major violation was found as 7 out of 51 cases. By contrast, there were no major violation and one minor violation in Arm2.

Conclusion: This ICR study with KROG-0806 showed the satisfactory protocol compliance in IMN irradiation and the major violation from several cases of IMN non-irradiation group. Quality assurance process using ICR is needed to evaluate and improve the quality of clinical trial in the field of radiation oncology.

EP-1941
Assessment of variation in planning benchmark case for ABC-07 trial of liver SBRT
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Purpose or Objective: Quality assurance of radiotherapy clinical trials ensures protocol compliance and robustness of outcome data. Benchmark cases are used to assess consistency of outlining and planning by different centres, and provide feedback before a centre starts recruitment. For a complex technique such as liver SBRT, it also facilitates sharing of best practice and supports centres with less experience.

Material and Methods: The planning benchmark case was a large (6cm) cholangiocarcinoma with target and organ-at-risk contours already outlined. This case was sent to all centres interested in joining the ABC-07 multicentre phase II trial (Addition of stereotactic body radiotherapy to systemic chemotherapy in locally advanced biliary tract cancers; CRUK A18752; Sponsor University College London). Centres were asked to produce a plan with prescription dose of 50Gy in 5 fractions, having PTV coverage D95% > 95% (optimal, 90% mandatory) and mean liver dose < 13Gy. If this was not possible, the prescription dose was reduced to 45Gy in 5 fractions and mean liver dose limit increased to 15Gy.

Results: 14 cases were submitted, covering a range of planning systems and treatment platforms. 5/10 VMAT, 1/1 IMRT and 0/3 Cyberknife plans were able to cover 95% of the PTV with ±90% of 50Gy, whilst maintaining the mean liver dose below 13Gy, as shown in the table.

<table>
<thead>
<tr>
<th>Modality (prescription dose)</th>
<th>Number of centres</th>
<th>D95% (% of 50 Gy)</th>
<th>Mean (D95%,% of PTV)</th>
<th>Mean liver dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMAT (50Gy)</td>
<td>5</td>
<td>44.9 - 52.2 Gy (91 - 93%)</td>
<td>103 - 117%</td>
<td>12.7 - 12.9 Gy</td>
</tr>
<tr>
<td>IMRT (50Gy)</td>
<td>1</td>
<td>48.2 Gy (90%)</td>
<td>106%</td>
<td>12.8 Gy</td>
</tr>
<tr>
<td>VMAT (50Gy)</td>
<td>5</td>
<td>42.4 - 45.0 Gy (90%)</td>
<td>103 - 120%</td>
<td>12.9 - 14.9 Gy</td>
</tr>
<tr>
<td>Cyberknife (50Gy)</td>
<td>3</td>
<td>42.7 - 44.5 Gy</td>
<td>114 - 129%</td>
<td>14.6 - 15.0 Gy</td>
</tr>
</tbody>
</table>

Conclusion: Achieving the planning objectives for this case was challenging and only 5/12 centres submitted an optimal plan. The other 7 centres are repeating the exercise after feedback on what was achievable with similar equipment. Achieving the optimal plan for this case involved reduced conformity of medium doses in order to spare other parts of the liver, and thereby reducing the total mean liver dose. This approach is contrary to typical Cyberknife planning, so it may not be the optimum treatment platform for these cases, although it is possible that differences between technologies and centres were accentuated by this large and challenging case, and may be reduced for smaller lesions. All patients treated within this trial will be prospectively reviewed, which will further inform this question.

EP-1942
Initial experience with the Elekta Leksell Gamma Knife Icon system: commissioning, QA and workflow
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Purpose or Objective: Icon enables fractionated stereotactic radiotherapy using a frameless patient positioning system (PPS). For submillimetre precision, the planning MRI scans are registered to a CBCT scan set acquired using Icon. Patient position is then adjusted using the Icon scan. Movement is monitored using an Intra Fraction Motion Management (IFMM) system.

This presentation reports on the commissioning of Icon plus baseline and ongoing QA measurements. This is the first use of Icon in the UK.

Material and Methods: CTDI was assessed for both the low and high dose settings and image quality checked using CatPhan. kVp measurements were made and dose to the imager assessed to confirm the Elekta presets and baseline values.

An new Focus Precision Check tool containing diodes and ball bearings was used to ensure the accuracy of the PPS relative to the radiation focus and CBCT image positions. The IFMM system was verified using a moveable phantom. A reflector was attached to the phantom and moved independently in the x,y and z directions in 0.5 mm steps. If the IFMM monitored position is outside tolerance for more than 2 seconds, the treatment pauses and the couch is retracted. Treatment resumes following a re-scan, with the plan recalculated on the new CBCT reference. To test this system an output measurement was interrupted using a remotely moved reflector.

An end-to-end check on a fractionated pituitary plan was made. The plan was recalculated on a CBCT scan of the spherical solid water phantom containing inserts for chamber and film. A film was positioned at the central axis with 2 additional films displaced 5 & 10 mm above and below.

Results: The Icon system performed within specification. Patient doses were acceptable and image quality resulted in good registration with the MRI scan sets. Ongoing QA results were highly reproducible demonstrating positioning ability of the system to within 0.5 mm. The IFMM readout agreed with the independent system to within 0.04mm and repositioning following interruption had no significant effect on the diode doserate. The end to end film dosimetry agreed to within ±3% of the planned dose. The Icon system has allowed us to use new clinical pathways with little loss in positional accuracy including:

(a) Single fraction patients who would not tolerate a fixed frame.
(b) Fixed frame patients who have their CT scan with Icon.
(c) Fractionated patients.

Conclusion: Icon is an efficient system which has enabled the delivery of fractionated stereotactic radiotherapy plus improvements for single fraction patients. Accuracy is comparable with fixed frame treatments.

EP-1943
Implications of gold nanoparticles used for dose enhancement in proton radiotherapy
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Purpose or Objective: Heavy metal nanoparticles (NPs) have been widely investigated within x-ray radiotherapy as radiosensitisers, where gold NPs (GNPs) have been deemed to be effective at enhancing the dose to the tumour. Few studies have been carried out for protons, where an extensive investigation of the enhancing factors needs to be carried out to determine the implications that introducing GNPs can have on known dose profiles. In the present work, we demonstrate our model which uses Geant4 to carry out Monte Carlo simulations of NP concentrations being irradiated by a proton beam. These simulations offer an indication as to
the macroscale effects that occur with varying concentrations of GNPs.

**Material and Methods:** Within our model, concentrations of NPs were simulated by calculating the inter-particle spacing of various concentrations, where this spacing was used to model a controllable concentration, whilst minimizing computational time. Investigations were carried out on the effect of concentration over a range of clinically relevant concentrations in line with previous studies (0.01 mg/ml, 0.1 mg/ml and 6.5 mg/ml) [1], [2], [3] at two incident proton energies (60 MeV and 226 MeV). Various results were recorded, such as the energy deposited across the phantom, types of secondary particles produced, the particle track lengths and energy deposited by secondary particles.

**Results:** The results highlight a measurable shift of the distal edge (Fig.1) in the order of millimeters due to the introduction of gold, which can be seen predominantly at high concentrations (6.5 mg/ml) achievable through direct injection. This shift was deemed to be energy dependent, where at lower energies (60 MeV) it was on the order of microns. As demonstrated by other groups, the enhancement in injection. This shift was deemed to be energy dependent, where at lower energies (60 MeV) it was on the order of microns. As demonstrated by other groups, the enhancement was attributed to an increase in the number of secondary electrons, which was proportional to GNP concentration as expected. Our model demonstrates that the magnitude of the effects observed can be related to the concentration.

**Conclusion:** This study has demonstrated bulk effects of multiple NPs on dosimetry, extending previous work on single NP models by other groups [4]. Results show that injectable concentrations can affect the range of protons, proving to be more significant at higher energies. Future work will investigate the effects that GNPs can have on treatment plans, assessing any changes that need to be made.


**EP-1944**

**Lessons from the findings of 31 QUATRO audits in Europe**

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**Purpose or Objective:** A methodology has been developed for comprehensive clinical quality audits of radiation therapy programmes called Quality Assurance Team for Radiation Oncology (QUATRO). The purpose of these audits, which are distinct from accreditation, is to assist the audited centres in identifying and implementing opportunities for improving the quality of services offered to patients. Aggregating the findings from audits carried out over 10 years in Europe sheds light on the degree to which various dimensions of quality are satisfied and suggests interventions which are likely to be effective in improving quality in the audited centres.

**Material and Methods:** Thirty one centres in Europe have been audited with this methodology since 2005. The voluntary, confidential audits are conducted by multidisciplinary teams and take 5 days on-site to complete. Reports to the audited centres include both commendations, i.e. positive findings, and recommendations for quality improvement. A subset of the audited centres were designated Centres of Competence (CCs) through QUATRO. A coding key has been developed to aggregate and analyse the extensive data generated from this audit series.

**Results:** 600 commendations and 759 recommendations for improvement have been reported in the 31 audit reports. Positive attributes of the audited centres included patient care, communication, facilities (with the marked exception of the availability of treatment units) and quality control. Areas for improvement included staffing and equipment levels, professional development, documentation and quality management. Overall, 10 centres were designated as CCs. Of the 600 commendations, 220 were given to 10 CCs and 380 to other centres. Of the 759 recommendations, CCs received 82 while the other centres 677. The levels of physicists and RTT staffing generally met international recommendations in CCs whereas in the other centres major staff shortages were recorded. RTT understaffing was most acute but other staff groups also needed strengthening. Education, training and professional development of all staff, but especially RTTs, was seen as a weakness in many centres.

**Conclusion:** QUATRO audits provided the radiotherapy centres with an opportunity for an in depth analysis of their practices. The detailed reports constitute a template for practice improvement and highlight the need to develop strategies on the future development of radiotherapy services. The analysis of the 31 audits has also identified the need for common action items for enhancing the quality of radiotherapy in the audited centres. In particular, there is a need for extending the reach of educational programmes and for expanding the educational offerings to include quality management and associated topics.

**EP-1945**

**Plan submission comparison for commissioning of spinal and nodal SABR for oligometastases**

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**Purpose or Objective:** NHS England selected 17 centres of varying experience to take part in the Commissioning through Evaluation (CtE) programme in order to improve access to SABR for patients with Oligometastatic disease. A QA group was formed from members of a national trials QA group and a national SABR development group to ensure patient safety and treatment quality across participating centres, which utilise a variety of different equipment and techniques.