Planning. No systematic non-conformances with dose-volume and planning requirements have been observed from the responses to date, but some deviations from the required dose reporting protocol were found in returns from 10 of the 32 reporting centres.

Conclusions: The pre-trial RTQA undertaken to date has highlighted some issues in outlining and planning but appropriate dialogue between the RTQA team and the participating centres has allowed these issues to be addressed. Thus the overall aim of compliance with protocol for all participating centres should be achievable. An on-trial QA process will also help support this requirement and is ongoing.

EP-1308
IAEA support to national audit networks for radiotherapy dosimetry
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Purpose/Objective: The IAEA has a longstanding history providing support and assistance for radiotherapy dosimetry audits in various countries. It has supported the development of methodology and establishment of several national TLD-based QA audit networks for radiotherapy dosimetry. The main objective was to extend the availability of radiotherapy dosimetry audits to as many radiotherapy centres as possible throughout the world.

Materials and Methods: A series of Co-ordinated Research Projects (CRPs) has been conducted by the IAEA as of 1995 to assist in developing such national dosimetry audit programmes. The overall radiotherapy dosimetry audit approach established and developed throughout these CRPs is based on a process of increasingly complex steps and parameters being checked. The first CRP focused on the basic phantom calibrations. The basic program was extended to audits in non-reference conditions through a second CRP. The third CRP concluded in 2012, has expanded the dosimetry audit tools for more complex techniques used for treatment of cancer patients. This approach was developed so that experience of previous levels is used to inform development, implementation and analysis of results for subsequent levels.

Results: New procedures have been developed that include TLD based dosimetry for irregular fields, for heterogeneous situations, and for small MLC shaped fields relevant to stereotactic radiosurgery which had applicable to dosimetry for IMRT. In addition the programme included a new development of film-based 3D dosimetry methodology for testing dose distributions in small field geometry. The IAEA Dosimetry Laboratory has actively participated in the experimental part of these CRPs, provided new phantoms and conducted multicentre pilot studies to test the newly developed methodology. The national audit networks participating in these CRPs have incorporated in their programmes procedures for auditing hospital dosimetry for these techniques. In addition, the IAEA contributes to strengthening QA of the national TLD systems by exchanging dosimeters and verifying the TLD work of the national auditing organizations.

Conclusions: The IAEA Dosimetry Laboratory, the national audit networks closely cooperate at the consecutive stages of developing the dosimetry audit methodology locally and by carrying out cross-measurements. In this way the national audit systems are interlinked to ensure that international and national radiotherapy dosimetry audit networks are working to the consistent levels and standards. When broadly implemented, the network of national audit groups for radiotherapy dosimetry will contribute to ensuring the consistency of quality in dosimetry in radiotherapy centres worldwide.

EP-1309
Dosimetry audit of the entire radiotherapy process using lithium formate EPR dosimeters
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Purpose/Objective: The purpose was to develop a mailed audit dosimetry system that takes into account influences from the whole treatment chain including CT scanning, treatment planning and treatment delivery. The purpose was also to use the audit system in our healthcare region to verify the quality of head and neck radiotherapy at the four included clinics.

Materials and Methods: A semi-anthropomorphic phantom was constructed, designed to mimic the head and neck region. The phantom was made of PMMA, including a tumour structure partially encompassing the spinal column (made of Teflon), two structures resembling salivary glands, and a small air cavity symbolising the trachea. PMMA rods containing lithium formate EPR (electron paramagnetic resonance) dosimeters were inserted at six different measurement points in the phantom, three in the target volume, one in each salivary gland and one in medulla. The phantom was sent by mail to the audit sites where it was treated as a patient; including CT scan, dose planning and treatment delivery. A conventional five-field dose plan was used. After a complete treatment, the phantom was sent back together with the absorbed doses reported by the treatment planning system.

Results: Audit measurements have been performed at all four clinics in the healthcare region, results are seen in figure 1.

Figure 1. Results from audit measurements showing the deviation (in percent) between measured and calculated dose in the six different measurement points.

Except for one clinic, all target and medulla measurement points agree within 1.5% between measured and calculated doses. The result for the two salivary glands shows a larger deviation, mainly because of the steep dose gradient over these structures. One clinic (triangle) is deviating compared to the other clinics. After additional measurements, the most likely explanation is a handling mistake. Within these clinics there are three different dose planning systems in use: pencil beam convolution, anisotropic analytic algorithm and collapsed cone. No significant difference can be seen between the different algorithms. The mailing procedure worked satisfying and the stability of the dosimeters was not affected by the transport.

Conclusions: We find that the elaborated system provides a useful tool to ensure the quality of the radiotherapy treatments delivered in a clinic, especially when introducing new treatment modalities. Our future plans are to use the audit system for IMRT and VMAT audits in the region and in the extension perform a national audit.

EP-1310
Brand-new vertical layout proton therapy system
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Purpose/Objective: Brand-new vertical layout type of small proton therapy system (PTS) has been developed. The first system has been installed at Aizawa Hospital in Japan since April 2012. Beam performance test is now underway.

Materials and Methods: The world’s first system which arranges compact rotating gantry and cyclotron in vertical direction has been developed to save space and cost of facility building. This system enables building space to be a half of that of the conventional type, and it makes PTS easy to be installed in a small area. Though the system becomes compact, its performance has been perfectly kept by using many state-of-the-art technologies. These are multi-purpose nozzle which has function of both wobbling and scanning irradiation,
two set of orthogonal X-ray DR system for patient positioning, robotic couch, in-room CT, On-Line PET system for checking dose distribution in patient, respiration gating system for moving organ, and so on.

Results: Performance test is now underway and it has been confirmed that the proton beam of the energy range of 70MeV to 230MeV is successfully transported from the cyclotron to the treatment room. Various beam performance and dose distributions required for medical treatments are being acquired in early 2013, and medical treatment is expected to be started in 2013. Conclusions: The world's first vertical layout proton therapy system has been developed and installed. Beam characteristics of both wobbling and pencil beam scanning irradiation are now being obtained. There results will be presented in this conference.

EP-1311
Digital analysis of MLC leaf position in static IMRT
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Purpose/Objective: To analyze the position error, gap error and the accuracy of fluence map between expected and derived multi-leaf collimator (MLC) position of static (step & shoot) intensity modulated radiotherapy (IMRT).

Materials and Methods: The treatment plans for 10 patients of nasopharyngeal carcinoma were enrolled. Each plan had seven beams with uniformly distributed angles (0°, 51°, 103°, 154°, 206°, 257° and 309°). For each patient and each beam, both planned MLC file (.mlc) from treatment planning system and actually derived Dynalog file (.dlg) from 4DTC station were collected for the first 10 fractions. Argus software (Varian V7.4.0.3) was used to load and quantitatively analyze the actually derived MLC leaf position from Varian 23EX medical linear accelerator during treatment. For each beam, errors of leaf positions, gaps and fluence maps were compared for both Bank A and Bank B.

Results: All the statistical results of 70 beams from 10 patients were summarized in the table below. The position errors of Bank A and B have similar absolute values but opposite directions, which were complementary to each other. Therefore, the gap errors were very small, where the maximum gap was smaller than 0.01 cm. The position errors for beams at 103° and 257° (horizontal) were compared with beam 0° (vertical) respectively by paired T-test, where all the differences were not significant.

<table>
<thead>
<tr>
<th>position error</th>
<th>gap error</th>
<th>Fluence error</th>
</tr>
</thead>
<tbody>
<tr>
<td>all leaves</td>
<td>all leaves</td>
<td>all leaves</td>
</tr>
<tr>
<td>Bank A</td>
<td>0.031±0.008cm*</td>
<td>0.045±0.015cm*</td>
</tr>
<tr>
<td>Bank B</td>
<td>0.028±0.010cm*</td>
<td>0.003±0.003cm</td>
</tr>
<tr>
<td>Max.</td>
<td>0.079cm</td>
<td>-0.010cm</td>
</tr>
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</table>

* average ± standard deviation

Conclusions: Based on the latest standard from report TG142 that 'Leaf position accuracy for IMRT<1mm', this study proposed that the 60 pairs of MLC leaves in Varian 23EX provide acceptable position accuracy and good repeatability. The T-test results between 0° and horizontal beams proposed that the gantry angle didn’t affect the leaf position accuracy significantly. The small fluence errors ensured the dose distribution accuracy and reliability between expected (plan) and executed (delivery) IMRT process.

EP-1312
Intraoperative technique versus whole breast radiotherapy: cost analysis from the hospital and societal viewpoint
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Purpose/Objective: Therapeutic strategies are usually evaluated on the basis of feasibility, clinical effectiveness and safety. More recently due to the limitation of resources the importance of economic factor has been stressed. Targeted intraoperative radiation therapy (IORT) has been described as an alternative to whole breast irradiation (WBI) for patients with early-stage breast cancer. The randomized phase III TARGIT trial has proved the equivalence of the two techniques in terms of recurrence rates and a lower overall toxicity profile in favor of IORT so that we are legitimate to perform a comparison in term of cost minimization analysis (CMA). The aim of the study is to estimate resources and infrastructures cost necessary for economic evaluations following the Activity Based Costing (ABC) methods.

Materials and Methods: According to the ABC approach we defined all the activities in the treatments. We assigned a cost to every activities module measuring the work times required by the various professional groups involved in IORT and WBI treatments. The exact times of attendance of the different occupational groups and the room occupancies for any core procedures of radiotherapy were prospectively documented. Data for 50 IORT and WBI were collected and subsequently statistically analyzed. A questionnaire has been administered to all patients to assess the indirect costs for every treatment modality like transports, lost of production and assistance fees.

Results: From the hospital point of view data provide a cost benefit ratio in favor of IORT. Operating room occupancy is quite similar in contrast to the staff attendance time. Definition of the target volume is the most time consuming procedure for the physicians taking 1 h on average. Medical doctors attends 60 min and 45 min in IORT a WBI respectively. The duration related to the presence of technicians. It has a mean value of 58 min in IORT while for routine radiotherapy sessions the overall time, including CT acquisition, set-up verification and daily treatment is 410 min, evaluated time will be converted in economic value. As questionnaires are being evaluated societal impact data are not still available.

Conclusions: The data presented here allow a cost comparison between IORT and WBI. Economic evaluation seems to be in favor of the IORT though one has to be aware that a comprehensive economic evaluation needs to consider the work load for every machine.

EP-1313
Feasibility of single-isocenter intensity modulated radiosurgery for multiple brain metastases
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Purpose/Objective: To assess the dosimetric feasibility to perform intensity modulated radiosurgery (IMRS) of multiple brain metastases by using fixed beams and a single isocenter.

Materials and Methods: Five cases of patients with multiple brain metastases (range from 4 to 19) were planned using Eclipse TPS (v 10.0) and the AAA algorithm (1.0 mm calculation grid). For each case, a single isocenter was used with several coplanar beams (range 12–18) with fixed gantry angles. Delivery was done using a Varian Clinac 2100 CD equipped with a Millennium 120 MLC (5 mm width on the central leaves) and an EPID (HS 500). The sliding-window technique with dose rate of 600 MU/min was used in all IMRS deliveries. The patient-related IMRS quality assurance was performed using three strategies: 1) fluence verification of each beam was done using portal dosimetry with the EPID and the PDIP algorithm (v 10.0) of EclipseTPS. Measured fluences were compared to predicted ones using 4%-1 mm gamma criteria. 2) Point absolute dose was checked in a high dose and low gradient region of a polystyrene phantom where the original patient plan was mapped. 3) Patient dose reconstruction was performed by using the Dynalog files registered during the irradiation of the phantom verification. An in-house program was developed by TT to generate the dynamic MLC from the Dynalog files. Original plan was compared with the Dynalog-based reconstructed one by using DVH data for the target and organs at risk outlined (brainstem, optic nerves and optic chiasma) on each patient case.

Results
1) The average gamma passing rate was 98.5% for the 80 IMRS fields analysed using 4%-1 mm criteria.