Purpose/Objective: Relevant dosimetric errors, which can be identified using sub-arc analyses, may be obscured when performing integral dose QA for VMAT. Sub-arc EPID-based pre-treatment dose verification requires synchronization of the acquired images to Control Points (CPs). Published methods use logging features provided by the linac vendor or specific hardware solutions. This work aimed to develop an independent software-based synchronization method relying exclusively on information from the acquired images. Moreover, the sensitivity of this novel QA method to detect clinically relevant errors in leaf positioning and dose rate was assessed, both for sub-arc and integral dose QA.

Materials and Methods: During VMAT delivery, raw EPID images are continuously acquired. The images are converted to Portal Dose Images (PDI) after correction for EPID induced effects like crosstalk. In contrast to other methods, synchronization of images to CPs of the VMAT sequence is based on the near maximum grey value in each image. The ratio between this value and the sum of all near maxima is proportional to the number of MU delivered during acquisition of that image. From the CPs, both the integral VMAT fluence and fluences corresponding to 10 ME sub-arcs can be derived, taking into account the dynamic behaviour of the plan. The method was tested using a cooled CCD-camera based EPID at six Elekta linacs for a group of 15 prostate cancer patients. PDI predictions were compared to the measurements using a gamma evaluation with 2%/2mm reference values for integral dose QA and 3%/3mm for sub-arc analyses. To assess the methods sensitivity, systematic and temporal perturbations in MLC positioning and dose delivery were introduced in a nominal plan.

Results: For the 15 patients, on average 99.6 ± 0.3% (1 SD) of pixels passed the gamma test for integral VMAT QA. The average mean gamma was 0.30 ± 0.02. Also sub-arc analyses showed good results with overall mean pass rates of 98.6 ± 0.9% and median mean gamma values of 0.25 ± 0.02 (see Figure 1). In time and between different linacs the QA results were highly reproducible. By evaluating integral PDIs, errors in MLC leaf positioning, reducing the distance between opposing leaves by 1 mm, resulting in a 2.4% change in mean prostate dose, could easily be detected. Using sub-arc analyses, temporal perturbations, like a stuck leaf for 5 CPs resulted in a large increase in near maximum gamma values (γ). Temporal dose perturbations, like an addition or reduction of 1 MU per CP over a range of 10 CPs, while maintaining the overall number of MUs constant, were also clearly detectable.

Conclusions: A novel method to synchronize acquired EPID images to VMAT delivery was developed, allowing accurate sub-arc VMAT dose verification. Without major adaptations it can also be used in other clinics. Even small deviations to nominal treatment plans could easily be detected. Currently, we apply this method routinely for VMAT QA.

Purpose/Objective: The purpose of this study is to develop statistically based action levels for error detection during real-time EPID-based patient treatment verification for IMRT and VMAT based on measured real-time patient verification results.

Materials and Methods: The real-time verification system (Watchdog) utilises a comprehensive physics-based model to generate a series of predicted transit cine EPID image as a reference data set, and compares these to measured cine-EPID images acquired during treatment. The agreement between the predicted and measured transit images is quantified using chi-comparison (currently 4%, 4 mm) on a cumulative frame basis. Cine-EPID images were acquired from the first two fractions of 37 IMRT patients to generate the action levels; 10 Prostate treatments, 10 head and neck treatments, 7 Pelvic treatments, and 10 rectum treatments. Statistical process control (SPC) was used to generate the action levels at 3 standard deviations from the mean for each treatment site. The action level function is separated into two phases; 0-2 seconds, and >2 seconds to account for uncertainty at the beginning of image acquisition.

Results: In the first 2 seconds of treatment, a linear action function was defined (see figure). The derived action levels (4%, 4 mm) after 2 seconds of image acquisition for prostate, H&N, pelvic, and rectum were 67%, 50%, 63%, and 61% respectively. In the figure, an error detected toward the end of the treatment course for a head and neck patient correlated with weight loss shown on CBCT scans.

Conclusions: We have developed preliminary action levels for a real-time EPID based treatment verification system (Watchdog). These action levels are designed to be applied to real-time verification during treatment with immediate intervention during SBRT treatments and post-delivery investigation during standard fractionation. Initial results found that the system detected significant changes in patient contour due to weight loss for a head and neck treatment.