, reflected in non-overlapping 95% confidence intervals (CIs). Moreover, all these studies group tumours by tumour site, though this might not be the most predictive factor for tumour biology.

The purpose of this study is to determine reliable values and CIs for α, β and α/β for biological modelling and explore factors that best explain the aforementioned heterogeneity.

**Materials and Methods:** A systematic search of the Medline database using PubMed was performed. Papers estimating α, β or α/β were included if their analysis was based on clinical data and if none of these parameters were kept fixed in the analysis.

The best statistical model for the meta-analyses of α, β and α/β was determined by a stepwise procedure. Different random effect models were compared based on the finite sample size Akaike Information Criterion (AICc). Next, factors were investigated for heterogeneity using different univariable models. Significant factors were then combined in multivariable models and the best model (lowest AICc) was used for the final meta-analysis. Factors that were tested were the type of LQ model, TCP model, clinical endpoint, tumour site and histology.

**Results:** Out of 1059 papers returned by the systematic search, 60 satisfied the selection criteria, reporting 65 estimates of α and β and 135 of α/β. The best statistical model for α included only the type of LQ model as factor, while for β and α/β the combinations LQ model + histology and LQ model + site provided the best (equally good) models.