Chapter 4

Equira™ (VoxelPHITS): Democratising Precision Radiopharmaceutical Therapy for Global Cancer Care

Basri Johan Jeet Abdullah[1]*, Shalaine Sana Tatu[2], Yin How Wong[2], Azahari Kasbollah[3], Subapriya Suppiah[4], S. Cheenu Kappadath[5], and Chai Hong Yeong[2]

[1]Department of Radiology, Hospital PICASO, Malaysia
[2]School of Medicine, Faculty of Health and Medical Sciences, Taylor's University, Malaysia
[3]Medical Technology Division, Malaysian Nuclear Agency, Malaysia
[4]Department of Radiology, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia
[5]Department of Imaging Physics, The University of Texas MD Anderson Cancer Center, United States of America

Abstract

Radiopharmaceutical therapy is an essential option for cancers such as hepatocellular carcinoma, metastatic prostate cancer, and neuroendocrine tumours, delivering radiation internally via targeted radiolabelled compounds. Yet, most patients are still treated with empirical, fixed-dose protocols, with limited knowledge of the absorbed dose to tumours and organs-at-risk (OARs), driving variability in outcomes and avoidable toxicity.

Equira™, developed from the VoxelPHITS platform, offers a practical, scalable solution to personalised dosimetry. The open-source, vendor-neutral software converts standard CT (anatomy/tissue density) and SPECT/PET (radioactivity) into patient-specific 3D dose maps using Monte Carlo simulation and pre-computed dose-voxel kernels for speed. It accepts routine DICOM inputs, runs on Windows and Linux, and is designed for deployment in both high- and low-resource settings without specialised infrastructure. Outputs include isodose overlays, dose-volume histograms (DVHs, and tabulated dose metrics (e.g. D_{mean}, D_{95}, V_x) suitable for pre-treatment planning and post-therapy verification.

By aligning treatment decisions with measured dose rather than surrogates, Equira™ can improve safety, efficacy, and equity in radionuclide therapy. Its development supports a broader shift toward accessible precision medicine, enabling centres worldwide to deliver "the right dose, first time" and to standardise protocol optimisation with interpretable task-based metrics.

Keywords: *Radiopharmaceutical therapy, Voxel-based dosimetry, Monte Carlo simulation, Personalised dosing, VoxelPHITS*

Introduction

Precision medicine in radiopharmaceutical therapy requires not only locating tumours but also quantifying the absorbed dose to tumours and organs-at-risks (OARs). For radionuclides such as Yttrium-90 (Y-90), Samarium-153 (Sm-153), Lutetium-177 (Lu-177), and Holmium-166 (Ho-166),

internal dosimetry is essential to balance efficacy against toxicity[1-7]. Yet, according to the European Association of Nuclear Medicine (EANM) Dosimetry Committee surveys, about 70% of radiopharmaceutical therapies worldwide still use empirical dosing, contributing to variability in outcomes and elevated toxicity risks[8-10]. A key barrier is the limited availability of practical, accessible tools for personalised dosimetry[11].

Equira™, built on the modular VoxelPHITS platform, addresses this gap by transforming routine CT (anatomy/tissue density) and SPECT/PET (radioactivity) into patient-specific 3D dose maps. Leveraging the PHITS Monte Carlo software with pre-computed dose-voxel kernels, it delivers high-fidelity voxel-based dosimetry on standard Windows/Linux workstations, avoiding the need for specialised computing infrastructure or advanced physics expertise[12]. Dosimetry outputs, such as isodose overlays, DVHs, and tabulated dose metrics, are integrated into familiar clinical workflow for pre-treatment planning and post-therapy verification.

By providing an open, vendor-neutral, and easily deployable platform, Equira™ offers a practical route to personalised dosing across both high- and low-resource settings.

Results and Discussion

Platform capability and robustness

Equira™ is designed to be easily accessible, adaptable, and technically robust. It runs on Windows or Linux, accepts standard Digital Imaging and Communications in Medicine (DICOM) inputs from any imaging modalities, and installs locally within hospital networks to comply with patient data privacy requirements while still allowing secure remote updates. A modular framework supports multiple

[1]C. Chiesa et al., "Radioembolization of Hepatocarcinoma with (90)Y Glass Microspheres," *European Journal of Nuclear Medicine and Molecular Imaging* 42, no. 11 (2015): 1718–38.

[2]U. Garske-Román et al., "Prospective Observational Study of 177Lu-DOTA-Octreotate Therapy," *European Journal of Nuclear Medicine and Molecular Imaging* 45, no. 6 (2018): 970–88.

[3]M. Del Prete et al., "Personalized 177Lu-Octreotate Therapy: P-PRRT Trial," *European Journal of Nuclear Medicine and Molecular Imaging* 46, no. 3 (2019): 728–42.

[4]A. Sundlöv et al., "Individualized 177Lu-DOTATATE Treatment of NET," *European Journal of Nuclear Medicine and Molecular Imaging* 49, no. 11 (2022): 3830–40.

[5]E. Garin et al., "DOSISPHERE-01 Trial," *The Lancet Gastroenterology & Hepatology* 6, no. 1 (2021): 17–29.

[6]F. Cicone et al., "Dosimetric Approaches in Radioimmunotherapy," *Seminars in Nuclear Medicine* 52, no. 2 (2022): 191–214.

[7]C. Kratochwil et al., "EANM/SNMMI 177Lu PSMA RLT Guideline," *European Journal of Nuclear Medicine and Molecular Imaging* 50, no. 8 (2023): 2830–45.

[8]F. Giammarile et al., "EANM Dosimetry Committee Guidance," *European Journal of Nuclear Medicine and Molecular Imaging* 48, no. 4 (2021): 1136–50.

[9]M. Sandström et al., "Individualised Dosimetry with 177Lu-DOTATATE," *European Journal of Nuclear Medicine and Molecular Imaging* 44 (2017): 1480–89.

[10]T. Finazzi et al., "Dosimetry in Molecular Radiotherapy: European Survey," *European Journal of Nuclear Medicine and Molecular Imaging* 49, no. 5 (2022): 1630–39.

[11]IAEA, "Theranostics: Combining Diagnosis and Treatment," 2025, https://www.iaea.org.

[12]OECD NEA, "PHITS Voxel Training Materials," 2025, https://git.oecd-nea.org/phits/package/phits-lecture.

radionuclides, voxel sizes, and tissue models. Built with open-source tools such as Python and FORTRAN on the VoxelPHITS core, the platform reduces dependence on costly commercial software and supports long-term scalability and maintainability. Figure **1** shows the overview of the Equira™ workflow.

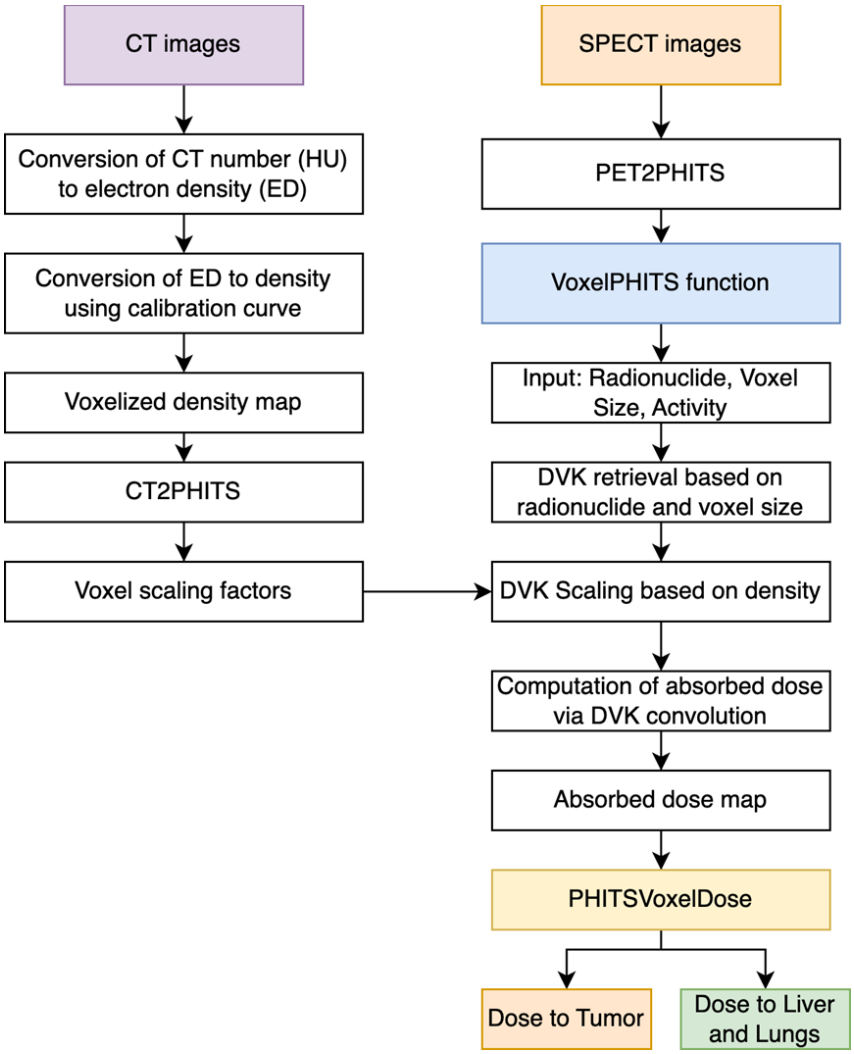

Figure 1: Overview of VoxelPHITS workflow.

Clinical utility

Equira™ quantifies absorbed dose to tumours and OARs, improving therapeutic confidence for both pre-treatment planning (to verify target coverage and OAR sparing) and post-therapy verification (to evaluate delivered dose). This aligns with modern theranostics, integrating imaging and therapy to enable patient-specific decision-making. Figure **2** illustrates a Y-90 selective internal radiation therapy (SIRT) case with baseline imaging, isodose mapping, follow-up response, and DVHs of a liver metastasis patient. Figure **3** shows multi-planar dose map visualisations generated by Equira™.

Implementation considerations and adoption

To support rapid adoption across diverse centres, Equira™ emphasises usability and trust: an intuitive interface requiring minimal training; colour-coded dose maps and location options for international

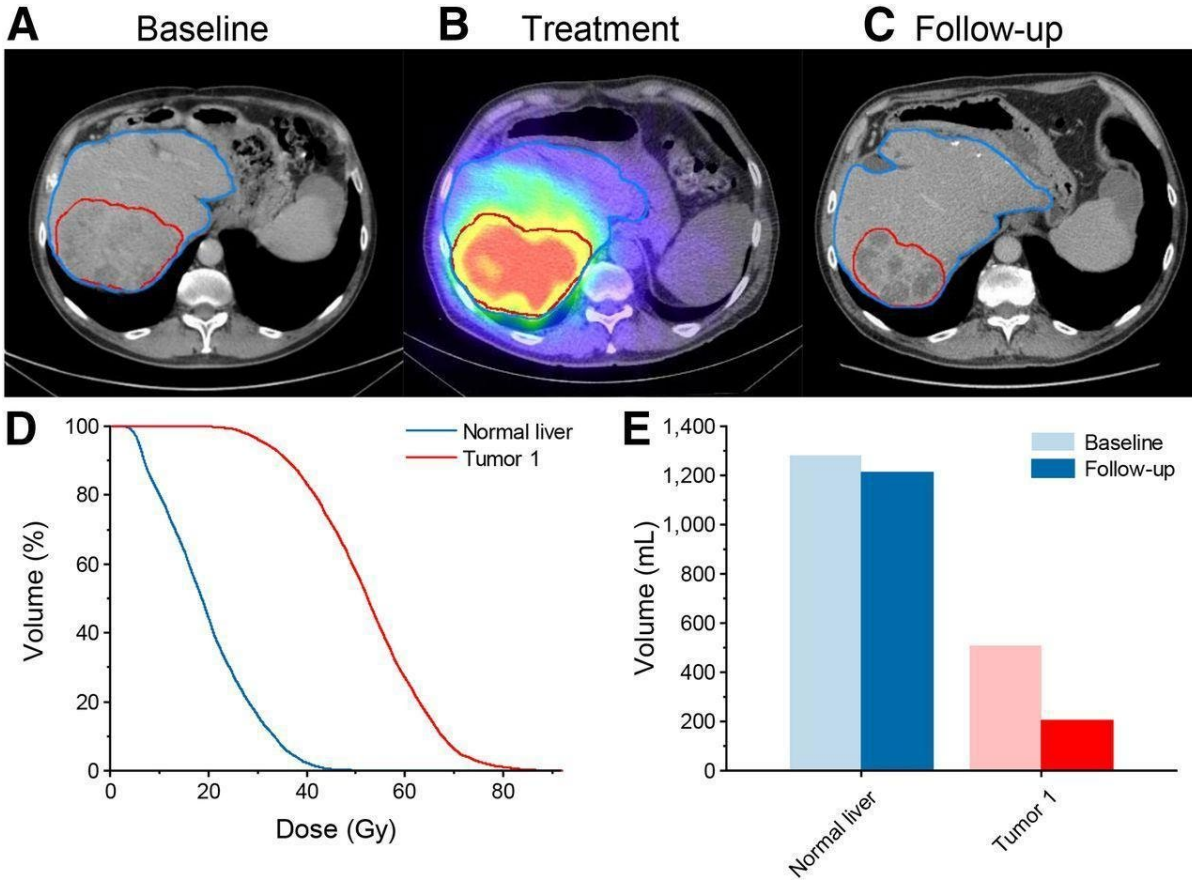

Figure 2: Personalised dosimetry for Y-90 selective internal radiation therapy (SIRT) of liver tumours. (A) Baseline CT prior to SIRT. (B) SPECT/CT with overlaid dose map demonstrating tumour and normal liver dose distribution. (C) Follow-up CT acquired at 80 days post-SIRT, revealing significant shrinkage of tumour. (D) Dose–volume histogram (DVH) for tumour and normal liver. (E) Volumetric response analysis. (Adapted from Abbott et al.[13]).

use; and commercial-grade packaging (documentation, verification cases, and user support) even though the software is open-source.

A sustainable deployment model is proposed: sites manage local installation and data control, while receiving secure online updates. A central support hub provides training materials, FAQs, peer discussion forums, and regular online training to encourage standardised practice and shared learning. Engagement with key opinion leaders (KOLs) will further strengthen credibility and accelerate clinical implementation.

Sustainability and governance

The project operates under a not-for-profit model supported by institutional partnerships and research grants, aligning the platform with global health-equity goals. Governance includes visioned radionuclide libraries, checksum-verified builds, and a minimal QA set (phantom cases, periodic checks) to ensure consistent performance across sites.

[13]E. M. Abbott et al., "The Impact of Radiobiologically Informed Dose Prescription on the Clinical Benefit of 90Y SIRT in Colorectal Cancer Patients," *JNM* 61, no. 11 (2020): 1658–64.

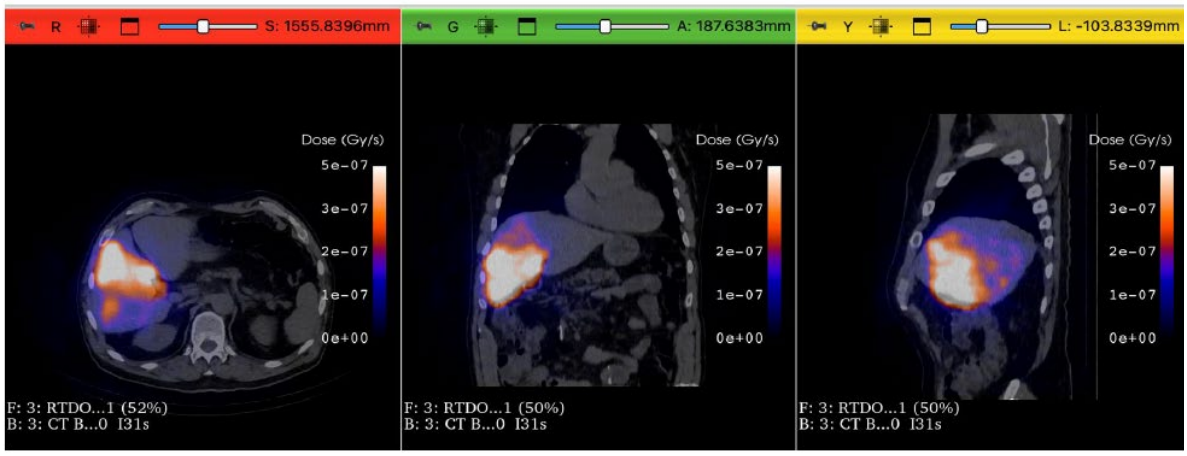

Figure 3: Cross sectional (axial, coronal and sagittal) views of a Y-90 SIRT 3D dose maps produced in EquiraTM.

Roadmap

Planned enhancements include AI-assisted organ segmentation, a cloud research mode (where policy permits), adaptations for paediatric and rare-disease protocols, and health-economic modules to inform policy and budget decisions. These additions aim to deepen clinical utility while keeping the system deployable in both high- and low-resource settings.

Conclusion

Equira™ represents a breakthrough in nuclear medicine dosimetry. By making personalised dosimetry accessible and affordable, it can improve safety, efficacy, and consistency of radiopharmaceutical therapy across diverse care settings. Our broader aim is clear: to advance precision care for every patient, irrespective of geography or socioeconomic status.

Acknowledgements

We acknowledge the support of Taylor's University, the Malaysian Nuclear Agency, the Philippine Nuclear Research Institute, and the Japan Atomic Energy Agency (JAEA). The project is funded by the Prototype Research Grant Scheme (PRGS/1/2023/SKK01/TAYLOR/01/1) under the Ministry of Higher Education, Malaysia, and partially supported by the DOST-HRDP Scholarship Programme.

References

C. Chiesa et al., "Radioembolization of Hepatocarcinoma with (^{90})Y Glass Microspheres," *European Journal of Nuclear Medicine and Molecular Imaging* 42, no. 11 (2015): 1718–38.

U. Garske-Román et al., "Prospective Observational Study of 177Lu-DOTA-Octreotate Therapy," *European Journal of Nuclear Medicine and Molecular Imaging* 45, no. 6 (2018): 970–88.

M. Del Prete et al., "Personalized 177Lu-Octreotate Therapy: P-PRRT Trial," *European Journal of Nuclear Medicine and Molecular Imaging* 46, no. 3 (2019): 728–42.

A. Sundlöv et al., "Individualized 177Lu-DOTATATE Treatment of NET," *European Journal of Nuclear Medicine and Molecular Imaging* 49, no. 11 (2022): 3830–40.

E. Garin et al., "DOSISPHERE-01 Trial," *The Lancet Gastroenterology & Hepatology* 6, no. 1 (2021): 17–29.

F. Cicone et al., "Dosimetric Approaches in Radioimmunotherapy," *Seminars in Nuclear Medicine* 52, no. 2 (2022): 191–214.

C. Kratochwil et al., "EANM/SNMMI 177Lu PSMA RLT Guideline," *European Journal of Nuclear Medicine and Molecular Imaging* 50, no. 8 (2023): 2830–45.

F. Giammarile et al., "EANM Dosimetry Committee Guidance," *European Journal of Nuclear Medicine and Molecular Imaging* 48, no. 4 (2021): 1136–50.

M. Sandström et al., "Individualised Dosimetry with 177Lu-DOTATATE," *European Journal of Nuclear Medicine and Molecular Imaging* 44 (2017): 1480–89.

T. Finazzi et al., "Dosimetry in Molecular Radiotherapy: European Survey," *European Journal of Nuclear Medicine and Molecular Imaging* 49, no. 5 (2022): 1630–39.

IAEA, "Theranostics: Combining Diagnosis and Treatment," 2025, https://www.iaea.org.

OECD NEA, "PHITS Voxel Training Materials," 2025, https://git.oecd-nea.org/phits/package/ phits-lecture.

E. M. Abbott et al., "The Impact of Radiobiologically Informed Dose Prescription of the Clinical Benefit of 90Y SIRT in Colorectal Cancer Patients," *JNM* 61, no. 11 (2020): 1658–64.