

Patient-Specific QA: How Measurement-Based and Software-Based Approaches Complement Each Other

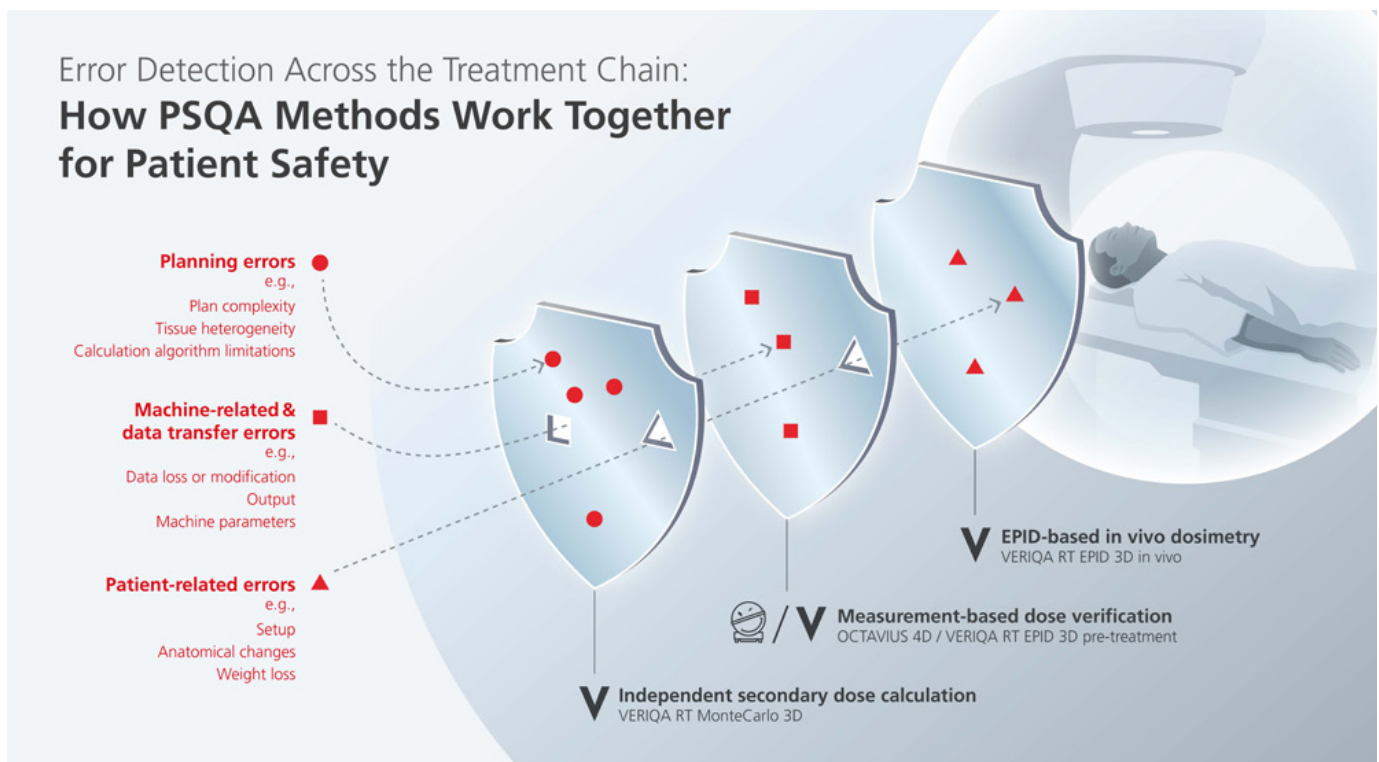


Figure 1. Different PSQA methods address different error sources. Independent dose recalculation, EPID dosimetry, and phantom-based measurements provide complementary verification of planning, transfer-related, machine-related, and patient-specific errors.

Patient-specific quality assurance (PSQA) must ensure the highest level of accuracy while operating within limited resources. For many years, PSQA relied exclusively on measurement-based methods, and the detectors and phantoms developed for this purpose have played a decisive role in shaping dosimetric quality assurance in radiation therapy. Software-based approaches for independent secondary dose calculation provide additional options. This article outlines how PSQA has evolved, which methods are available today, and how their targeted use can be combined into a robust and efficient quality assurance system.

PSQA: Measurement-Based or Software-Based?

The purpose of PSQA is to detect errors and provide insight into their causes. Potential errors in radiation therapy may arise in four main areas: in addition to planning errors, transfer errors, machine-related errors, and, not least, patient-specific errors can occur. The latter can only be reliably detected during patient treatment, for example through EPID in vivo dosimetry.

According to established guidelines and recommendations (DIN 6875-3 or AAPM TG-218/TG-

219), pre-treatment dose verification can be performed either through measurements (e.g., using a phantom or EPID) or through dose recalculations. However, the two approaches differ significantly in terms of accuracy and required effort.

Historically, PSQA was based exclusively on measurement-based methods: initially using film, followed by ionisation chambers, and today employing sophisticated detector array systems and phantoms such as OCTAVIUS by PTW. These methods require manual procedures and are therefore time- and resource-intensive. Nevertheless, they remain an important reference standard for dosimetric quality assurance of both patient treatments and linear accelerators.

Digital, software-based solutions for independent secondary dose calculation are becoming increasingly important. At the centre of this development is the Monte Carlo algorithm.

Independent Dose Recalculation with Monte Carlo

Independent secondary dose calculations automatically recalculate a treatment plan and compare the result with the primary dose calculation, without requiring additional machine time or staff effort. Clinically unremarkable plans that pass the secondary calculation generally do not require further review by the medical physics team.

The proportion of plans that pass stringent acceptance criteria depends strongly on the algorithm used. Analytical methods exhibit greater variability, resulting in a higher number of false alarms that must subsequently be reviewed manually. In contrast, Monte Carlo (MC) algorithms provide greater accuracy while requiring no additional effort.

A study published in 2025 by Hoffmann et al. [1] in the Journal of Applied Clinical Medical Physics compared the MC algorithm SciMoCa, as implemented in PTW's VERIQA RT MonteCarlo 3D,

with the analytical algorithm used in Mobius3D. While the latter showed dose differences of up to 6% and gamma pass rates as low as 30%, SciMoCa achieved pass rates exceeding 95% and demonstrated only minor variability, with deviations remaining close to the acceptance threshold. The study concluded that MC-based dose recalculation provides a significant clinical benefit for PSQA and enables substantially more stringent acceptance criteria while reducing verification effort.

EPID Dosimetry: Dose Verification Before and During Patient Treatment

EPID dosimetry can be used in two distinct ways: before treatment ("pre-treatment") and during treatment ("in vivo").

For pre-treatment plan verification, EPID dosimetry with VERIQA RT EPID 3D pre-treatment provides a fast and efficient solution without the need for phantom setup.

EPID-based in vivo dosimetry with VERIQA RT EPID 3D captures the dose actually delivered during each fraction, enabling continuous monitoring of the entire treatment delivery chain, including patient-specific factors such as anatomical changes or positioning deviations. Errors arising after plan verification become visible and quantifiable.

Not Every Method Fits Every Plan

The availability of software-based approaches expands the PSQA toolkit but does not completely replace measurement-based methods. Phantom measurements, independent dose recalculations, and EPID dosimetry each have distinct strengths, address different error sources, and vary in the effort required. Their areas of application overlap only partially, and it is precisely this limited overlap that creates their complementary value.

Monte Carlo dose recalculations evaluate the treatment plan in the background without addi-

tional effort and provide fast, accurate dose verification before treatment. They primarily detect planning-related errors but can be applied automatically to every plan.

Pre-treatment EPID dosimetry extends this approach by additionally accounting for transfer-related and machine-related errors. EPID-based in vivo dosimetry further identifies deviations that arise only during treatment delivery to the patient.

When a measurement is required, either EPID-based measurements or conventional phantom measurements with OCTAVIUS may be selected, depending on the application. Both approaches have a well-defined role within a comprehensive PSQA program. EPID-based measurements with VERIQA RT EPID pre-treatment do not require phantom setup and are well suited for standard treatment plans and routine applications. In contrast, phantom measurements with OCTAVIUS remain indispensable for very large treatment fields, off-axis or non-coplanar fields, and complex stereotactic treatments with demanding dosimetric requirements.

The Art Lies in Choosing the Right Combination

The key challenge in modern PSQA is no longer access to verification methods but their intelligent combination. An effective program defines differentiated verification protocols for different classes of treatment plans according to their respective risk profiles.

Not all treatment plans carry the same level of risk. Highly modulated or hypofractionated treatment plans, moving target volumes, and patients with highly variable anatomy require more intensive verification than less complex plans. Automation and clearly defined acceptance criteria therefore become the foundation of a consistently reliable PSQA program.

A Proven Combination in Clinical Routine: MC Dose Calculation and EPID In Vivo

For the majority of treatment plans used in routine clinical practice, particularly standard plans and applications, one combination has proven especially effective: MC-based dose recalculation together with EPID in vivo dosimetry. Both methods can be integrated smoothly into the clinical workflow, with many processes running automatically in the background.

MC enables verification of dose calculation accuracy without additional clinical workload. EPID in vivo dosimetry indicates whether deviations occur later in the treatment delivery chain, both on a fraction-by-fraction basis and throughout the entire course of treatment.

This is particularly relevant for online adaptive radiation therapy (oART). Since a new treatment plan is generated each day and conventional measurement-based dose verification before treatment is no longer feasible, EPID in vivo dosimetry takes on a special role: it confirms that the daily adaptive plan has been delivered correctly.

Conclusion

MC-based dose recalculation and EPID in vivo dosimetry (e.g., with VERIQA) form the foundation of an efficient and safety-oriented PSQA program for the majority of treatment plans. The MC approach enables accurate and efficient dose verification prior to treatment while reducing false alarms compared with systems based on other algorithms. EPID-based in vivo dosimetry extends quality assurance to the entire error chain and treatment phase.

When a measurement is beneficial or required, for example in specialised applications, either EPID-based measurement with VERIQA RT EPID 3D pre-treatment or conventional phantom measurement with OCTAVIUS can be used, depending on the application. The goal is not a PSQA program that measures as much as possible, but one that

measures what matters, at the right time, using the appropriate method.

References:

- [1] Hoffmann L, Linaa M-B, Møller DS, Independent secondary dose calculation for patient-specific quality assurance: Quantitative benefit of Monte-Carlo and custom beam modeling, Journal of Applied Clinical Medical Physics 26, e70265 (2025). <https://doi.org/10.1002/acm2.70265>

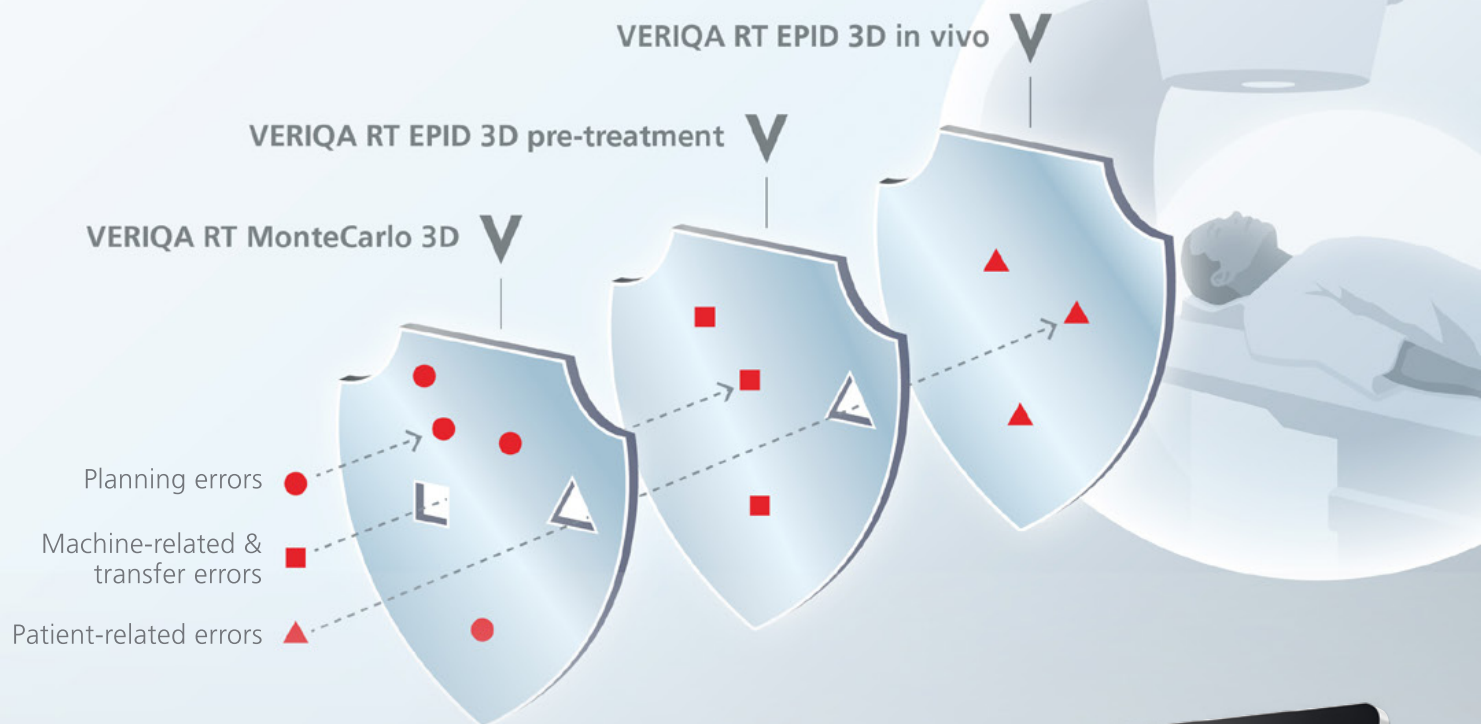


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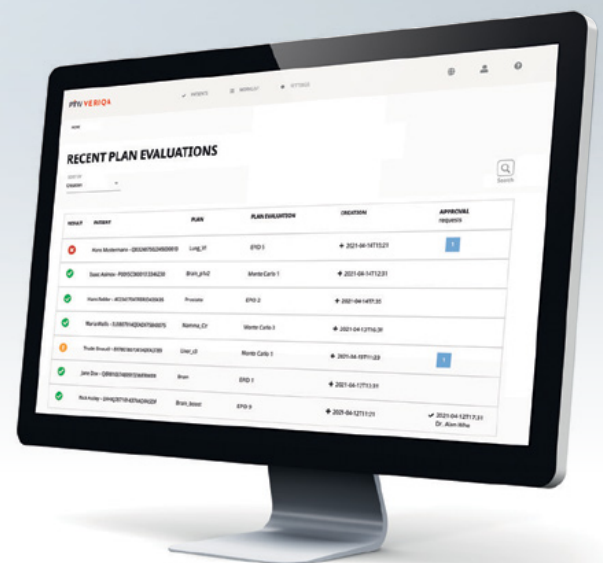
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How Confident Are You in Your Patient QA?



VERIQA combines Monte Carlo dose calculation and true 3D EPID dosimetry in one platform for fast, reliable dose verification before and during treatment – across standard and adaptive workflows.

- **Pre-treatment & in vivo**
- **Complete error coverage**
- **Automated workflows**



**VERIQA – your multi-layer safety net
for confident patient QA.**

Today. And tomorrow.