The intra-fractional uncertainties due to baseline drift of lung tumors are:

Direction	M (mm)	Σ (mm)	σ (mm)
LR	-0.1	0.1	0.4
AP	-0.1	0.3	0.6
SI	0.1	0.5	0.8

M: the overall mean or group systematic error, Σ: the standard deviation (SD) of the systematic error, σ: the SD of the random error.
In the absence of intra-fraction IGRT, the baseline drift uncertainties does not imply the use of increased standarized margins in any direction in SBRT for lung tumors when the rest of uncertainties are minimized. Nevertheless this uncertainty can be very important in some patients leading to the needance of increased margins.**Conclusion**
Real-time monitoring and frequent adjustments of the couch position are suggested to be necesary to compensate for possible underdosage in CC direction due to baseline drift in SBRT for lung tumors in some patients.

Electronic Poster: Physics track: Adaptive radiotherapy and inter-fraction motion management

EP-1982 Pancoast tumours. A good candidate for proton spot scanning?

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Purpose or Objective
Large anatomical changes and respiratory motion during radiotherapy for lung cancer patients challenge precise delivery of proton spot scanning, with high risk of target under dosage. Upper-lobe pancoast tumors are less influenced by respiration and may be good proton-candidates, but setup-errors and longitudinal anatomical changes may still deteriorate the dose distribution.
Material and Methods
Nine patients with stage III NSCLC Pancoast tumours, treated with photon volumetric arc therapy (VMAT) were retrospectively planned using three-field intensity modulated proton therapy (IMPT) and single field uniform dose (SFUD) with field directions avoiding distal fall off in front of the spinal cord. The brachial plexus (BP) overlapped with the target for all patients and was delineated by an experienced radiologist (Fig 1). Target coverage and dose to oesophagus, lungs, BP and spinal cord of the initial treatment plans were compared. To evaluate the dose deterioration due to setup errors, all treatment plans were shifted 3 mm in each of the six directions and recalculated. To evaluate the dose deterioration due to tumor shrinkage, the daily CBCT scans acquired for setup were used. The tumor shrinkage present at the CBCT of the last treatment day was delineated and each plan was recalculated on a CT, where the HU inside the delineated structure were set to lung density. For both scenarios, CTV receiving 95% of the prescribed dose ($V95\%_{CTV}$) and the dose to the hottest 1 cm^3 of the spinal cord ($D1cm^3_{spinal}$) was analyzed.

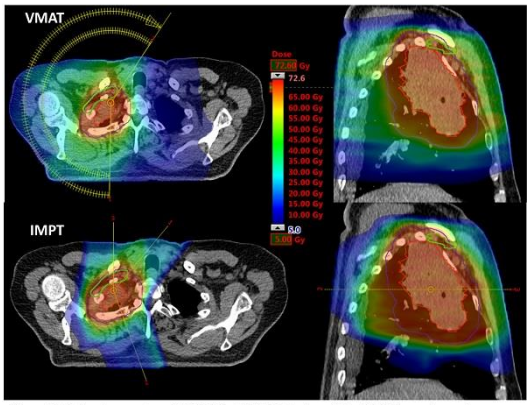

Figure 1: Patient example with GTV (red), PTV (blue) and Brachial Plexus (green) delineated. Dose color wash of doses above 5 Gy is shown for VMAT (upper panel) and IMPT (lower panel).

Results
Lung dose metrics (mean dose, V20Gy and V5Gy) were significantly reduced (Fig 2), while no reduction was seen for the mean dose to oesophagus and BP (Fig 2) compared to VMAT. There were no significant differences in normal tissue dose between IMPT and SFUD. For target coverage, the $V95\%_{PTV}$ differed between patients and planning strategies depending on target proximity to the spinal cord ($D1cm^3_{spinal}$ < 45 Gy for all plans). For SFUD $V95\%_{PTV}$ was median[range] 93%[64-100], while IMPT and VMAT achieved 99%[97-100] and 94%[85-98]. Setup errors decreased target coverage of up to 3%, 4% and 10% and increased $D1cm^3_{spinal}$ by 4Gy, 2 Gy and 6Gy for VMAT, SFUD and IMPT, respectively. Robustness towards tumor shrinkage was high for all SFUD/IMPT, where the field directions selected ensured <0.1 Gy increase in $D1cm^3_{spinal}$. VMAT was less robust and $D1cm^3_{spinal}$ increased 2-9 Gy, but low initial spinal cord doses prevented over dosage. All plans maintained initial target coverage regardless of tumor shrinkage.

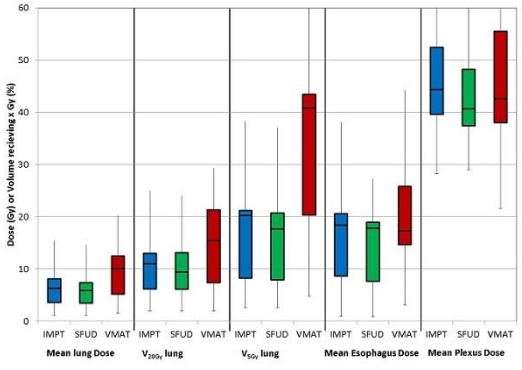

Figure 2: Difference in dose to organs at risk using IMPT, SFUD and VMAT presented as a boxplot. The box shows the range between 1st and 3rd inter quartile ranges, the vertical line in the middle indicates the median value and the whiskers range from minimum to maximum value. For both IMPT and SFUD the reduction in lung dose (mean, V_{20Gy} and V_{5Gy}) compared to IMRT was statistically significant (Wilcoxon sign rank, p<0.05).

Conclusion
Pancoast tumors are candidates for proton spot scanning reducing lung dose significantly compared to VMAT. IMPT is preferred over SFUD due to superior target coverage. No sparing of the BP was seen due to large overlap with the target. For field directions avoiding distal fall off in front of the spinal cord, both IMPT and SFUD were highly robust towards tumor shrinkage, while setup errors posed a risk of target under dosage or spinal cord over dosage mainly for IMPT.

EP-1983 Inter and intra-fraction bowel motion during abdomino-pelvic stereotactic ablative radiotherapy

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Purpose or Objective
Abdomino-pelvic Stereotactic Ablative Radiotherapy (AP-SABR) is increasingly used to treat oligometastatic pelvic nodal disease. Bowel within or adjacent to the Planning Target Volume (PTV) is often the most significant organ at risk. Bowel motion is dynamic and unpredictable and could result in significantly different dose delivered than planned. This retrospective single centre study quantifies inter and intra-fractional changes in bowel using cone beam CT (CBCT) and calculates the impact on delivered bowel doses.

Material and Methods
10 consecutive patients treated with AP-SABR delivered using flattening filter free (FFF) volumetric modulated arc therapy (VMAT) to a dose of 30Gy in 3 or 5 fractions were investigated (5 fractions used for re-irradiation cases). Delivery times are around 90 seconds. Median intra-fraction imaging time period was around 6 minutes. 84 CBCT images acquired immediately pre and post each SABR fraction were exported to Monaco Treatment Planning System and rigidly co-registered with the planning CT scan. Individual bowel loops within a 3cm expansion beyond the PTV were contoured on each CBCT (majority of dose fall off occurs within this region). Inter-fraction bowel changes were calculated by comparing the planning CT to each pre-treatment CBCT. Intra-fraction bowel changes were calculated by comparing each pre and post-treatment CBCT. Dosimetric consequences of changes in bowel volume and position were determined by superimposing the planned dose distribution onto each CBCT and generating dose volume histogram data. Bowel volume, maximum dose to 0.5cc (Dmax) and 5cc (D5cc) within 3cm of the PTV on planning CT and CBCT were compared using a Wilcoxon signed-rank test.

Results
Significantly higher bowel volumes within a 3cm PTV expansion were consistently found on CBCT compared to planning images, resulting in greater delivered than planned bowel doses (Figures 1 and 2). Bowel volumes within 3cm of the PTV, Dmax and D5cc were greater on CBCT images compared to planning CT (all $p<0.0001$). Dmax of bowel on treatment CBCTs was greater than that planned in 37 of 42 (88.1%) pre-treatment CBCTs and 33 of 42 (78.6%) of post-treatment CBCTs. By summating the delivered Dmax per fraction for individual patients, the median net increase over the whole treatment course on pre and post-treatment CBCTs was 33.7% (range -18.5 to 133.1%) and 29.9% (range -23.8 to 135.9%) respectively. 5 of 10 (50%) patients had greater than 20% net increase in Dmax compared to planned doses. No significant difference was observed for intra-fraction variations in bowel volume, Dmax and D5cc within 3cm of the PTV.

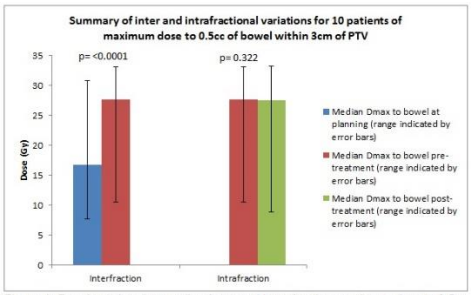

Figure 1: Bar chart showing median inter and intra-fraction maximum dose to 0.5cc of bowel (Dmax) within 3cm of the PTV for 10 patients with minimum and maximum ranges of Dmax indicated by error bars. Significantly greater inter-fraction variation in Dmax during treatment compared to planning was demonstrated (p= <0.0001). Intra-fraction variation was non-significant.

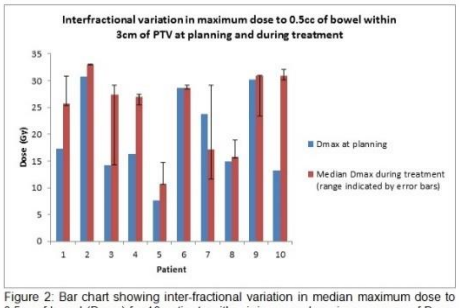

Figure 2: Bar chart showing inter-fractional variation in median maximum dose to 0.5cc of bowel (Dmax) for 10 patients with minimum and maximum ranges of Dmax indicated by error bars. Significantly greater median Dmax to bowel was observed during treatment compared to planning (p= <0.0001).

Conclusion
Significantly greater volume of bowel within a 3cm expansion of the PTV was observed during treatment than at planning, resulting in significantly higher than planned bowel doses. Little intra-fraction change in bowel was observed. Developing adaptive workflows that utilise plan-of-the day or daily fast adaptive re-planning could compensate for inter-fraction bowel changes.

EP-1984 Cone beam computed tomography (CBCT) interobserver variability in patient setup error evaluation

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Purpose or Objective
To evaluate the interobserver variability in registration of daily CBCT to treatment-planning-CT (TPCT) in patients treated in five different anatomical sites, with volumetric modulated arc therapy (VMAT).

Material and Methods
In an off-line retrospective approach, 16 well-trained radiotherapy technicians/radiotherapists (RT) performed manual CBCT/TPCT registrations for five patients, treated with VMAT for head and neck, lung, breast, prostate and gastric tumors. An Elekta Synergy XVI linac was used for CBCT acquisition and CBCT/TPCT registration. Each RT quantified the patient setup error in all three axes, by manually matching CBCT and TPCT datasets after automatic pre-matching either based on a gray scale or bone algorithm. Matching results obtained by RTs were compared to those obtained by 1 board certified radiation oncologist with extensive experience in image guided radiotherapy: differences between technologists and radiation oncologist's results were quantified. A statistical analysis was performed to calculate the minimum threshold of agreement between the observers.

Results
In total, 137 CBCT datasets were acquired and 2281 CBCT/TPCT registrations and setup error evaluations