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Adaptation of a Matrixx Evolution Two-Dimensional Array Detector for Dose Assessment In High-Dose-Rate Brachytherapy with a Cobalt-60 Source

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ABSTRACT

High-dose-rate (HDR) brachytherapy (BT) is characterized by steep dose gradients and the delivery of high doses per treatment fraction over a short period. These characteristics, together with the multiple steps involved in treatment delivery, make rigorous dose assessment and quality assurance (QA) essential. Although dose assessment in HDR BT has traditionally relied on point-dose measurements, the field is progressively transitioning toward three-dimensional (3D) volume-based evaluation.

This study aimed to evaluate the feasibility of using the MatriXX Evolution two-dimensional (2D) array detector system, originally designed for patient-specific QA and treatment machine QA in external beam radiotherapy (EBRT), for dose assessment in cobalt-60 HDR BT. To adapt the detector for BT dose measurements, an in-house Perspex slab phantom was constructed to sandwich the 2D array detector. The phantom incorporated two holes, centred 4.1 cm apart, to accommodate Bebig universal applicators (LAA1400-RU). HDR BT treatment plans were generated using the HDRplus treatment planning system (TPS), which employs the AAPM TG-43 dose calculation formalism.

Because the TG-43 formalism is based on dose calculations in water, depth-dependent conversion factors were experimentally determined to convert the doses measured in the Perspex phantom to their water-equivalent values for comparison with TPS-calculated doses. Agreement between measured and calculated dose distributions was evaluated using a gamma analysis criterion of 3%/3 mm with a 5% dose threshold. Treatment plans with source-to-measurement plane distances of 1.31 cm and 3.31 cm achieved gamma passing rates of 93.7–96.9% (mean: 94.8 ± 0.31%; standard error: ±0.18%) and 95.0–98.3% (mean: 96.6 ± 0.34%; standard error: ±0.20%), respectively. These findings demonstrate that the MatriXX Evolution 2D array detector system can be successfully adapted for dose assessment in cobalt-60 HDR brachytherapy, providing reliable and reproducible measurements. Measurements acquired at a source-to-measurement plane distance of 3.31 cm exhibited the smallest dose discrepancies and are therefore recommended for routine QA applications.

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INTRODUCTION

Radiotherapy is a cornerstone of cancer treatment, with approximately half of all cancer patients requiring it during the course of their care. Although external beam radiotherapy (EBRT) accounts for the majority of treatments, it has limitations in achieving optimal normal tissue sparing and radiobiological effectiveness in certain anatomical sites, particularly gynaecological cancers, where brachytherapy (BT) remains indispensable for improving clinical outcomes. By placing radioactive sources within or adjacent to the tumor, BT delivers highly localized radiation with a rapid dose fall-off, maximizing tumor coverage while minimizing the dose to surrounding healthy tissues.

HDR brachytherapy, in particular, achieves highly conformal dose distributions through optimization of source dwell positions and dwell times. However, its steep dose gradients and the delivery of large doses per fraction make it highly sensitive to uncertainties in source positioning, dose calculation, source calibration, and treatment delivery. Consequently, accurate dose verification and rigorous quality assurance (QA) are essential. Current HDR BT dose verification methods, including in vivo dosimetry, point-based phantom measurements, and Monte Carlo simulations, each have inherent limitations related to practicality, measurement accuracy, computational requirements, or ethical considerations. Plane-based dosimetry using an in-house phantom provides a practical, reproducible, and cost-effective alternative for pre-treatment verification and routine QA, particularly in settings where commercial brachytherapy phantoms are unavailable or limited.

Accordingly, this study investigates the feasibility of adapting the MatriXX Evolution two-dimensional ionization chamber array, originally developed for patient-specific QA in EBRT, for two-dimensional dose distribution assessment in cobalt-60 HDR brachytherapy using an in-house phantom.

METHODS AND MATERIALS

An in-house Perspex slab phantom was constructed to house a MatriXX Evolution two-dimensional (2D) array detector (IBA Dosimetry, Germany). The phantom consisted of Perspex slabs with a central insert containing two holes, centred 4.1 cm apart, to accommodate LAA1400-RU universal applicators (Eckert & Ziegler BEBIG GmbH, Germany). An in-house water phantom with identical dimensions and applicator geometry was also fabricated from 4 mm Perspex sheets. The slab and water phantoms were used to experimentally determine plastic-to-water conversion factors ($f_{p,w}$) at different source-to-measurement plane distances using a CC13 cylindrical ionization chamber (IBA Dosimetry, Germany) connected to a UNIDOS electrometer. A brachytherapy treatment plan comprising dwell positions from 0.5 to 10.0 cm, with a step size of 0.5 cm for each applicator, was generated using the HDRplus TPS (Eckert & Ziegler BEBIG GmbH, Germany). The plan was delivered with a MultiSource HDR afterloader to obtain dose measurements along the central measurement plane of each phantom. The MatriXX detector system was cross-calibrated against a Farmer-type ionization chamber using a telecobalt beam, with the, $f_{p,w}$, incorporated into the calibration procedure. Following calibration, the MatriXX detector was positioned within the Perspex slab phantom and irradiated using multiple brachytherapy treatment plans with source-to-measurement plane distances of 1.31 cm and 3.31 cm. The measured dose distributions were subsequently compared with the corresponding dose distributions calculated by the TPS.

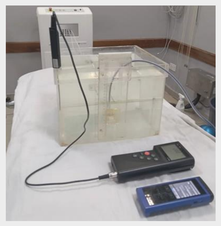

Figure 1. Set up with the in-house water phantom.

Figure 2. Measurement set-up with the MatriXX detector.

RESULTS

Chart 1 illustrates the relationship between the experimentally determined plastic-to-water conversion factor and the source-to-measurement distance. Tables 1 and 2 compare the dose distributions measured with the MatriXX detector system with the corresponding dose distributions calculated by the treatment planning system (TPS) at source-to-measurement plane distances of 1.31 cm and 3.31 cm, respectively. The tables also present the gamma passing rates obtained using myQA Patient software (IBA Dosimetry, Germany), applying a gamma analysis criterion of 3%/3 mm with a 5% dose threshold.

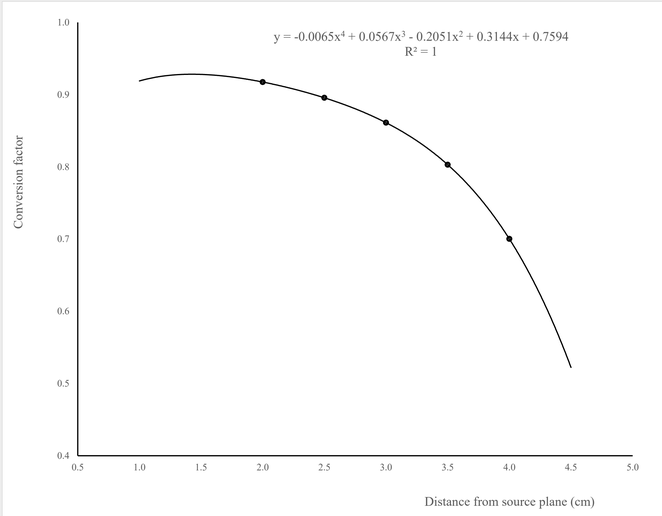

Chart 1. Conversion factor as a function of distance from the source plane.

Table 1. Comparison of doses at a distance of 1.31 cm from the source plane.

Case	Reference point dose (Gy)		Percentage difference between TPS calculated and measured doses (%)	Gamma passing rate (%)
	TPS calculated	Measured		
1	1.2551	1.2325±0.0009	1.8007±0.0690	94.5667±0.1764
2	1.1026	1.0845±0.0003	1.5104±0.0889	94.2000±0.1732
3	1.1898	1.1695±0.0006	1.7062±0.0485	93.9333±0.1453
4	1.2377	1.2157±0.0004	1.7802±0.0356	96.5000±0.2309

Table 2. Comparison of doses at a distance of 3.31 cm from the source plane.

Case	Reference point dose (Gy)		Percentage difference between TPS calculated and measured doses (%)	Gamma passing rate (%)
	TPS calculated	Measured		
1	1.1104	1.0905±0.0015	1.7921±0.1351	97.9667±0.3512
2	1.1097	1.0898±0.0013	1.7903±0.1134	95.5667±0.5132
3	1.1074	1.0875±0.0010	1.7970±0.0903	95.0000±0.2000
4	1.1284	1.1077±0.0012	1.8374±0.1115	97.9000±0.3000

DISCUSSION

- Perspex phantom exhibited higher dose measurements than water due to its higher physical density, indicating increased photon scattering and electron transport effects.
- Plastic-to-water conversion factors were distance-dependent, demonstrating that a single correction factor is insufficient for accurate dose conversion to TG-43 water-equivalent conditions.
- Extrapolated conversion factors of 0.9276 (1.31 cm) and 0.8289 (3.31 cm) were derived using a fourth-order polynomial model (R^2 = 1.00) to account for measurement geometry (see Chart 1).
- Excellent agreement was observed between MatriXX-measured and TPS-calculated dose distributions after applying the conversion factors, with all point-dose differences within 2%.
- Higher gamma passing rates were achieved at a 3.31 cm source-to-measurement distance than at 1.31 cm, reflecting the reduced influence of steep dose gradients farther from the source.
- A comprehensive uncertainty analysis yielded an overall measurement uncertainty of 4.62%, which is clinically acceptable for HDR brachytherapy quality assurance.
- The study demonstrates that the MatriXX Evolution 2D array detector, combined with an in-house Perspex phantom and appropriate plastic-to-water corrections, is a feasible, reliable, and cost-effective tool for routine HDR brachytherapy dose verification and quality assurance.
- Measurements performed at 3.31 cm from the source plane are recommended because they provide the highest agreement with TPS calculations.

CONCLUSIONS

The MatriXX Evolution 2D array detector, integrated with an in-house Perspex phantom and appropriate plastic-to-water conversion factors, provides a feasible, reliable, and cost-effective solution for dose verification in cobalt-60 HDR brachytherapy. Measured dose distributions showed good agreement with TPS calculations, with point-dose differences within 2%, gamma passing rates exceeding 93%, and an overall measurement uncertainty of 4.62%. Measurements performed at a source-to-measurement plane distance of 3.31 cm yielded the best agreement and are recommended for routine HDR brachytherapy quality assurance.

REFERENCES

1. **Jayakody, M., Jeyasugiththan, J., Rajasooriyar, C., & Chougule, A.** (2022). Dosimetry procedure to verify dose in High Dose Rate (HDR) brachytherapy treatment of cancer patients: A systematic review. Physica Medica, 96, 70–80. https://doi.org/10.1016/j.ejmp.2022.02.022
2. **Zeman, J., Valenta, J., Gabris, F., Grezdo, J., & Stastna, S.** (2012). Feasibility of MatriXX 2D detector array for HDR brachytherapy planning system assessment. Metrologia, 49(5), S237–S241. https://doi.org/10.1088/0026-1394/49/5/S237
3. **Sina, S., Lotfalizadeh, F., Karimipourfard, M., Zaker, N., Amanat, B., Zehtabian, M., & Meigooni, A. S.** (2015). Material-specific conversion factors for different solid phantoms used in the dosimetry of different brachytherapy sources. Iranian Journal of Medical Physics, 12(2), 109–120.
4. **Kirisits, C., Rivard, M. J., Baltas, D., et al.** (2014). Review of clinical brachytherapy uncertainties: Analysis guidelines of GEC-ESTRO and the AAPM. Radiotherapy and Oncology, 110(1), 199–212. https://doi.org/10.1016/j.radonc.2013.11.002

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