bony structure fusion without any translational or rotational limitations was done. Secondly, the treatment isocenter position was reproduced with only a translation registration. In the first technique, target volume deformation and translation relative to the best bony anatomy match enabled the evaluation of the IM. With the second technique, direct evaluation of the complete PTV (combined IM and SM) margin is possible. For both, we tested symmetric and asymmetric margins around the nodal CTV ranging from 0 to 10 mm. For each patient, the tested margins were applied on all CTs and CBCTs data sets forming either an ITV or a PTV. This way, different virtual planning and treatment sequences were simulated. For each sequences, statistics of the relative volume of nodal CTV not overlapping the planned PTV or ITV was measured. Margin recipes were compared based on their maximum relative Non Overlapping CTV Volume (NOV) for 95% of treatment fractions, 90% of possible planning and 90% of patients. Delineation error was evaluated by repeating contouring of the same images.
Results: The symmetric expansion analysis showed that with a NOV threshold of 3%, the obtained margins are 4 mm and 5 mm for ITV and PTV respectively. For asymmetric ITV, with same NOV threshold, the margins are 3 mm in all directions except anteriorly and internally which are 5 mm. With one observer, the measured delineation error was 1 mm. This value might increase with multiple observers.
Conclusion: In the future, we will validate this geometric margin analysis with a dosimetric approach involving 3 different methods of adaptive radiation therapy where PLN are treated with a bony anatomy match while simultaneously treating the prostate located by implanted gold markers. These techniques may further reduce both prostate and PLN margins.

2060 POSTER

Flattening Filter-free Beams for Extreme Hypofractionated Radiotherapy of Localized Prostate Cancer

D.R. Zwahlen[1], S. Lang[1], S. Kloeck[1], Y. Najafi[1], G. Studer[1], K. Zaugg[1], U.M. Luetolf[1]. [1]*Universitätsspital Zürich, Radiation Oncology, Zürich, Switzerland*

Background: Short hypofractionated schedules for localized prostate cancer are investigated with high-dose-rate brachytherapy or Cyberknife® stereotactic body radiotherapy (SBRT). We tested the ability to deliver the dose of 38 Gy in 4 fractions and distributions of flattening filter-free (FFF) photon beams with TrueBeam® linear accelerator SBRT plans.
Material and Methods: Treatment planning study was performed on CT scans of 7 patients with localized carcinoma of prostate using 10 MV FFF photon beams (X10FFF) of TrueBeam® linear accelerator (Varian Medical Systems). Planning target volume (PTV) included the prostate and base of seminal vesicles defined by MRI and CT imaging, plus a 2 mm volume expansion in all directions, except posterior, where the prostate abutted the rectum and expansion was reduced to zero. Urethra and rectum were identified on MRI and CT imaging and delineated on CT slices where PTV contour was present. Volumetric intensity modulated arc therapy (VMAT) plans were prepared in Eclipse® treatment planning system (PRO 8.9, AAA 8.9). The prescribed dose (PD) was 4 x 9.5 Gy = 38 Gy. PTV coverage was 95% of PD, allowing maximum dose of 200% of PD. Maximum dose (Dmax) for organs at risk (OAR) including rectum and rectal mucosa was 100% and 75%, for urethra and bladder 120% of PD, respectively. Two 360º arcs with maximum dose rate of 2400 monitor units (MU)/min were used. Plans were normalized to Dmax. Number of MU, treatment delivery time, dose parameter for PTV coverage and dose to OAR were recorded.
Results: Prescription isodose was 74.8–81.0%. PTV coverage, urethra, rectum and bladder statistics are shown in the table.

	Mean ± 1 Standard Deviation
PTV V100 (%)	97.72±0.16
PTV D90 (Gy)	39.15±0.13
Urethra Dmax (Gy)	41.42±1.07
D10 Urethra (Gy)	40.47±0.81
D50 Urethra (Gy)	39.71±0.78
Rectum solid	9.04±1.50
Rectal mucosa Dmax (Gy)	28.95±1.07
Rectal mucosa D1 (Gy)	27.47±0.98
Rectal mucosa D10 (Gy)	21.99±1.15
Rectal mucosa D25 (Gy)	14.77±2.31
Bladder solid	3.34±1.51
Bladder Dmax (Gy)	35.92±2.39

On average 3677 MU ± 542 were used and maximum dose rate was 1462–2400 MU/min. Average dose rate was 1961 MU/min ±468. Treatment delivery time for all patients was 2 min.

Conclusion: Non-invasive FFF SBRT is feasible and dose constraints for PTV coverage and OAR are met similar to high-dose-rate brachytherapy or Cyberknife®. Homogeneous target coverage is achieved while sparing urethra and rectum. FFF SBRT for localized prostate cancer allows fast and safe delivery of extreme hypofractionated radiotherapy and may help to reduce the impact of organ motion.

2061 POSTER

Clinical Evaluation of 6 Degree-of-freedom X-ray Image-guidance Fusion Algorithm and Robotic Positioning System for Frameless Cranial Radiosurgery

M. Graveline[1], D. Marti[1], V. Thakur[2], R. Ruo[2], E.T. Soisson[2], H. Patrocinio[2], D. Roberge[1]. [1]*McGill University Health Centre, Radiation Oncology (D5–400), Montréal, Canada;* [2]*McGill University Health Centre, Medical Physics, Montréal, Canada*

Purpose: (1) To use stereoscopic x-rays paired with infrared (IR) tracking (ExacTrac®) to determine patient positioning error in frameless cranial radiosurgery, and (2) to evaluate the effects of region-of-interest (ROI) exclusion on 6D fusion results.
Methods and Materials: (1) Positioning errors were quantified through restrospective analysis of ExacTrac images taken for 17 patients (23 targets). All images (196) were sorted into 2 categories: initial and verification. Initial images are acquired after patient setup using an IR camera system and fiducial array. Verification refers to subsequent images used to check patient position. Corrections greater than the tolerance of 0.7 mm/1º were required in 49/173 image sets requiring patient repositioning, no corrections were made in the remaining 124 sets.
(2) ROIs including (i) air external to the skull, (ii) mandible, and (iii) neck are often manually excluded from 6D fusion. The effect of various ROI exclusion on the 6D fusion was assessed by repeating fusions using varying ROIs for 12 patients.
Results: See the table.

Displacement	Study					
	(1) Deviation detected in:			(2) Difference in fusion: no blocking vs. blocking of ROI:		
	Initial	Verification		(i)	(ii)	(iii)
		Correction	No correction			
Translation (mm)						
Lat	0.3±1.2	0.3±0.9	0.0±0.3	0.05±0.07	0.03±0.04	0.07±0.07
Lng	−0.2±1.9	0.5±1.1	0.1±0.3	0.06±0.04	0.16±0.28	0.09±0.10
Vrt	−1.1±0.9	−0.6±1.2	−0.1±0.3	0.05±0.04	0.19±0.40	0.06±0.06
Rotation (degrees)						
Lat	0.0±0.9	0.0±0.9	0.0±0.3	0.08±0.09	0.21±0.25	0.12±0.09
Lng	0.2±1.0	0.0±0.0	−0.1±0.3	0.06±0.03	0.19±0.35	0.20±0.21
Vrt	0.0±0.6	0.5±0.9	0.0±0.3	0.11±0.25	0.22±0.46	0.12±0.19

Mean±SD (SD = Std. Dev.)

(1) The largest shifts were detected upon initial positioning in the mask using the IR array only. SD of applied corrections was up to 1.2 mm/0.9º. In 71% of image sets, detected shifts were below the pre-determined tolerance (SD 0.3 mm/0.3º in all directions).
(2) ROI exclusion effects 6D fusion. Minimal differences were seen when excluding air only but deviations up to 1.4 mm/1.6º were seen when bony anatomy (lower jaw & neck) were excluded from 6D fusion.
Conclusion: Large initial positioning errors (>1 mm) were detected with ExcaTrac when using the mask, fiducial array and camera only for patient setup. Intrafraction motion greater than 0.7 mm/1º were observed in 29% of images. Residual shifts detected by ExacTrac are on the order of 0.3 mm (95% CI < 0.7 mm). Excluding bony anatomy that is not rigid with respect to intracranial target (lower jaw and neck) will effect the magnitude of shifts detected using 6D fusion.

2062 POSTER

Comparative Study Between Coplanar and Non-coplanar Techniques in Radiotherapy of Abdominal Tumours

L. Diaz[1], A. Ureña[2], I. Castro[2], V. Díaz[1], I. Villanego[1], E. Gonzalez[1], J. Lupiani[1], M.D. De las Peñas[1], M. Iborra[2], E. Alonso[1]. [1]*Hospital Puerta Del Mar, Radiation Oncology, Cadiz, Spain;* [2]*Hospital Puerta Del Mar, Radiophysics, Cadiz, Spain*

Background: Radiotherapy treatment using 3D techniques for abdominal tumours is usually extremely difficult if we focus on gastric or pancreatic cancers, due to the irregularity of the PTV's and the proximity of many organs at risk. Of these, the most critical are often the kidneys due to its constraints that are hard to achieve. To overcome this, in our center are using non-coplanar treatment techniques, and the comparison with previously used techniques is the aim of our study.

Materials and Methods: We used PCRT v5.08 planner and EMAMI and Quantec tolerance tables for OAR. Ten patients with pancreatic or gastric neoplasm have been chosen, with 45 or 50. 4 Gy treatment dose prescription. All treatments were planned with two types of plans: one with coplanar beams and the other one with non-coplanar and introducing table's turns. Schemes with three beams (anterior and two sides) or four fields in a box were used, depending on the suitability of them in each case. All plans with non-coplanar fields have made a turn table in the anterior beam and some of them, on the sides to fully optimize the kidneys blocked by the multileaf collimator. In any case, leaf conformations are made automatically (with a margin of 5 mm) to avoid the variability introduced by the dosimetrist and that the comparison is valid and reproducible plans. We have also used the same turns of collimator for plans with coplanar and non-coplanar beams. We evaluated a number of indicators to evaluate the goodness of the new technique in an objective manner. In this regard, we have never received doses greater than 107% of the prescribed dose in the PTV of any plans. For the isodose of the 95%, we are trying to get at least 95% for the coberture of the target volume. In the case of kidneys evaluated the mean dose and V15 (%). To evaluate the liver only measures the mean dose.
Results and Conclusions: Our results show that in most of cases there is an improvement in the dose delivered to organ at risk while there isn't luck of coverage of dose in PTV (Table 1). On other hand, this technique involves a higher treatment time delivery compared to standard box techniques.

Table 1

Volume	Right kidney				Left kidney				Liver		PTV	
Unit	V15 (%)		Mean dose (Gy)		V15 (%)		Mean dose (Gy)		Mean dose (Gy)		V95 (%)	
Technique	COP	No COP	COP	No COP	COP	No COP	COP	No COP	COP	No COP	COP	No COP
Mean	28.4	16.9	10.2	8.0	42.1	30.7	14.0	11.8	17.4	16.8	98.8	99.0

2063 POSTER

Volume Dose Prescription in Stereotactic Body Radiotherapy for Lung Cancer

A. Terahara[1], N. Saotome[1], K. Miyamoto[1], M. Omori[1]. [1]*Toho University Medical Center Omori Hospital, Radiology, Tokyo, Japan*

Background: 3D treatment planning system and dose-volume calculations are commonly used now and the dose prescription method is changing. The reference point dose was recommended for prescription, however, volume dose is becoming popular for IMRT and also for 3D-CRT. In stereotactic body radiotherapy (SBRT), PTV for early stage lung cancer usually includes low density lung field area around tumour volume. Because of that, the periphery of PTV tends to receive relatively lower dose even with appropriate leaf margin of 5 mm.
Material and Methods: We analyze dose distributions in four cases with lung cancer treated by SBRT. We calculated dose distributions with Xio 4.5 using superposition algorithm. PTV margin was added 5 mm around CTV, and leaf margin of 3 to 5 mm was also added for SBRT. We prescribed by isocenter dose in clinical practice. We compared doses for CTV with those for PTV. We also moved isocenter by 5 mm, which is the same as PTV margin, to 6 directions and the same dose comparison was made in each movement.
Results: D95, minimum dose (DMin), and mean dose (DMean) for PTV were 89.5, 80.2, and 96.0% of the prescription dose on an average respectively, and they were lower than those for CTV, that were 95.9, 92.8, and 98.9%. With the shift of isocenter, D95, DMin, and DMean for CTV were reduced to 94.5, 88.5, and 98.5% on an average respectively, which were still much higher than those for PTV. Even though the reduction of CTV dose was largest, DMin was an average of 85.7%, when isocenter moved to cranial and caudal direction, it was higher than that of PTV dose of 80.2%.
Conclusions: If we add appropriate leaf margin around PTV, the dose reduction for CTV by isocenter shift in the range of PTV margin was relatively small. Therefore, It is not considered essential to cover the whole PTV by high dose volume when sufficient margin is added around CTV.

2064 POSTER

Comparing Volumetric Intensity Modulated Arc Therapy With Multiple Static Field Radiosurgery for Brain Metastases

J.E.C. Brock[1], C. Jones[1], E. Wells[1], H. Chapman[1], L. Corsini[1], K. Burke[1], M. Brada[1]. [1]*Royal Marsden Hospital, Radiotherapy, London, United Kingdom*

Background: Stereotactic radiosurgery (SRS) is an effective treatment for oligometastases in the brain. Multiple static field (MSF) techniques can achieve excellent dose conformity and rapid dose fall-off outside the target but are resource intensive with long treatment times if 2 or more lesions are treated. Arc therapy offers potentially equivalent or improved dosimetry with shorter treatment times.
Materials and Methods: Linear accelerator MSF radiosurgery or 3−4 field conformal plans for 10 patients with 1, 2 or 3 brain metastases were compared with RapidArc (RA) plans generated using 2 coplanar arcs with a single isocentre. Clinical target volume (CTV) was all tumour visible on MRI with a 3 mm margin applied to generate the planning target volume (PTV). 18−25 Gy was prescribed in a single fraction with 99% of the PTV to receive at least 90% of the prescription dose. Dose constraints of 8 Gy were applied to critical structures (optic nerves, optic chiasm and brainstem).
Conformity index for 90% of the prescription dose (CI90%), conformity gradient index (CGIg), mean dose to normal brain and treatment delivery time were compared.
Results: 7/10 patients were female. Mean age (range) was 58.2 (44−66) years. Lesions were metastatic from breast (4), lower gastrointestinal (1), renal cell (2), lung (1) and oesophagus (1) carcinomas and carcinoma of unknown primary (1). 6 lesions were solitary, 2 patients had 2 metastases and 2 had 3 metastases. Combined PTV volume was 7.44 cm^3 (small solitary cerebral peduncle lesion) to 123.11 cm^3 (3 large left cerebral lesions).
RA plans had significantly better CI90% (mean 1.22 vs. 1.56, $p < 0.01$) compared with MSF plans for 7 patients (8 lesions). Dose to normal brain was not significantly different although CGIg was inferior (mean 46.5 vs. 59.4, $p = 0.02$). Treatment time (limited by a maximum dose rate of 600 monitor units per minute) was equivalent for solitary lesions but was approximately half for RA when 2 metastases were treated (21 vs. 43.5 minutes).
For 3 patients (2 or 3 metastases each) RA plans reduced mean dose to normal brain by approximately 50% compared to 3−4 field conformal plans.
Conclusions: RapidArc can be used to treat 1 to 3 brain metastases with SRS. Treatment (and planning) time should be considerably shorter when using RA compared with MSF for 2 or 3 metastases. Reduced dose to normal brain when treating multiple mets with RA versus 3−4 field conformal plans may be clinically significant.

2065 POSTER

Confirmation of Internal Target Volume and Dosiology Study for Lung Cancer Using 4D-CT Technology

T. Bai[1], J. Lu[1], Y. Yin[1]. [1]*Shandong Cancer Hospital & Institute, Radiation Physics, Jinan Shandong, China*

Purpose: For the effect of breathing motion, it is difficult to confirm the tumour accurately in lung cancer in the intensity-modulated radiotherapy (IMRT). This study is to confirm the internal target volume (ITV) and compare the volumetric and dosiology differences between 3D-CT and 4D-CT, using 4D-CT technology.
Materials and Methods: Eight patients with primarily lung cancer were enrolled and both 3D and 4D-CT were taken. For each patient, 3D-CT was taken as reference image and clinical target volume (CTV) was defined on it. Extended CTV with setup margin was defined as PTV-3D; for each respiratory phase, CTV were drawn separately and mixed together as ITV, which was extended as PTV-4D. Design different IMRT plans on PTV-3D and 4D separately for each patient with same prescription doses, field degrees and optimization target functions. The differences of target volumes, dose distributions on targets and organs as risk (OAR) were compared.
Results: The volume is 150.67$\pm$86.67 cm^3 for PTV-3D and 130.17$\pm$79.89 cm^3 for PTV-4D, which is 13.61% (8.51–23.53%) smaller. There is no significant difference of target conformal index (CI) and homogeneity index (HI). About the dose on OARs (including lung, heart and spinal-cord), 4D plans have lower dose to the 3D plans: V5, V10, V20 and V30 for total-lung is cut separately from 41.25%, 29.75%, 21.25%, 13.00% to 38.13%, 27.00%, 17.25%, 9.13%; mean lung dose (MLD) is cut from 1103.63 cGy to 911.21 cGy; mean heart dose is cut from 450.43 cGy to 372.20 cGy; maximum dose for spinal-cord is cut from 3162.83 cGy to 2967.63 cGy.
Conclusions: 4D-CT technology can be used to bridge the gap of missing or extending the target volume on 3D radiotherapy. It will bring better accuracy an lower dose on OARs as well.