Materials and Methods: The error detection system considered here consists of three layers: 1) a software algorithm to detect errors in a treatment plan based on hard-coded rules, 2) a software algorithm to detect errors based on a probabilistic Bayesian network model which draws from prior radiotherapy plans, and 3) EPID dosimetry performed either prior to treatment or during treatment. The multi-layered system is intended to detect different classes of error and provide a 'defence in depth'. The system was validated against a radiotherapy incident database consisting of 2,599 reports collected over a 2.5 year period. Results presented here focus on external beam treatments with photon beams. The sensitivity and specificity of the probabilistic Bayesian error network was validated by introducing simulated errors and benchmarking against expert observers.

Results: The sensitivity of the multi-layered system is 91%. EPID dosimetry alone provide a 74% sensitivity for, but only if used during the treatment (i.e. 'in vivo'). If performed prior to treatment the sensitivity falls to 6%. The rules-based algorithm has a sensitivity of 24%, while the probabilistic network has a sensitivity of 25%. The three layers provide complimentary detection sensitivity as observed in combination studies. The ROC analysis of the probabilistic Bayesian error network showed an AUC of 0.98, 0.88, and 0.89 for the brain, lung and breast networks respectively. This compares favorably to expert observers using brain cases where an AUC of 0.90±0.01 was observed.

Conclusions: When used in combination, the multi-layer automatic detection system is capable of detecting a vast majority of errors that are actually observed in clinical radiotherapy practice. Key components are EPID dosimetry performed during treatment and a probabilistic error prediction network. While each can be used on its own, these approaches are most effective when used in combination.

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Investigation and validation of using a single energy-specific model to calibrate EPID panels for in-vivo dosimetry
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Purpose/Objective: EPID based in-vivo dosimetry is one of the most efficient and effective methods of confirming the correct delivery of complex radiotherapy. Software used to perform EPID in-vivo dosimetry typically needs to be commissioned for every linac and energy combination where EPID data is to be used. Previous work has demonstrated that a single energy-specific calibration model can be used to dosimetrically analyse EPID data acquired from multiple linacs by determining a linac-specific offset factor. Using this method has reduced the per-linac commissioning time for EPID based in-vivo dosimetry from 11 hours to 30 minutes. Auditing of the results of EPID in-vivo dosimetry performed on 7 clinical linacs has confirmed the validity of using these linac-specific offset factors. Investigation of the lifetime response of EPID panels has attributed the cause of these offset factors to differences in the software calibration of EPID panels rather than the dosimetric characteristics of the linac.

Materials and Methods: The EPID in-vivo software was fully commissioned for an Elekta MLCi2 linac at 6 & 10MV and an Elekta Beam Modulator linac at 15MV. These energy-specific models were then used to analyse EPID images acquired on multiple linacs. From this a series of linac-specific offset factors was determined that would allow an EPID dosimetry model commissioned for one linac to be used on multiple other linacs. By comparing EPID in-vivo results from patients treated on each of these linacs over a period of 5 years the validity of this offset factor approach could be determined. The change in the linac specific offset factor has been tracked along the lifetime of several EPID panels. Changes in EPID panel response as a result of image recalibration were correlated with changes in the linac-specific offset factors applied to EPID dosimetry results.

Results: The EPID in-vivo results of over 4000 patients has been analysed. No significant differences were found between patient treatments from different linacs, thereby validating this commissioning approach. The linac-offset factors determined were found to vary significantly (as much as 34%) when an EPID underwent image software calibration, despite there being no change in imaging or treatment hardware. This implies that it is the software determined response of the EPID panel and not the dosimetric characteristics of the linac that have the greatest impact on offset factors determined.

Conclusions: The in-vivo results of over 4000 patients has confirmed the validity of using an energy-specific EPID in-vivo dosimetry model on multiple linacs when combined with linac-specific offset factors. Furthermore, by investigating the behaviour of this offset factor along the lifetime of an EPID panel the cause of this offset factor can be attributed to the software calibration of the EPID panel rather than dosimetric characteristics of the linac.