optics was measured in 2D lateral images with and without the nozzle using a scintillator based detector (Lynx, IBA, Schwarzenbruck, Germany). Spot size measurements were performed at 5 selected energies (62.4, 97.4, 148.2, 198.0, 252.7 MeV), representative for the complete range of clinical energies available. Measurements with nozzle were performed at positions from the nozzle exit window until 20 cm after the isocenter. Without nozzle the same positions plus additional upstream positions until the vacuum window were measured. Gate/Geant4 based Monte Carlo (MC) simulations were performed to study the impact on the beam optics parameters at nozzle entrance on the delivered beam size, using a fully detailed model of the medical nozzle.

Results

The WET of the exit window and DDS was measured to be 1.1 mm. The WET of the full medical nozzle including air filled cavities and the exit window was quantified to be 2.4mm.

Fig. 1 shows the FWHM of the beam in air with and without nozzle. The measurements with nozzle suggest a diverging beam, whereas a converging beam was measured without nozzle. In addition, without nozzle, the beam shape was noticeably deviating from a double Gaussian shape. This was attributed to the employed so called slow beam extraction method (Benedikt et al, EJP Plus, 2015). The additional scattering inside the nozzle material was found sufficient to compensate the detected beam shape irregularities and asymmetry. The non-symmetric spot shape encountered at the vacuum window, is compensated for protons due to the additional scattering induced by the nozzle components.

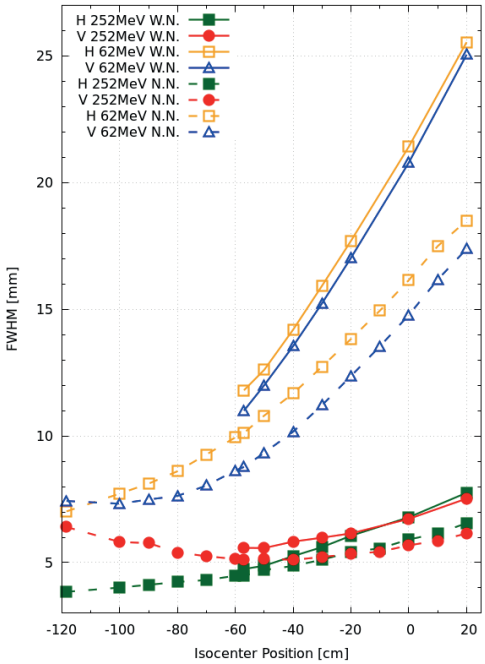

Fig. 1: Spot size over distance from isocenter with (solid lines, W.N.) and without (dashed lines, N.N.) medical nozzle for both planes.

Conclusion

MC simulations showed, that a beam model can be created without prior knowledge of beam behavior inside the nozzle, matching the measurement data outside the nozzle, without correctly modeling the beam behavior inside the nozzle. The change from a convergent to a divergent beam inside the nozzle needs to be considered during beam modelling. The creation of a beam model considering the effects measured, will enable investigations on the impact of the nozzle in terms of secondary fragment production.

EP-1808 Dose delivery quality audit for IMRT technique in Poland

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Purpose or Objective

The delivery of accurate intensity-modulated radiation therapy (IMRT) or stereotactic radiotherapy depends on a multitude of steps in the treatment delivery process. The purpose of this audit is to verify the dose delivery for an end-to-end clinical IMRT treatment executed with either a static gantry or VMAT technique. The extension of the programme to an end-to-end evaluation of advanced technology (IMRT) treatments provides an independent verification of the entire radiotherapy chain including imaging, the dose distribution calculated by the treatment planning system and treatment delivery. The methodology of the audit is presented here.

Material and Methods

The methodology of the end-to-end clinical IMRT audit was established within the framework of the CRP E2.40.18 "Development of Quality Audits for Advanced Technology (IMRT) in Radiotherapy Dose Delivery" run by the Dosimetry and Medical Radiation Physics Section of the IAEA or alternatively run by the Division of Human Health of the IAEA. A dedicated PMMA phantom was designed and manufactured. The phantom contains defined regions PTV (Planning Target Volume) and OAR (Organ At Risk). The phantom contains a special insert for placing radiochromic films and tubes with TLD powder. The participants of the audit are asked to CT scan the phantom, to prepare a IMRT treatment plan according to the given limitations concerning the homogeneity of the dose in the PTV, and limitation of the dose in the OAR, and finally to irradiate the phantom according to the plan. The gamma index evaluation for plan/film comparisons was applied. The percentage passing rate (3%/3mm) was evaluated with the acceptance level of 95%. The plan/TLD dose differences were evaluated.

Results

The audit in Poland is in the pilot phase. Until October 2017, 13 centres (out of 35) were audited. In the audit program 6 Varian, 4 Elekta, 2 Siemens and 1 CyberKnife treatment units were examined. The results of film measurements in terms of percentage passing rate for gamma index evaluation (3 mm/3% of isocenter dose) exceed 95% for 12 centers. The discrepancies in PTV and OAR between doses planned and determined with TLD were not higher than 5% in 10 and 9 centres respectively. The dose discrepancies higher than 5% require revealing and repeating of measurements. It is planned that all centres in Poland will be audited until the end of 2018.

Conclusion

The audit was planned as a postal audit. However, for practical reasons it is carried out in the form of the visits to particular centres. Such form of the audit makes it possible to supervise the local staff in their and assure that the procedures are carried out correctly. A high impact of positioning errors on the results was observed. The results obtained with films are correlated with TLD. Already in this phase it may be stated that the elaborated methodology functions well in practice and makes it possible to evaluate the radiotherapy procedures in particular centres. However the minor improvements were needed.

EP-1809 Dosimetric Verification of Roll Setup Correction in Tomotherapy

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Purpose or Objective
MVCT imaging is done for pretreatment patient position verification in Tomotherapy system. MVCT images are registered to treatment planning CT images and translational setup errors are corrected via couch shifts. Additionally rotational setup errors in longitudinal axis (Roll) are compansated automaticly changing start position of the gantry angle. The purpose of this study is to dosimetricly evaluate the reliability of roll correction of the Tomotherapy system.

Material and Methods
Target and avodiance structures (AS) were deliniated on the Cheese phantom CT images in VoLO treatment planning system (Version 5.1) and three different helical treatment plans were made. First plan was created only to cover target but not blocked AS (unblocked, UB). Directional Blocked (DB) option was used in second plan and complete blocked (CB) option was choosen in third plan to protect AS. Cheese phantom was positioned on the treatment couch. EBT3 film was placed between slabs to evaluate two dimensional dose distribution and 0.125 cc ion chamber (IC) was inserted to the 0.5 cm depth hole to measure point dose. The roll angle of the phantom was adjusted at 0^0 using digital leveling device (LD) and three of the plans were irradiated. Films were changed and IC measurements were also noted for each plan. These 0^0 measurements were taken as refference. Cheese phantom was rotated 1^0, 3^0, 5^0 and 10^0 in clockwise (CW) and counter clockwise (CCW) directions using LD. After acquire MVCT images of the phantom, theese roll angles were entered as roll setup correction angle to the system and all plans were irradiated for each angle. Film and IC measurements were repeated for each angles and each plans. Exposed films were compared with refference films using gamma analysis method in PTW verisoft software (version 7.0). The passing criteria in gamma analysis was 3mm and %3 for distance to agreement and dose differences respectively. In addition IC measurements were compared with reference point doses.

Results
For gamma value <1, max-min values were 99.8-97.2% for UB plans, 98.5-97.2% for DB plans and 99.6-97.9% for CB plans. The min value was measured for 1^0 roll error in CCW direction for all three plans. Altough the min gamma values were found in 1^0 CCW direction, gamma values were found in the limits for all plans, all roll angles and all directions. When IC measurements were compared, the differences were found < 1.5% for UB and DB plans and < 1% for CB plans.

Conclusion
Roll setup corrections were succesfully done by Tomotherapy system independently of plan compexity, the size of the rotation angle and the direction of the rotation.

EP-1810 Assessing the dose significance of unplanned rectal filling in pelvic MR Guided Radiotherapy

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Purpose or Objective
Propositions that opposing beams can be used to compensate for Electron Return Effect (ERE) during MR guided radiotherapy may not always be achievable in pelvic patients where rectal or intestine walls lie in the path of a single radiation beam. This work evaluates the dosimetrical effects to the rectal wall due to ERE, comparing unplanned gaseous and solid filling during pelvic MR guided therapy.

Material and Methods
Monaco 5.19.02 (Elekta) was used to produce Monte Carlo simulations of a single radiation beam under the influence of a 1.5T transverse magnetic field. Contours representing a rectal wall containing solid or gaseous filling were simulated. The wall thickness was adapted to accommodate transverse expansion assuming a constant cross sectional area of $3.6cm^2$.
Fig. 1A illustrates a simulated rectal structure transversely expanded due to filling. Note that the wall thickness around the filling becomes thinner as the expansion increases. Fig. 1B and C present simulated dose distributions through a cross section of the rectal wall containing solid or gaseous filling respectively.
DVHs calculated with in house software were used to assess the dosimetrical effects of ERE due to unplanned gaseous filling compared to solid filling. To omit effects due to geometrical changes, comparisons were made only between equivalent solid and gaseous filling.

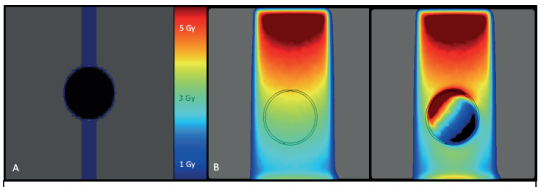

Figure 1 A) – The contoured rectal wall structure used to simulate rectal filling. This shows filling of approximately $100cm^3$, which is equivalent to a sphere of 6 cm diameter. Note that the wall becomes thinner depending on the transverse expansion. B) – The dose distribution of a single beam passing through the rectal wall expanded due to $100cm^3$ solid filling. C) - Dose distribution of a single beam passing through the rectal wall expanded due to $100cm^3$ gaseous filling.

Results
No significant change to the mean rectal wall dose was found between solid and gaseous filling. Likely because the anterior overdosage due to ERE is counterbalanced by underdosage on the posterior aspect (Fig. 1C).
Differences are observed when comparing the maximum doses. Fig. 2 shows the volume of rectal wall receiving an increased dose when unplanned gaseous filling occurs compared with solid filling. The maximum dose in the rectal wall increases by over 50% for large gaseous filling, compared to equivalent solid filling. Over $6cm^3$ of the rectal wall is subject to a 20% dose increase when gaseous filling of over $100cm^3$ occurs. It is indicated that ERE becomes more significant for larger gaseous filling, where a larger volume of rectal wall is exposed to a larger dose increase.

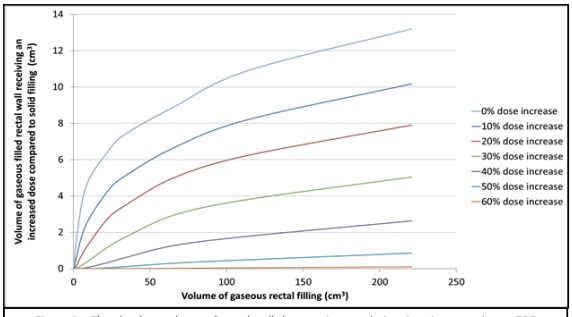

Figure 2 – The absolute volume of rectal wall that receives a relative dose increase due to ERE occurring during various volumes of gaseous filling, compared to the maximum dose received in the rectal wall during solid filling. Each coloured line represents a fixed percentage increase to the rectal wall.

Conclusion
Although the mean dose is unaffected, unplanned gaseous filling subjects the rectal wall to sizeable hotspots where doses in the rectal wall are increased by over 50% compared to solid filling. Generally, this effect becomes more significant for larger gaseous volumes contained in a single beam. However, considering multiple beams is anticipated to reduce this effect.