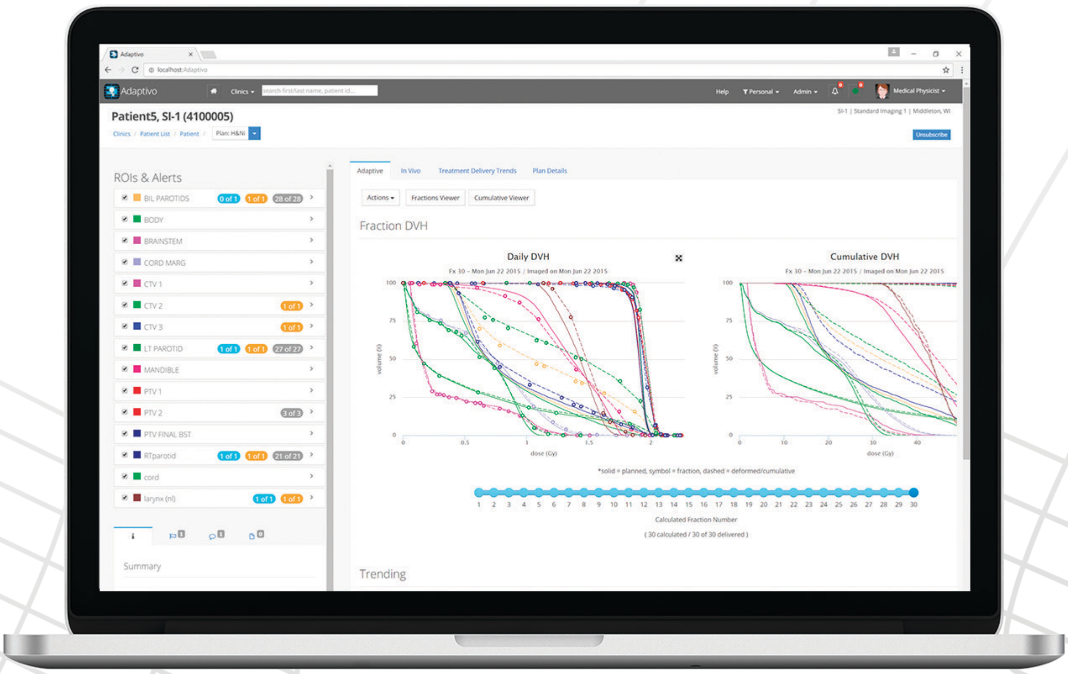
STANDARD IMAGING®

PATIENT DOSIMETRY

QUALITY TREATMENT FOR EVERY FRACTION



ADAPTIVO™

STANDARD IMAGING

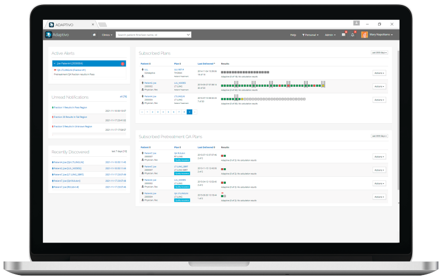
ADAPTIVO

EMPOWERING OFFLINE ADAPTIVE THERAPY
WITH YOUR EXISTING TECHNOLOGY

STAY FOCUSED ON PRECISION

QUALITY TREATMENT FOR EVERY FRACTION

Adaptivo provides real-time, automated dosimetry data to optimize your treatment approach and enhance patient care:

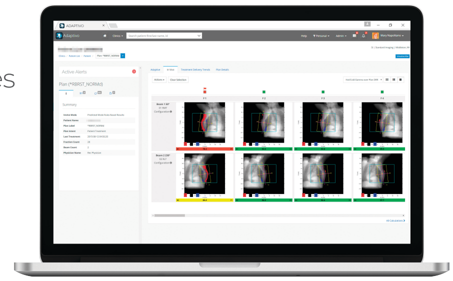


— Seamless Workflow Integration

Seamlessly integrates into clinical workflows, leveraging your existing high-resolution EPID technology for real-time treatment monitoring and precise patient-specific data capture.

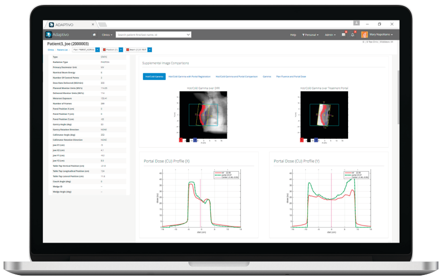
— Automated InVivo Dosimetry

Continuously monitors transit dosimetry against the planned dose, automatically detecting discrepancies beyond user-defined tolerances and generating alerts for timely, accurate treatment adjustments.



— Enhanced Treatment Accuracy & Safety

Increases setup precision and treatment accuracy, ensuring high-quality care tailored to each patient's needs.



— Data-Driven Decision Support

Provides intuitive dashboards and trending data to guide treatment decisions, supporting offline adaptive radiation therapy (ART) and ensuring optimal outcomes.

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Transforming Radiation Therapy: Standard Imaging's Adaptivo In Vivo EPID Dosimetry Solution for Personalized Treatment Precision — A Comprehensive Clinical Use Case Review

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Transforming Radiation Therapy: Standard Imaging's Adaptivo In Vivo EPID Dosimetry Solution for Personalized Treatment Precision — A Comprehensive Clinical Use Case Review

1 Introduction

Maintaining precision in radiation therapy is challenging due to anatomical changes like tumor shrinkage, weight loss, and organ motion over the course of treatment. Adaptive Radiotherapy (ART) is rapidly emerging as a solution, allowing treatment plan adjustments either in real-time (online ART) or retrospectively (offline ART) to ensure accurate dose delivery.

Similarly, in vivo dosimetry (IVD), particularly EPID-based transit dosimetry, plays an increasingly critical role in verifying delivered doses and supporting the offline ART process by providing retrospective dose assessment and identifying deviations from the treatment plan. Endorsed by organizations such as the IAEA and AAPM, EPID-based IVD enhances treatment accuracy and patient safety.

This paper explores the rapidly evolving role of EPID-based IVD in supporting offline ART, focusing on clinical examples that demonstrate the benefits of Standard Imaging's Adaptivo EPID-based in vivo solution in improving treatment accuracy, identifying setup errors, and supporting adaptive decision-making.

1.1 Precision Treatment in Radiotherapy

Precision in radiation therapy is becoming increasingly critical as cancer treatment moves towards more personalized and targeted approaches. Advances in imaging, treatment planning, and delivery techniques have made it possible to target tumors precisely while sparing surrounding healthy tissue. However, clinicians must ensure this level of precision extends beyond the treatment planning phase, as changes in patient anatomy, such as tumor regression, weight loss, or organ motion, during the course of treatment can impact the accuracy of dose delivery. This is particularly important for cancers such as head and neck and thoracic, where anatomical changes during therapy can often result in a mismatch between the original treatment plan and the patient's evolving anatomy, leading to challenges in accurately delivering the prescribed dose while sparing healthy tissues.

In head and neck cancers, tumor reduction is common during treatment and can cause shifts in the tumor's position and nearby organs-at-risk (OARs), such as the esophagus, salivary glands, and brainstem. Weight loss, often seen in these patients due to treatment-related side effects like difficulty swallowing or reduced appetite, further alters the anatomy. These changes can impact the fit of immobilization devices and increase the risk of positional errors during daily setup. The result can be an underdose to the tumor or unintentional exposure of OARs to higher doses of radiation, increasing the likelihood of side effects like dry mouth or difficulty swallowing.

In thoracic cancers, tumor shrinkage during treatment and weight loss can similarly alter the position and shape of the tumor as well as the surrounding organs, such as the lungs, heart, and esophagus. These changes are especially critical given the proximity of vital structures in the thoracic region. Even small anatomical shifts can lead to significant deviations in dose delivery, potentially causing underdosing of the tumor or overdosing of healthy tissues. For example, shifts in low-density lung position can lead to inaccuracies in dose distribution, reducing the effectiveness of treatment and increasing the risk of complications.

1.2 The Emergence of Adaptive Radiotherapy

Both online and offline ART is gaining prominence in radiation oncology as an essential strategy for optimizing treatment precision and improving patient outcomes.

Online ART involves making real-time adjustments to radiation treatment plans during a patient's treatment session based on anatomical changes observed through imaging technologies like CBCT or MR-guided imaging. This approach ensures precise tumor targeting while sparing healthy tissues, particularly in cases with significant tumor motion or rapid anatomical changes. Online ART offers unmatched precision and personalization but comes with challenges, including extended treatment times and the need for advanced computational tools and highly trained staff. These requirements make it resource-intensive and may limit its widespread adoption in clinics with constrained financial resources or infrastructure.

Offline ART provides a practical and accessible approach to improving treatment accuracy without the resource-intensive demands of online ART. Offline ART integrates seamlessly into existing workflows by leveraging retrospective imaging and in vivo dosimetry data, allowing clinicians to assess anatomical changes and adjust treatment plans outside of live treatment sessions. This flexibility avoids the need for extended appointment times or specialized equipment required for real-time adaptations, making it an ideal entry point for clinics with limited resources or expertise. Offline ART ensures high-quality outcomes while maintaining operational efficiency by enabling personalized care and precise dose delivery through retrospective evaluation. Its straightforward integration into standard practices highlights its value as a stepping stone toward broader adoption of adaptive strategies in radiation oncology.

1.3 IVD Guidelines and Recommendations

IVD is becoming increasingly essential in radiation therapy to ensure patient safety and treatment accuracy. As radiation therapy techniques advance, particularly with complex modalities like VMAT and IMRT, IVD has become critical for verifying that the correct dose is delivered to the right location. Requirements for IVD vary by country, often guided by national regulations, but global standards from organizations such as the International Atomic Energy Agency (IAEA) and the American Association of Physicists in Medicine (AAPM) are driving broader adoption, particularly in countries with advanced radiation therapy infrastructure. Emerging guidelines emphasize the use of EPID-based IVD solutions to improve treatment precision, safety, and quality, especially in ART workflows. The IAEA1 and AAPM Task Group 307 (TG-307)2 both recognize EPID transit dosimetry as the gold standard for IVD, supporting real-time and pre-treatment dose verification. Their guidelines underscore the value of automated analysis and data trending in identifying setup errors and refining treatment plans, enhancing workflow efficiency and accuracy.

2 Adaptivo EPID Dosimetry

Standard Imaging's Adaptivo software offers seamless pre-treatment and in vivo EPID dosimetry solutions that integrate effortlessly into any clinical workflow by leveraging the linac's high-resolution EPID technology. The In Vivo module captures transit dosimetry data during treatment, followed by an automated gamma comparison to the planned dose. Any dose discrepancies outside user-defined tolerances trigger automated alerts to notify clinical staff. Results are presented through intuitive dashboards, gamma image overlays, trending data, and detailed reports for easy assessment and decision-making. By automating daily in vivo 2D transit dose evaluation, Adaptivo enhances treatment precision, ensures setup accuracy, and improves patient safety while minimizing manual intervention and workflow disruptions. In addition, daily data trending supports retrospective assessments, aiding the off-line ART decision-making process throughout treatment.

3 Clinical Application of EPID IVD

3.1 Limitations of Traditional QA Methods

Traditional phantom-based QA and logfile analysis solutions in radiation therapy have notable limitations when compared to in vivo EPID dosimetry. Phantom-based QA involves measuring the radiation dose delivered to a phantom or detector array, providing insights into system performance and treatment delivery. However, it fails to account for patient-specific variables such as setup errors, anatomical changes, and tissue density variations, which can significantly impact daily treatment accuracy. These patient-specific factors cannot be accurately captured by a phantom, making phantom-based QA insufficient for addressing the largest complexities of real-world patient treatment. Similarly, logfile-based QA offers valuable insights into plan deliverability but does not account for individual patient variations. However, logfile-based solutions, like Standard Imaging's LinacView software, can seamlessly work alongside Adaptivo's EPID IVD solution, evaluating linac performance during treatment while Adaptivo directly addresses patient-specific factors, together ensuring a more comprehensive and accurate QA approach.

3.2 Real-world Adaptivo Application

In contrast to traditional methods, Adaptivo's in vivo EPID dosimetry solution evaluates the dose delivered during treatment, providing daily, patient-specific feedback, enabling the detection of errors related to patient setup, anatomical changes, or differences between the planned and actual treatment delivery. By incorporating the patient's actual setup, anatomy, and response into the QA process, in vivo EPID dosimetry offers a more complete and personalized assessment of treatment accuracy, ultimately improving treatment safety and efficacy. The following examples provide details regarding clinical case examples of Adaptivo's EPID IVD module.

Citations:

1. *INTERNATIONAL ATOMIC ENERGY AGENCY, Development of Procedures for In Vivo Dosimetry in Radiotherapy, IAEA Human Health Reports No. 8, IAEA, Vienna (2013)*
2. *Dogan N, Mijnheer BJ, Padgett K, et al. AAPM Task Group Report 307: Use of EPIDs for Patient-Specific IMRT and VMAT QA. Med Phys. 2023; 50: e865–e903. https://doi.org/10.1002/mp.16536*

Transforming Radiation Therapy: Standard Imaging's Adaptivo In Vivo EPID Dosimetry Solution for Personalized Treatment Precision — A Comprehensive Clinical Use Case Review

Clinical Use Case #1: Patient Setup Evaluation for Head and Neck

Dr. Paul Retif, Head of Medical Physics, Department of Radiation Oncology, CHR Metz-Thionville, Metz, France

Dx: H&N Squamous Cell

Rx: 55Gy/66Gy in 33 fxs

Plan: 2-Arc VMAT int. boost

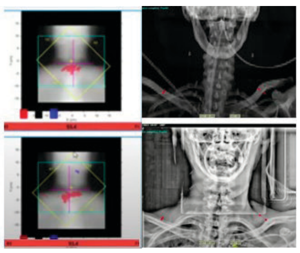
Immobilization: 5-point mask

IGRT: 2 orthogonal kV images.

CT Simulation: H&N protocol

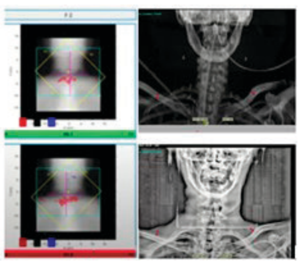
Background: During CT simulation, the patient tensed her shoulders due to nervousness. She was more relaxed during treatment, causing setup issues that Adaptivo quickly identified.

Fraction 1: Both Arcs Failed at 5%/3mm



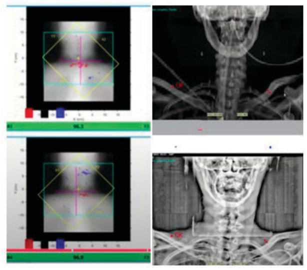
The setup was evaluated, but clavicle misalignment was missed as therapists focused on spine alignment. Corrections were made in Fraction 2.

Fraction 2: Single Arc Failed at 5%/3mm



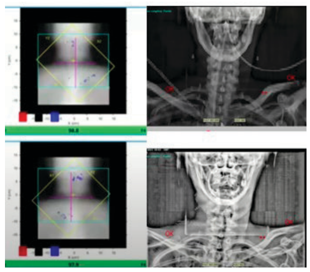
Therapists focused on clavicle misalignment during setup, however gamma analysis failed for one of the two fields, revealing a slight clavicle misalignment on the patient's right side.

Fraction 3: Both Arcs Passed 5%/3mm



Although both treatment fields passed at 5%/3mm, the therapists identified a remaining area of gamma disagreement and further refined the setup for the fourth fraction.

Fraction 4: Both Arcs Passed 3%/3mm

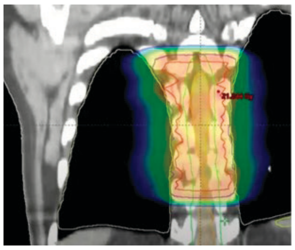


The patient setup was optimized with a passing rate of 3%/3mm, successfully eliminating gamma hotspots.

Summary: Adaptivo enabled the rapid identification of setup issues, allowing therapists to proactively fine-tune and optimize patient setup, reducing daily setup variations in treatment delivery.

Clinical Use Case #2: Treatment Planning CT Evaluation

Dr. Paul Retif, Head of Medical Physics, Department of Radiation Oncology, CHR Metz-Thionville, Metz, France



Dx: Palliative Spine RT

Rx: 20Gy in 5 fxs

Plan: 2-Arc VMAT

Immobilization: none

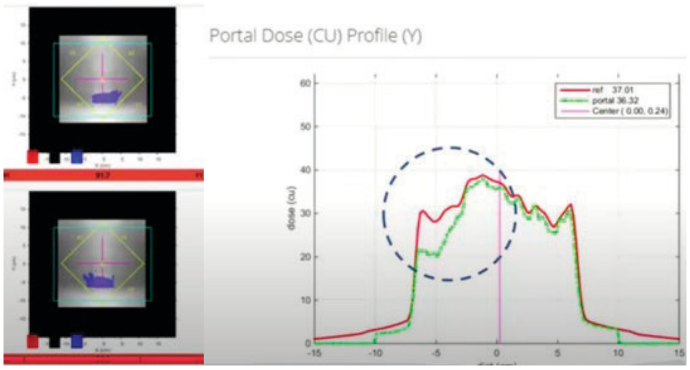
IGRT: 2 orthogonal kV images.

CT Simulation: 4DCT

Background: The simulation CT was acquired in 4D to account for respiratory motion, and the RT planning should have been performed on the Average Intensity Projection (AIP) CT, which represents the average voxel intensity over all respiratory phases, providing a more stable representation of the patient's anatomy for treatment planning. Instead, the RT plan was inadvertently generated on a phase-based reconstructed CT, which doesn't account for respiratory motion.

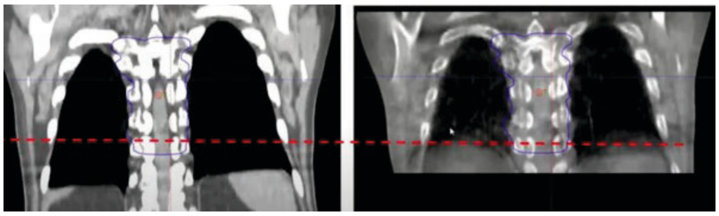
Fraction 1: Both Arcs Failed at 5%/3mm

Adaptivo revealed a large under-dosage in the inferior portion of the field, prompting a CBCT acquisition prior to the second fraction to assess the deviation.



Fraction 2: CBCT Acquisition

The CBCT showed density changes due to diaphragm movement. The planning CT was identified as a phased CT rather than the intended AIP. Adaptivo revealed the dosimetric impact of the incorrect planning CT on the lower treatment volume.



Fractions 3-5:

The plan was revised using the average intensity projection scan, and the final three fractions passed gamma agreement. Clinicians believe they would not have identified this issue without the use of the Adaptivo In Vivo module.

Clinical Use Case #3: Lung Offline Adaptive RT Evaluation

Brian Pomije, MSc, DABR, Medical Physicist, Genesis Care, Florida

Dx: Lung Mediastinum

Rx: Conventional Fractionation

Plan: 4-Arc VMAT

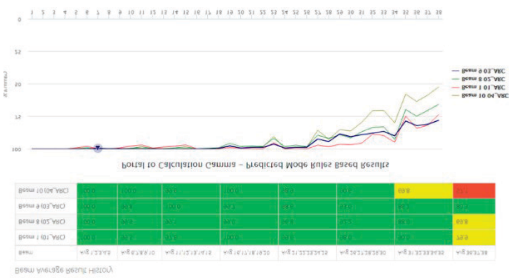
Immobilization: custom cradle

IGRT: Daily

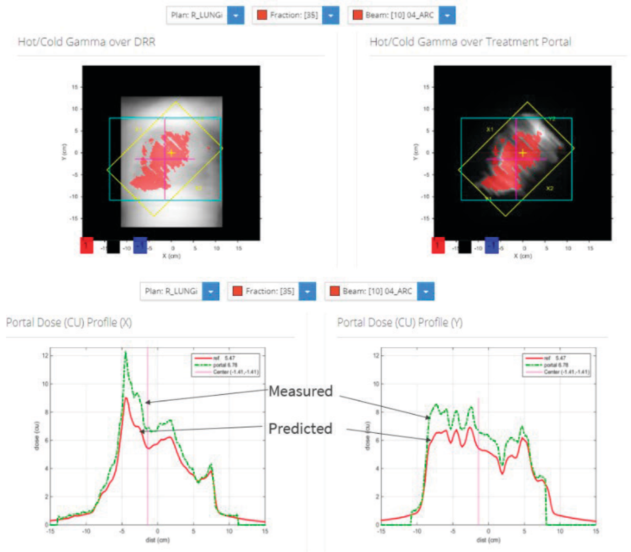
Background: The patient had Pulmonary Edema at the time of the CT simulation.

Treatment Progression:

The patient completed 5 weeks of treatment with passing gamma results for all four VMAT arcs, but after week five, the gamma agreement began to decline.

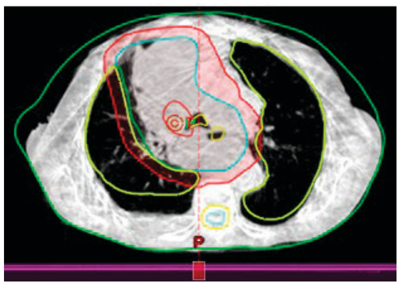


By weeks 7 and 8, the gamma results entered the warning or failing region. A closer review of the gamma results overlaid on the DRR, as well as the profile view, showed a higher-than-expected transit dose, indicating a dose discrepancy between the delivered and planned dose.



Offline Adaptive Therapy Assessment:

A review of the CBCT with the planning structure set overlay revealed that the patient's pulmonary edema had cleared, weight had been lost, and the tumor had regressed, causing a more significant difference between the intended and delivered dose. The decision was made to acquire a new planning CT and to start the boost early.



4 Summary

Adaptivo's EPID IVD solution offers key advantages over traditional QA methods by providing daily, patient-specific dosimetric feedback and trending data, equipping clinicians with actionable metrics to proactively identify setup issues and dosimetric impacts from anatomical changes. These real-time insights are crucial for ensuring safety and maintaining treatment quality throughout radiation treatment.

5 Conclusion

In conclusion, Adaptivo's In Vivo EPID dosimetry enhances radiation therapy QA by overcoming the limitations of traditional methods, offering personalized and precise assessments of treatment delivery for every fraction. As the shift toward adaptive, patient-centered care continues, Adaptivo's EPID dosimetry will play a vital role in ensuring the accuracy and effectiveness of radiation therapy.

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