Supplementary Table 1: A summary of the published studies investigating the detectability of different errors using offline and online EPID-based IVD systems

EPID-based IVD system	Reference	Year published	EPID dosimetry methods	Error introduction mode	Error sources	The detectability of introduced errors	Research highlight
Offline EPID-based IVD system	Bedford *et al*[1]	2014	Forward-projection	Introduced error into treatment plans	(1) MU errors; (2) Field shaping; (3) Gantry angle; (4) Phantom position	Highly sensitive to errors in monitor units and field shape, but less sensitive to errors in gantry angle or phantom position.	This method of predicting integrated portal images, using the forward-projection model, provided a convenient means of verifying the dose delivered to phantom; and the sensitivity of this method to errors was also evaluated through treatment planning system (TPS) simulations.
	Bojechko and Ford[2]	2015	Back-projection	Introduced error into treatment plans	(1) MU scaling; (2) MLC Gaussian noise; (3) MLC systematic shift; (4) Patient shifts; (5) Body contour changes	IVD was most sensitive to variations in the MU, changes in patient body contours, and systematic shifts in the MLC bank positions, but displacements in the patient's position and random variations in MLC leaf positions were not readily detectable.	*In vivo* EPID measurements were converted to a 2D planar dose at isocenter by a back-projection method and compared to the planned dose. The ability of EPID dosimetry to detect various types of variations when used during treatment has been assessed.
	Bedford *et al*[3]	2018	Forward-projection and back-projection	Phantom measurements	(1) MU errors; (2) Aperture size; (3) MLC shifts; (4) Rectal gas	(1) MU and aperture size errors have a large impact on the treatment plan and can be detected by both forward- and back-projection methods. (2) Spatial shift is detected only by the forward-projection method. (3) Pockets of rectal gas are detected by both forward- and back-projection methods.	Both forward-projection and back-projection EPID dosimetry methods have been compared for a cohort of prostate VMAT patients and comparable results were obtained. Forward-projection using integrated images is relatively straightforward to implement, whereas back-projection has the advantage of providing a measured dose distribution for comparison with the planned dose.
	Mijnheer *et al*[4]	2018	Back-projection	Phantom measurements	(1) Delivery errors (MLC leaf position, MU, gantry angle, collimator angle, energy); (2) Anatomy changes (thickness); (3) Setup errors (horizontal shift, vertical shift, rotation)	EPID-based 3D transit dosimetry can detect the number of serious errors in dose delivery, and leaf bank position and patient thickness during VMAT delivery. Errors in patient setup and single leaf position can be detected only in specific cases.	This study investigated the effectiveness of the EPID-based IVD method for error detection during VMAT treatments for a limited number of error types and treatment sites. It assessed the appropriateness of the clinical data as alert criteria in detecting these errors.
	Olaciregui-Ruiz *et al*[5]	2019	Back-projection (virtual dose reconstruction method used in air EPID measurements to calculate virtual 3D dose distributions in a planning CT data set)	Modified CT images	(1) Translational shifts; (2) Rotational shifts; (3) Patient contour changes; (4) Lung expansions and contractions	(1) As regards patient position shifts, error detectability is worse for the pelvic site and best for head-and-neck and brain sites. (2) Translations (5 mm) in head-and-neck plans and rotations (4°) in brain plans show excellent detectability; all sites but prostate show good-to-excellent detectability for translations (10 mm) and rotations (8°) and excellent detectability for patient contour changes (±6 mm). (3) Expansions of 3 mm and contractions of 6 mm are detected for lung sites.	The detectability of each introduced error is specific to the treatment sites and indicator used. Optimal alert criteria can be determined to ensure excellent detectability for each combination of error type and indicator. The alert threshold values and the magnitude of the error that can be detected are site-specific.
	Olaciregui-Ruiz *et al*[6]	2020	Back-projection (virtual dose reconstruction method used in air EPID measurements to calculate virtual 3D dose distributions in a synthetic daily CT data set)	Modified CT images	(1) Patient position; (2) Patient anatomy	Translational setup error (3 mm), rotational setup error (3°), and patient contour expansion/contraction (6 mm) for prostate, head-and-neck, brain, rectum, and bladder can be detected easily.	The use of the daily patient position and anatomy as a patient model for *in vivo* 3D EPID transit dosimetry improves the ability of the system to detect uncorrected errors in patient position and reduces the likelihood of false positives due to patient anatomical changes.
Online EPID-based IVD system	The University of Newcastle[7–9]	2013	Forward-projection	Introduced error into treatment plans	(1) MU errors; (2) Individual MLC leaf positioning errors; (3) Leaf bank systematic errors	(1) The system can detect a 10% MU error using 3%/3 mm criteria in approximately 10 s. (2) The EPID-based real-time delivery verification system successfully detected simulated gross errors (MLC leaf positioning errors, incorrect plan delivery, and MU errors) introduced into patient plan deliveries in near real-time (within 0.1 s).	A real-time radiation delivery verification system was developed, and the detectability of the system was demonstrated using simulated error case studies.
		2015	Forward-projection	Actual patient treatment cases	No specific error type was selected, and the error sources depended on the actual patient treatment cases	(1) EPID images acquired continuously during treatment were synchronized and compared with model-generated transit EPID images within a frame time (~0.1 s). (2) A treatment field was flagged as failed if over four consecutive frames were below the 40% γ pass rate.	The WatchDog, an independent system to verify external beam radiation therapy in real time using EPIDs, has been successfully implemented clinically. The system can simultaneously detect major mistreatments in radiotherapy. The data collected in the present study will serve to determine the site-specific alert criteria for future *in vivo* real-time transit dosimetry software.
		2016	Forward-projection	Introduced error into treatment plans	(1) Patient position misalignment; (2) MU errors; (3) Wrong patient or plan; (4) Wrong gantry angle	(1) The system could detect gross errors (e.g., wrong patient, wrong plan, wrong gantry angle) immediately after EPID stabilization. (2) The detected errors were classified as either clinical in origin (e.g., patient anatomical changes), or non-clinical in origin (e.g., detection system errors). The classified errors were 3.2 % clinical and 3.9 % non-clinical.	Treatment site-specific alert criteria for error detection have been developed to evaluate the online system. Manual investigation of patient detected errors was able to distinguish the errors as either clinical or non-clinical (system errors). Results showed that the system can detect gross errors in real-time; however, improvement in system robustness is required to reduce the non-clinical sources of error detection.
	Spreeuw *et al*[10]	2016	Back-projection	Phantom measurements	(1) Leaves open error; (2) Double MU error	(1) The complete processing of a single portal frame, including dose verification, took 266 ±11 ms. (2) The introduced delivery errors were detected after 5–10 s treatment delivery time.	A prototype online 3D dose verification tool using EPID images based on back-projection has been developed and successfully tested for two different types of gross delivery errors. Dose reconstruction was accelerated and made faster than EPID frame rate to achieve "real-time" verification.
	Bedford and Hanson[11]	2019	Forward-projection	Phantom measurements	(1) MU errors; (2) Aperture size; (3) MLC shifts; (4) Rectal gas	(1) Using 12% as a tolerance level for the error plans, the following can be detected: a 10% increase in MU, 4 mm increase or shift in MLC settings, and an air gap of dimensions 40 mm × 50 mm. (2) Gross errors can also be detected instantly after the first 10% of segments.	This study investigates the use of a running sum of images during segment-resolved intrafraction portal dosimetry, to alert the operator to an error before it becomes irremediable. Four error types have been introduced to verify the system. A suitable caution level and error level were proposed, amounting to 10% and 12%, respectively. Using these tolerance levels, a range of minor delivery errors can be detected before the end of each treatment, while major errors are detected immediately.

EPID: Electronic portal imaging device; IVD: *In vivo* dosimetry; MU: Monitor unit; MLC: Multi-leaf collimator; VMAT: Volumetric-modulated arc therapy.

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