Conquering the Tyranny of Distance in Radiotherapy

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Approximately 50% of cancer patients could benefit from radiotherapy [1]. Due to the high costs and infrastructure demands, this treatment is primarily available in major urban centres, covering 84% of New Zealand's population. This urban-centric distribution leads to significant disparities for rural patients, who face lower screening rates, delayed diagnoses, later-stage disease at presentation, and consequently, poorer outcomes due to distance issues [2].

Current radiotherapy technology, rooted in early 20th-century radio frequency (RF) production, remains unchanged despite advances in particle acceleration. However, there are possible avenues to new treatment technology through fabrication of structures at the microscale, and integrating laser technologies operating at terahertz (THz) frequencies.

Traditional RF accelerating waveguides are about 2 meters long, whereas THz waveguides can be two orders of magnitude smaller (see Figure 1). As our research is currently subject to a pending patent application, no specific technical details will be discussed to protect the intellectual property. The general concepts, intended applications, and other publicly available aspects of the project will be presented.

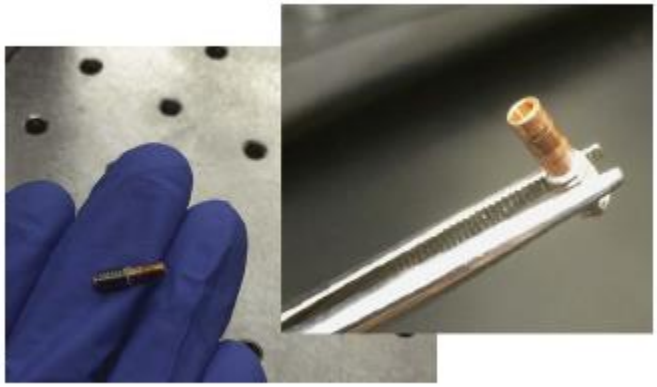

Figure 1: Images for the purposes of demonstrating the scale of THz electron linear accelerators from [3]

University of Canterbury is building an ambitious research group to solve accessibility issues related to radiotherapy for rural and remote populations. There are significant problems to solve and multiple stakeholders to engage with. However, the challenge will generate theses, publications, and patents if not a paradigm shift in how we address the tyranny of distance in radiotherapy.

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Shielding Design and Feasibility of Mobile THz Linear Accelerators for Palliative Treatment in Remote New Zealand Communities

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Introduction

Access to radiation therapy remains a significant challenge for patients in remote regions of New Zealand. This study explores the feasibility of integrating a terahertz (THz) linear accelerator within a mobile unit to provide palliative radiation therapy. The primary focus is on shielding design, dose distribution, and regulatory considerations for mobile deployment.

Method

A mobile treatment unit was conceptualized, see Figure 1, incorporating a THz linear accelerator and an integrated shielding solution to mitigate radiation exposure. Various treatment modalities were explored with relevant design criteria. Monte Carlo simulations using TOPAS were designed to assess radiation scatter and dose rates at various locations inside and outside the mobile unit. Additional optimization of shielding materials and configurations was explored to balance radiation safety with the constraints of a transportable system.

Results

Preliminary NCRP 151 calculations indicated that a combination of high-Z alloys and a layered shielding approach effectively attenuates radiation exposure while remaining within regulatory limits. To further reduce cost and weight, a water wall was integrated into the shielding design. Monte Carlo simulations validated these strategies, demonstrating their feasibility. Unlike conventional designs, this study incorporates patient attenuation, an often-overlooked factor in shielding calculations. Furthermore, by critically assessing the linear no-threshold (LNT) model and comparing existing data on radiation detriment and biological effects, this research challenges traditional safety margins defined by ICRP 103. The findings suggest that the proposed shielding design supports the safe deployment of a THz linear accelerator within a mobile unit while adhering to New Zealand's regulatory standards.

Conclusion

The feasibility of deploying a mobile THz linear accelerator for palliative radiation therapy in remote New Zealand appears promising. The integrated shielding design ensures regulatory compliance while maintaining portability. Future work includes refining dose rate calculations, validating treatment effectiveness, and addressing logistical challenges associated with mobile healthcare services.

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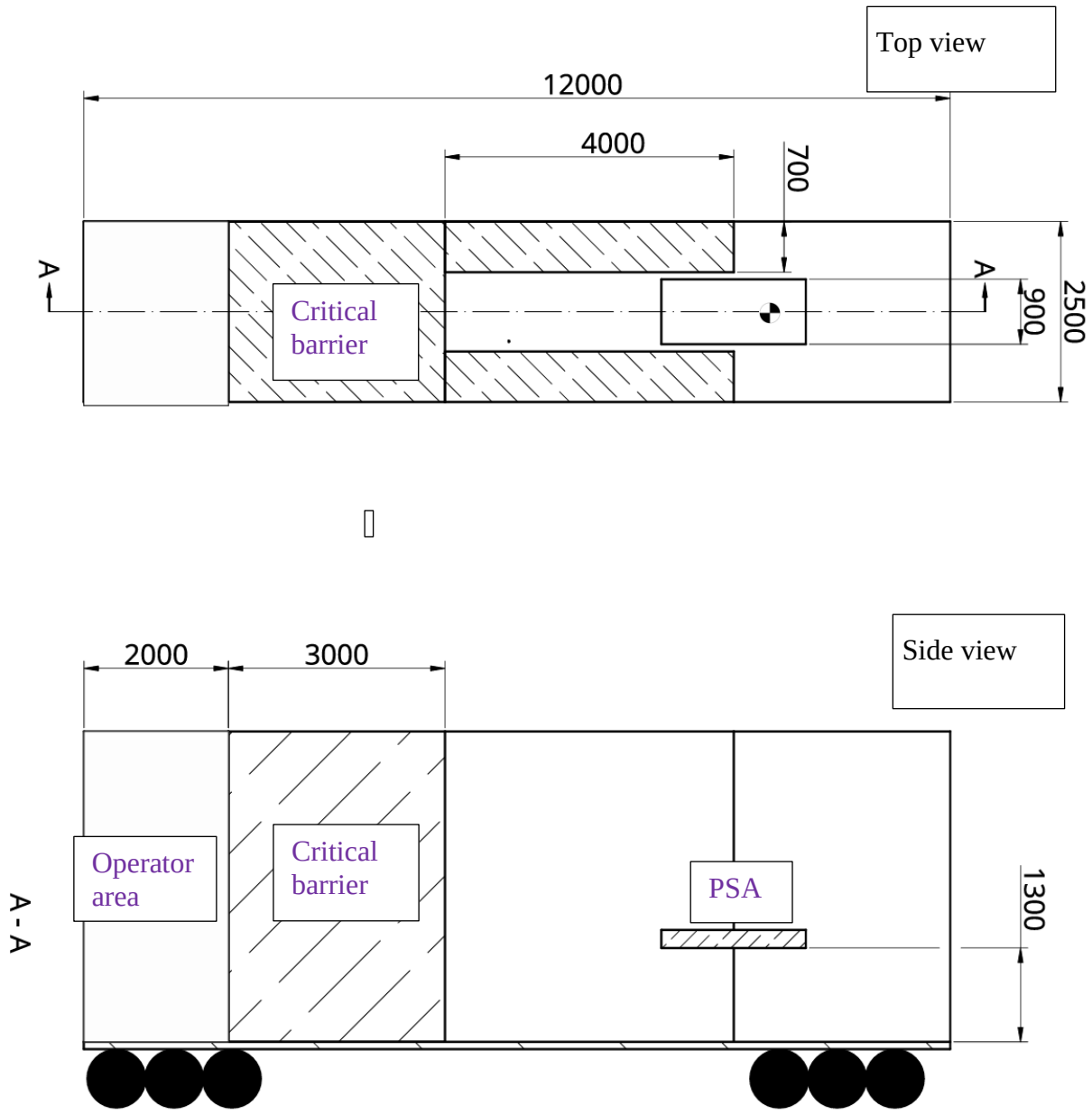

Figure 1. Conceptual Schematic of Mobile THz linear accelerator

A low-cost anthropomorphic phantom for use in NZ-wide inter-department SABR dosimetry verification measurements

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University of Canterbury

Introduction

This study focussed on the design, fabrication and verification of a low-cost anthropomorphic thorax phantom suitable for performing clinically useful dosimetry verification measurements for lung and spine SABR treatments within NZ. This work was motivated by a 2021 NZ SABR survey where NZ departments expressed interest in locally organized nationwide dosimetry verification measurements to improve our confidence in the accuracy of local SABR treatment deliveries.

Method

Suitable materials were investigated for their tissue equivalence and manufacturability. These were confirmed to be acceptable through CT and transmission measurement analysis. Tumour motion and adaptive capability were key interests expressed by the departments, driving the modular phantom design while meeting financial constraints. Anatomical representation was based on SABR patient DICOM datasets. The phantom was created to be transportable, radioresistant, physically robust, and reproducible in its setup. Verification has been performed at multiple radiation oncology departments.

Results

Polyurethane, epoxy resin, phenolic microspheres, and Teflon were utilised as tissue equivalent materials and implemented through additive manufacturing and 3D printing. Acceptable electron densities were achieved when compared to ICRU recommendations regarding respective human tissues. The final phantom is shown in Figure 1. Simple and complex 2D tumour motion was achieved with linearised servo motors. Adaptive treatments can be investigated through a range of tumours with varying sizes and densities. Complex SABR plans were delivered to the phantom for validation. Ionisation chamber measurements recorded differences <3%, and a 3%/2 mm gamma criterion resulted in pass rates of 97.1% for lung and 99.6% for spine.

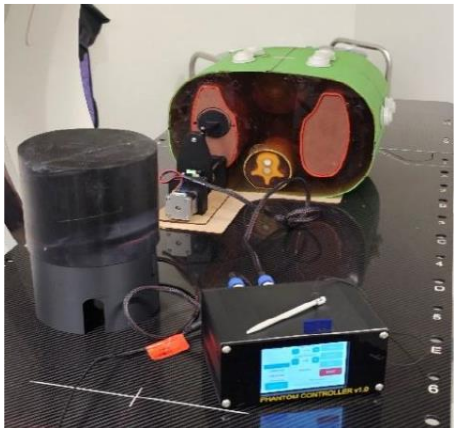

Figure 1: Phantom with soft tissue, lung, heart, spine and spinal canal equivalent components. Servo motors were used to generate synchronous superior-inferior tumour motion and anterior-posterior surrogate motion.

Conclusion

Phantom validation has demonstrated the suitability of this low-cost phantom for NZ inter-departmental dosimetry verification measurements of lung and spine SABR treatments.

Investigating MRI for real-time in-vivo dose monitoring using PhoenixMR; the good, the bad, and the noisy

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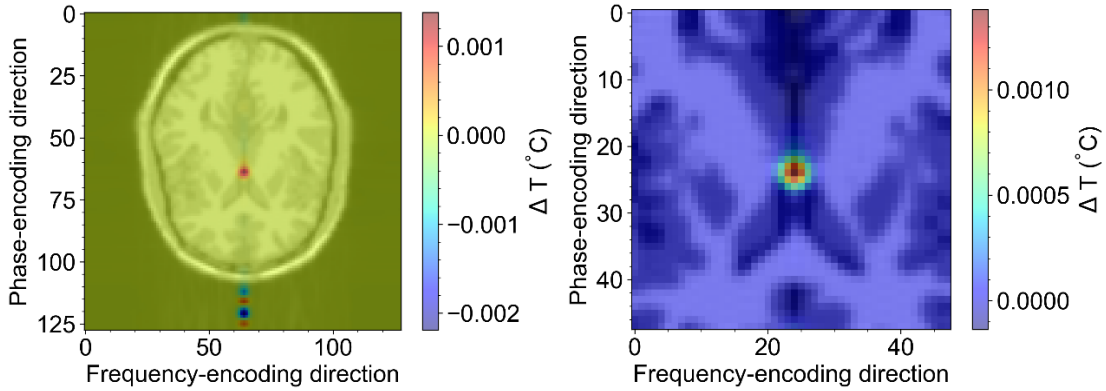
Introduction

PhoenixMR has been previously introduced as a fast, accurate, and flexible MRI simulation framework. The framework has several unique features including the ability to simulate additional processes in real time. One of these processes that we have investigated is whether MRI can be used for real-time dose monitoring in-vivo by using proton resonance frequency thermometry.

Method

Simulations were performed using the McGill brain phantom and a spoiled gradient-recalled echo sequence (TE = 8 ms, TR = 102 ms), with a decomposed Fourier solution to the heat equations to model a thermal source with a radius of ~4 mm. This thermal source was approximated using an average dose rate of 0.158 Gy/s, along with thermal conductivity, specific heat and density of brain tissue from literature.

Results



A single reconstructed slice at t = 13.05 seconds of the brain phantom with a ΔT overlay (left) and a zoomed in image (right) are shown. Of note are phase errors induced by the sequence located in the full left image. Different levels and types of noise were then tested, and it was found that due to the relative insensitivity of off-resonance changes with respect to temperature, preserving quantitative signal is challenging, although qualitative distribution of dose can still be achieved and is dependent on the noise distribution.

Conclusion

PhoenixMR can model complex phenomena and execute on fast GPUs without direct user modification of the simulator. Existing simulators have yet to achieve this capability, making performing simulations of advanced MRI techniques possible. PhoenixMR will be made freely available upon request to non-commercial researchers in medical physics soon. It is expected to increase and improve MRI simulation-related research.

Evaluation of MRI Protocols for Gynaecological Brachytherapy at Wellington Blood and Cancer Centre

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Introduction

Imaging plays a critical role in ensuring accurate tumour localisation and source placement within the patient for treating cervical cancer with high dose rate (HDR) brachytherapy (BT).

At Wellington Blood and Cancer Centre (WBCC), the current imaging workflow relies on computed tomography (CT) for applicator reconstruction and magnetic resonance imaging (MRI) for target contouring. This process involves MR-CT image registration, multiple patient transfers and long treatment planning times, increasing the risk of discrepancies between the planned and delivered dose. Implementing an MRI-only workflow or reducing the number of images acquired will substantially simplify the imaging protocol, with a consequent improvement in treatment accuracy. This study aims to develop the methodologies for evaluation of MRI sequences and the resulting workflows to be used for cervix HDR BT planning at WBCC.

Methods

An MRI-safe phantom was fabricated for MRI sequence optimisation, and a methodology for assessing image quality was developed to compare new MR sequences against the current protocol. Processes for evaluating the test workflows were established using three patient cases. For these three cases, the test workflows were compared against the standard workflow in terms of: equivalence of applicator reconstruction, target volume contouring variability, and resource efficiency. Two radiation therapists performed applicator reconstruction and two radiation oncologists delineated the target volume for inter-observer and inter-method analyses.

Results

The MR-only workflow was found to be the most time-efficient. Inter-observer contouring variability was found to be lower in the test workflows than the standard workflow. On the other hand, inter-observer applicator reconstruction for the MR-based method was found to be inferior to that of the CT-based method.

Conclusion

The findings provide valuable insight into the contouring and applicator reconstruction variability at WBCC. The developed methodologies for MRI sequence evaluation will support future research and clinical implementation of an optimised imaging protocol.

Clinical implementation of HIPO optimization in HDR Prostate Brachytherapy

Nicola Thomas, David Little, Victoria Beenstock, Alvin Kumar
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Introduction

Elekta's Oncentra treatment planning system for HDR Brachytherapy has two inverse planning algorithms: Inverse Planning by Simulated Annealing (IPSA) and Hybrid Inverse Planning Optimisation (HIPO). The IPSA algorithm was designed specifically for prostate planning and is recommended for this site. We initially followed this recommendation. However, there are several aspects of the HIPO algorithm and workflow which appealed, particularly for replanning following corrective action. The HIPO algorithm contains a smoothing function which reduces variations in dwell times across a needle and thus the need to smooth dwells manually. Additionally, dwell position activation is independent of optimisation allowing targeted inclusion or exclusion of dwells prior to optimisation.
This work describes our recent implementation of HIPO for HDR prostate planning.

Method

The departmental planning procedure was adjusted to account for the difference in workflow for HIPO. Study sets from six recent HDR prostate cases were copied for testing. A Brachytherapy radiation therapist (RT) created new plans using the HIPO workflow. The HIPO plan was compared to the clinically treated plan and the efficiency of the process assessed by the RT.
Corrective action, where a second planning CT is taken pre-treatment and needle position assessed, is performed for all patients clinically. Where needle movement warrants it, the original plan is adjusted to account for needle movement and the plan re-optimised. The process for corrective action was also completed with HIPO planning.

Results

The HIPO plans gave DVH parameters comparable to the clinically treated plan. The HDRCTV D200% parameter was typically lower for the HIPO optimised plan which is preferred. Dwell times within a needle were smoother following optimisation. The RT reported that planning with HIPO was faster, with less manual adjustment of the plan required.

Conclusion

HIPO optimisation of HDR Prostate Brachytherapy plans offered improved workflow and quality of treatment plans.

Waikato's Commissioning Experience with Halcyon

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Introduction

In August 2022, New Zealand's first Varian Halcyon Linear Accelerator (linac) was installed at Waikato hospital. The Halycon delivers on a single flattening-filter-free (FFF) photon beam with an energy of 6 MV. Halcyon utilises pre-configured calculation model, provided by Varian, with almost no department measured beam data or configuration required. The aim of this study is to describe the commissioning that was performed on the machine.

Method

The percent depth dose curves (PDDs) and beams profiles were measured for different field sizes (2 x 2 cm^2 up to 28 x 28 cm^2) using a CC13 ionisation chamber, and output factors were measured using a PTW Diamond detector. These measurements were compared with Eclipse preconfigured model values. DLG was also measured using the Varian provided plans, and compare to nominal value

An interdepartmental audit for absolute dosimetry was performed by the Kathleen Kilgour Centre (KKC). An End-to-End testing was also done using MD Anderson IMRT prostate phantom. The phantom was scanned, planned, and treated following guidelines and according to departmental procedures.

Results

When comparing PDDs and off axis beam profiles to Varian's golden beam data, we found the difference to be less than 0.3%, with gamma index (2%, 2mm) of 100% for all field sizes.

The output variation between the measurements and golden data is -0.3%. The audit showed 1.3% difference in $TPR_{20,10}$, the absolute output was within 1%.

Measured DLG values were 0.1mm on average for both the proximal and distal banks which compared well with the Varian beam data.

The results of in-phantom End-to-End dosimetry audit was 1% high, as reported by MD Anderson.

Conclusion

The Varian's golden beam and preconfigured data agree well with our independent measurements. Beam data validation was sufficient to verify Varian's beam data instead of full commissioning.

Elekta EVO: Commissioning and Early Clinical Experience

Jonathan Littler, Suzzane Lydiard
Kathleen Kilgour Centre

Introduction

We are one of the first centres in the world to commission the new Elekta EVO LINAC and clinically use IRIS, Elekta's new AI-enhanced Pelvis CBCT imaging technology. Here we detail our key learnings and experiences throughout our commissioning and early clinical adoption.

Method

In February 2025 an Elekta Versa HD LINAC had an xvi upgrade (v5.1), that included IRIS. The arrival and installation of the EVO LINAC began in February, and it will be beam-matched to our existing LINACs. Acceptance testing and commissioning have and will continue to follow international and vendor guidelines.

Results

The xvi upgrade installation took 5 days instead of the scheduled 2 days due to problem solving multiple unforeseen issues including Mosaiq cloud communication issues, the volume.ini file content needing to be altered, and limited instructions regarding a required IRIS calibration. Consequent IRIS commissioning included basic testing evaluating phantom image quality, geometrical accuracy and CTDI measurements, as well as a multi-disciplinary retrospective image review assessing image quality on pre-acquired patient data. Of note, IRIS is currently only offered for the single Pelvis M20 preset. IRIS has been used on pelvis patients as the standard CBCT imaging preset since March. Preliminary findings indicate that IRIS provides enhanced soft-tissue visualization but is prone to more evident artifacts around mobile gas and metal implants.

The EVO LINAC is currently being installed with an expected go-live date in May, prior to NZPEM. Acceptance has already been delayed due to the modulator being broken on delivery and awaiting a replacement. The local repercussions of the change/removal of the 'response' gating interface used to integrate ABC and Clarity is yet to be determined.

Conclusions

Being one of the first in the world to clinically use IRIS and early adopters of the EVO LINAC is exciting but has already provided unforeseen challenges and learnings.

Evaluating the auto-levelling functionality of a 3D scanning water tank

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Health New Zealand Capital, Coast and Hutt Valley

Introduction

Some 3D scanning water tanks use a partially automated setup and specific detector holders to position the effective point of measurement at the water surface, promising fast and reproducible tank setup. Such features must be validated prior to use and be well understood to avoid undetected errors.

In this work, the virtual auto-levelling functionality of a scanning water tank was evaluated.

Method

Pitch and roll errors were applied intentionally and deviations detected by the water tank compared to digital level readings.

Profile and depth-dose measurements with a manually levelled water tank were compared to measurements that relied on auto-levelling to correct 1.0° pitch and roll.

Results

Virtual auto-levelling detected and corrected errors up to 1.0° to within ±0.1°.

However, for 1.0° pitch and roll corrections, a systematic offset of depth-dose curves of approximately 1 mm occurred due to vertical displacement of the detector relative to the water level sensor defining the surface (Figure 1). Manually re-zeroing the depth axis after auto-levelling removed the offset but risks introducing other errors.

Differences for profiles were negligible except for small (≤0.5 mm) field size differences caused by the depth offset.

Conclusion

The auto-levelling functionality of a 3D scanning water tank was evaluated by introducing relatively large 1.0° pitch and roll setup errors.

Profiles were correctly measured, but a vertical displacement of the detector relative to the water surface resulted in systematic offsets in depth-dose curves.

This highlights that automated setup features require careful validation and a good understanding of the implementation and limitations of such features.

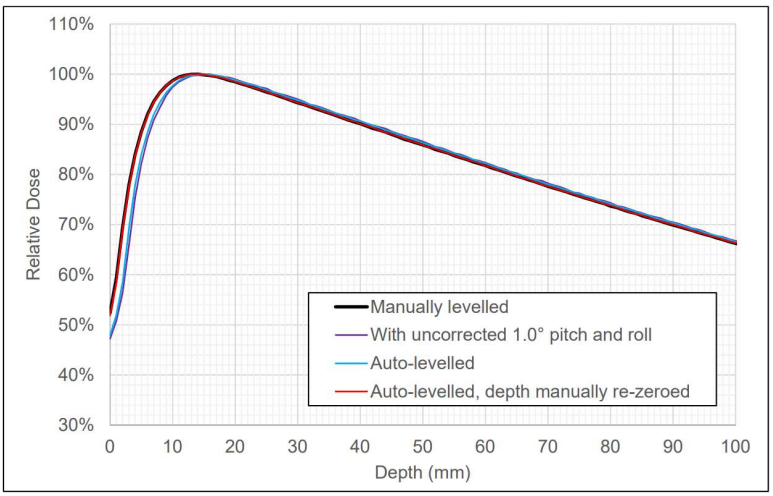

Figure 1: Depth-dose curves (6 MV, 10 cm x 10 cm, 100 cm SSD) showing a systematic offset of the detector position due to the applied pitch and roll that is not corrected by the auto-levelling functionality.

Implementing QATrack+ to streamline QA workflows in radiation oncology

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Introduction

Quality assurance (QA) in radiation oncology is critical for patient safety and treatment accuracy. However, managing QA tasks often requires multiple software solutions, leading to inefficiencies, data fragmentation, and importantly: increased administrative burden.

Method

QATrack+ is a “fully configurable, free, and open-source web application” [1] for physicists to manage their QA program. QATrack+ was installed at our institution in 2025. A full suite of tests is being created to manage QA of all machines and ancillary equipment. Automated image analysis will be scripted in Pylinac [2], which is specifically designed to conform to TG-142 [3] requirements.

Results

QATrack+ will be implemented and tested over March-April 2025, and a report on usability and efficiency gain will be presented. Based on initial testing, we expect to see greater ease of use and reduced time spent in manual data entry. Key features such as flexible and clear scheduling, automated image retrieval and analysis will be discussed, as well as potential limitations encountered. It is anticipated the consolidation of multiple software tools into QATrack+ will reduce licensing costs and IT administration demands.

Conclusion

QATrack+ is expected to streamline the QA workflow by centralising QA data management and automating routine tasks. We anticipate our experience will demonstrate the potential benefits of adopting a centralised, integrated QA platform in radiation oncology.

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Streamlining monthly linear accelerator quality assurance at the Waikato Regional Cancer Centre

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Waikato Hospital

Introduction

Monthly linear accelerator (linac) quality assurance (QA) at the Waikato Regional Cancer Centre has not been reviewed for a significant time period. Several departmental tools, including DoseLab [1], the IC Profiler (ICP) [2], and the Penta-Guide phantom (PG) [3], could streamline QA processes. This study aims to optimise the efficiency of monthly QA by utilising available tools within the department.

Method

Monthly QA procedures were reviewed against international guidelines including AAPM TG198 [4]. A single plan was developed for all imaging tests and the feasibility of DoseLab's autoQA feature for automated analysis was investigated. The ICP was compared with ion chamber (IC) measurements for output and beam quality constancy for photons and electrons. The PG phantom was evaluated for streamlining multiple tests into a single process which involved checking external laser alignment based on gantry crosshair positioning of the phantom, then checking the imaging system orthogonality and 6 DoF image-based couch corrections.

Results

Imaging data was gathered over an extended time period for planar kV, planar MV, CBCT, field size, MLC, and Winston-Lutz tests with baselines and tolerances defined. There was no significant difference between IC and ICP for output constancy (table 1). For photon beam quality, the differences between measured and nominal D10 using ICP range from -0.1% to -0.3%, indicating consistency across photon energies. For electrons, R50 differences from R_{50},ref range from 0.00 to 0.04 cm, demonstrating minimal variation across energies. Testing conducted with the PG proved to be reliable and results were within tolerance (1 mm and 0.5^{o}) for all parameters.

Table 1: Comparison between ion chamber (IC) measurements and the IC profiler (ICP) for output constancy

Modality	IC		ICP		Pair t-test value	Significant difference?
	Mean	Standard deviation	Mean	Standard deviation		
Photons	-0.12%	0.0034	0.38%	0.011	0.1361	No
Electrons	-0.44%	0.0063	-0.89%	0.063	0.7833	No

Conclusion

Monthly linac QA has been streamlined by utilising Doselab, ICP and the PG. This has reduced average monthly QA from 8 hours to only 5 hours for TrueBeam linacs and reduced Halcyon QA to 2 hours. The optimized QA improved efficiency in both monthly QA processes and increased machine time for treatment.

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AI Applications in Medical Physics: Challenges and Opportunities

Aidan Soal, Steven Marsh, Bryn Currie
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Introduction

Artificial Intelligence (AI) has rapidly evolved in recent years and is increasingly integrated into various fields, including medical physics. One area where AI presents a unique opportunity is in image reconstruction for Digital Holographic Interferometry (DHI) [1]. Traditional analytical methods can unwrap DHI phase maps but often struggle with noise or discontinuities. However, AI-based approaches, such as generative adversarial networks (GANs), can be trained using paired images to overcome these limitations. These models have the potential to improve phase unwrapping accuracy, making AI potentially a valuable tool in medical physics.

Method

There are many AI models, each demonstrating success in different applications. This study began by evaluating various models based on their capabilities and performance in medical physics, specifically in phase unwrapping for DHI. Synthetic data was used to train these AI algorithms, allowing them to learn relationships between images and generalize the process to previously unseen data.

For image denoising tasks, Pix2Pix GAN [2] was tested to evaluate its ability to perform both denoising and unwrapping within a single training model. This approach was compared to a two-step process where a GAN specifically designed for denoising [3] was followed by a separate unwrapping stage. Both AI-based methods were then assessed against standard analytical techniques to determine the viability of AI in medical physics.

Results

Preliminary results suggest that AI models can perform phase unwrapping and denoising of wrapped images. However, denoising appears to remove fine details essential for accurate unwrapping. This motivates the creation of a hybrid model to improve both unwrapping accuracy and noise management.

Conclusion

AI's growing success across various fields highlights its potential for broader integration into medical physics. As AI advances, improved learning algorithms will enhance accuracy, making it potentially a valuable tool for applications like DHI.

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A Retrospective Evaluation of AI-based Auto-contouring Software Solutions

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Introduction

This work assessed a selection of 5 commercially available AI-based auto-contouring systems for their suitability for use in local radiotherapy planning. Both a qualitative evaluation based on visual review and a quantitative comparison to local structures were made.

Method

Planning images were anonymised and sent to each vendor for auto-contouring. The structure sets received were processed to ensure consistent labelling prior to import into the TPS. The relevant subset of structures was then selected into blinded datasets for visual review and scored on a simple Likert scale. Scoring was performed at least twice independently by either a radiation therapist or radiation oncologist.

Dice coefficients were calculated for all relevant structures where a manually delineated example was available from the original patient treatment plan. These were calculated using the local structure as a reference for each vendor's auto-contoured structure. Where appropriate, nodal CTVs were compared to the union of the applicable auto-contoured lymph node structures.

Results

7,087 scores covering 3,197 distinct auto-contoured structures were made during visual review and 3,644 dice-coefficients calculated. The overall mean score was highly consistent between vendors, ranging from 2.1 ± 0.8 to 2.3 ± 0.8 (1σ), where a score of 2 indicates minor edits. Overall mean Dice coefficients were similarly in agreement between vendors, ranging from 0.7 ± 0.2 to 0.8 ± 0.2 (1σ). Specific examples where one solution was clearly favoured were identified, but were relatively rare.

Examples of anatomy where most solutions performed poorly included brachial plexus, bowel, pelvic lymph nodes, spinal cord/canal, and selected female pelvic anatomy. The accuracy of auto-contoured structures was also found to degrade with image quality (artifacts in particular) and unusual patient positions.

Conclusion

While differences between each were found, no single solution stood out as clearly superior in terms of accuracy or potential for efficiency gains.

Can Artificial Intelligence Guide Decision-Making in Head and Neck Cancer? Using Ensemble Learning to Predict Patients Benefiting from Adaptive Radiotherapy

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Health New Zealand Waikato

Abstract

Adaptive radiotherapy (ART) is an advanced treatment technique in radiotherapy that adjusts treatment plans to better suit individual patient needs and has been shown to have significant benefits for patients with head and neck carcinoma. New technologies allow us to review and adjust plans clinically on a day-to-day basis; however, identifying which patients will benefit from ART early in their treatment journey remains a challenge. This work evaluated the use of artificial intelligence (AI) models to predict patients who might require ART, in particular focussing on the use of ensemble learning on tabulated data, offering a more proactive approach to treatment.

We retrospectively analysed data from 100 head and neck cancer patients. An initial AI model was developed using a decision tree method and compared with other advanced algorithms like random forest and gradient boosting. Model accuracy and reliability were assessed using multiple measures, including precision and sensitivity. Input features were initially guided by expert clinical judgment and later refined through a systematic process. The final model, a random forest, was validated using data from an additional 110 patients not used in the training or development of the model.

Initial results showed the model achieved moderate accuracy, with 65% precision and a test accuracy of 60% and identified 21 cases as likely candidates for ART that were initially classified as false positives. Upon review, these cases represented patients requiring varying degrees of adaptive intervention, suggesting the model could identify subtle indicators of ART needs that were not immediately apparent. With this in mind the testing was repeated and these false positive reassigned, where appropriate, giving final scores of 85% precision, and 92% specificity

This study highlights the potential of AI-based tools to support clinical decision-making in radiotherapy. By identifying patients who may benefit from ART earlier, clinicians can provide more tailored treatments, improving outcomes and reducing unnecessary procedures. This approach could pave the way for a shift from reactive adjustments during treatment to proactive patient management, ultimately enhancing care for individuals with head and neck cancer.

AI or DIR? Comparative Analysis of Contours on Daily CBCT in Prostate Radiotherapy.

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Health New Zealand, Waikato, Hamilton, New Zealand

Purpose

Deep learning-based auto-segmentation has emerged as a stateof- the-art method in radiotherapy planning, offering significant time savings and geometric accuracy comparable to expert-derived contours. While extensively validated on planning CTs (CTp), its application to cone-beam computed tomography (CBCT)—critical for daily image guidance in prostate cancer radiotherapy— remains underexplored, traditionally addressed by deformable image registration (DIR). This study retrospectively analyzes prostate cancer patients to compare AI-generated and DIR-derived contours on CBCT, assessing their accuracy and dosimetric impact.

Methods

A retrospective analysis was conducted on N = 10 prostate cancer patients. The accuracy of AI-generated contours on CBCT images was initially assessed, followed by a comparison with contours derived using deformable image registration (DIR) techniques on the same images. Structural similarity metrics, including the Dice Similarity Coefficient (DSC), Hausdorff Distance (HD), and mean distance, were statistically analyzed to determine the significance of any differences. Additionally, the resulting dosimetry on the CBCT images was evaluated for both AI- and DIR-generated contours to assess their clinical impact.

Results

AI Scoring: 63% of contour sets would be usable with minimal to no editing required by an expert in Table 1. AI VS DIR comparison showed significant differences in the bladder and rectum, whilst prostates were consistently similar: Figure [1]. Dosimetric impact on different contours was more pronounced in rectum, particularly in the high dose areas that are adjacent to the prostate. Statistical scores are summarized in Table 2.

Conclusion

This study highlights organ-specific differences in contouring accuracy and dosimetric impact when comparing AI- and DIR-derived contours on CBCT images for adaptive radiotherapy. Prostate contours exhibited minimal differences across metrics, with negligible dosimetric impact. In contrast, bladder contours showed significant discrepancies in contour metrics but minimal dosimetric effect, while rectum contours, though less variable, had a more pronounced dosimetric impact due to their proximity to high-dose gradients. These findings underscore the importance of considering organ-specific variability and dosimetric sensitivity when integrating AI or DIR methods into adaptive radiotherapy workflows.

Keywords: AI; DIR; Contouring; Prostate; Adaptive Radiotherapy

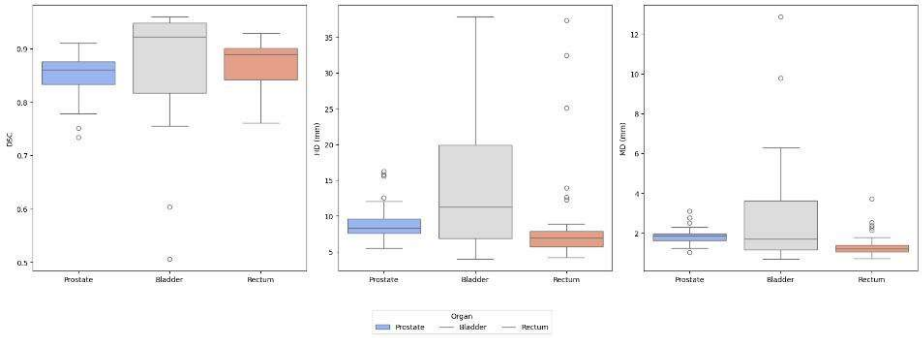

Figure 1: Box Plots for average similarity metrics for organs of concern.

Table 1: Likert Scale for AI Contour Scoring of CBCT images and number of images at that level

Level	Corrections	Images
1	Severe: Large and obvious errors	1
2	Medium: Minor errors that need a small amount of editing	23
3	Slight: Accepted: Minor errors, but not clinically significant	32
4	None:Accepted: Contour is very precise	9

Table 2: Statistical test results for dosimetric metrics across organs.

Organ	Metric	T-Test_P	Wilcoxon_P
Prostate	D98% [%]	0.947	0.167
	D2% [%]	0.248	0.903
	Max [Gy]	0.048	0.004
	Mean [Gy]	0.093	0.536
Bladder	Mean [Gy]	0.665	0.188
	V18.1Gy [%]	0.528	0.175
	V37Gy [cc]	0.054	0.317
Rectum	Mean [Gy]	0.000	0.000
	V29Gy [%]	0.001	0.001
	V18.1Gy [%]	0.000	0.000
	V36Gy [cc]	0.010	0.016

Feasibility of AI/ML-Assisted VMAT Patient-Specific QA Predictions and Modular Automated Plan Checks

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Introduction:
As radiotherapy techniques such as volumetric modulated arc therapy (VMAT) become more complex, the clinical workload for patient-specific quality assurance (PSQA) and plan verification increases. This study evaluates the feasibility of (1) using artificial intelligence and machine learning (AI/ML) to predict PSQA outcomes and (2) developing modular tools to automate components of plan checks, with the overarching goal of streamlining these resource-intensive clinical processes.

Methods:
We propose a dual-stream framework: (1) AI/ML-based PSQA prediction and (2) modular automated plan checks. For stream (1), ~20 plan features and complexity metrics—including treatment site, beam energy, total dose, monitor units (MU), gantry sweep angle, modulation complexity score (MCS), and modulation factor (MF)—were extracted from ~100 VMAT plans across five treatment sites (anus, breast, head and neck, prostate, rectum). These were paired with 2%/2 mm and 3%/3 mm gamma pass rates to train ML classifiers, then evaluated on ~10 additional cases. For stream (2), automated modules were developed for dose-volume histogram (DVH) verification (for Varian TrueBeam and Elekta Versa plans) and for checking setup instructions in complex 3D breast plans.

Results:
In stream (1), ML models achieved 90% accuracy in predicting binary PSQA outcomes (pass/fail). Feature importance analysis identified MF, treatment depth, field size, and MCS as moderate predictors, in ascending order of influence. In stream (2), the modular plan check tools successfully flagged deviations in DVH goals and setup instructions with over 99% accuracy, improving reliability and efficiency.

Conclusion:
This study demonstrates the feasibility of AI/ML-assisted PSQA prediction and modular automated plan checks. With further validation using larger datasets (>1000 cases) and expanded feature sets (~60 metrics), the proposed framework offers a scalable foundation for enhancing radiotherapy QA through AI and automating plan checks, with the potential to significantly reduce LINAC use and staff workload.

Radiation therapy for a pregnant patient

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Introduction

Radiation therapy is contraindicated for pregnant patients. In 2024, Auckland Hospital had the rare case of treating a 25-year-old female with brain cancer who was 21 weeks pregnant at the time of referral. The question was raised as to whether radiation therapy can be safely and effectively delivered to the patient whilst pregnant, or if other options needed to be considered for this patient. To understand if the treatment was safe, the dose delivered to the foetus over the course of the treatment needed to be known.

As a foetus is undergoing rapid mitosis during gestation, the impact of radiation dose can be much more detrimental to the foetus than an adult. AAPM report TG-36 [1] has covered the impacts of foetal radiation exposure. Previously, lead shielding has been used at Auckland Hospital to reduce radiation dose to the foetus. Lead aprons and lead skirts were available at Auckland Hospital which can be used for shielding the foetus. Determining the dose to the foetus with and without lead shielding will determine whether the treatment was safe, or if the treatment course will have to be modified.

Method

The dose to the foetus was measured using an anthropomorphic phantom and solid water setup. Foetal dose was measured at the foetal fundal point using a 0.6 cc Farmer ionisation chamber and MOSFETs at the foetal fundal point and at the surface. The dose was measured with differing layers of lead shielding provided with a lead apron (0.5 mm lead equivalent).

Results

The ionisation chamber dose to the foetus without lead shielding (≈0.2 cGy±7%) was shown be well below the accepted dose limits (5 cGy) [1].

Conclusion

Treatment was to continue as planned. Lead shielding was used but was not dosimetrically necessary.

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Tracking Fiducial Markers with Varian TrueBeam MV-kV and Exactrac Dynamic Marker Matching algorithms

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Introduction

This study explores the positional and intrafraction tracking of fiducial markers as prostate surrogates using Varian TrueBeam MV-kV and ExacTrac Dynamic (ETD) 2.0 marker matching modules. Both systems enhance radiotherapy precision by tracking marker positions and facilitating TrueBeam 6DOF couch realignment.

Methods

The Varian TrueBeam MV-kV and ETD marker matching modules were compared by evaluating the positions and shifts of implanted PolyMark markers placed in a CIRS Pelvis Phantom (phantom) under simulated treatment conditions using Varian TrueBeam equipped with ETD Motion Management system. The phantom was scanned with a slice thickness of 1.0 mm using a Siemens goOpenPro CT Simulator. The CT Study set was exported Monaco 6.0 for contouring and VMAT planning. The treatment plan was exported to Mosaiq and ETD for pre-treatment preparation utilising TrueBeam's MV-kV marker matching capabilities and ETD marker matching templates for intrafraction positional monitoring. ETD Surface/Preposition and x-ray shifts were acquired and exported to TrueBeam for couch correction prior to CBCT acquisition and treatment delivery. Phantom shifts were deliberately introduced to simulate patient motion during treatment. Differences in shifts and image quality as a function of gantry angle were assessed.

Results

The study evaluates the strengths and limitations of TrueBeam MV-kV and ETD marker matching algorithms. Automatic matching depends on image quality. TrueBeam MV-kV image quality is heavily dependent on gantry positions, while ETD image quality was consistent through all angles. Poor lateral kV and MV images compromised automatic matching for TrueBeam MV-kV due to increased separation and overlapping femoral heads, requiring manual matching. TrueBeam marker motion management is compromised at certain angles but can be used at any angle. ETD can only acquire images and calculate shifts at fixed gantry positions. Overlapping markers compromise automatic matching for both systems.

Conclusion

Both TrueBeam kV-MV and ETD gave similar translational shifts, but rotational shifts differed quite a bit when phantom was manually moved and images acquired to assess the shifts. Lateral MV images lacked sufficient contrast and were not suitable for kV-MV matching.

Installation, Acceptance, Commissioning and Use of a TEMA µDDA Dispenser

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Introduction

The liquid I-131 dispenser, used primarily for the endocrine clinic was decommissioned due to age and reliability issues. The department continued the patient treatments using I-131 capsules until a suitable replacement could be found.

A new TEMA µDDA Dispenser was purchased and installed by Cyclomedica Australia and accepted in June 2024. The system consists of: a PC, µDDSA Control unit, Dispenser, lift actuator; Label printer, Dose calibrator control unit, Dose calibrator and environmental shield. Waikato is the first centre worldwide to commission a µDDA Dispenser for I-131 therapeutic use.

Method

Dispensing I-131 into vials required changing the default configuration and using a number of workarounds in place of the normal PET dispensing workflow.

Testing of the system required a revalidation of the existing well chamber since it was now surrounded in an environmental steel shield and the manual source insertion was replaced with a plastic shuttle attached to an automated, aluminium and steel, lift actuator. The TEMA PC is directly connected to the dose calibrator control unit. As a consequence it was necessary to measure and apply: attenuation, volumetric and geometric factors to the default settings.

Results

The dispenser required considerable familiarisation and training to use in the bespoke set-up for therapy level dose dispensing into open vials. The testing for consistency was done over a period of 3 months. All changes to the attenuation and shielding factors were applied and verified using ANSTO calibrated liquid I-131 and a Cs-137 sealed source before clinical use.

Conclusion

The TEMA µDDA Dispenser can be adapted for use to dispense: therapy levels of I-131. Care must be taken to ensure the calibration accuracy of the system before use. Effective staff training is essential in order to minimise radiation safety risks and contamination.

Phantoms for testing multi-energy CT

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Introduction

Multi-energy photon-counting CT scanners are arriving in New Zealand, improving the accuracy of material identification software. AAPM Task Group Report 299: Quality control in multi-energy computed tomography [1], describes several phantoms for testing multi-energy scanners which are discussed in this presentation.

Method

The AAPM Task Group Report 299 report describes three phantoms:
Kyoto Kagaku MECT phantom, Model PH-75,
QRM spectral CT phantom, model QRM-DEP-002 and
Sun Nuclear Corporation MECT phantom, Model 1472.

They typically consist of a tissue equivalent head phantom with additional material to create a body sized object, with inserts. The inserts are typically water equivalent, liver tissue equivalent, adipose tissue equivalent, brain tissue equivalent, blood equivalent with varying degrees of coagulation, iodine of varying concentrations in water and blood equivalent backgrounds, calcium of varying concentrations, uric acid, titanium, and user-customizable vials.

The phantom inserts can verify the accuracy of material identification software such as virtual iodine removal, calcium scoring, gout and kidney stone identification and metal artifact removal. Other phantoms are required to do traditional CT tests such as low contrast resolution and spatial resolution. One limitation of existing phantoms is the spatial resolution insert which typically goes to 21 lp/cm. The Siemens Naeotom claims a significantly higher resolution capability, so existing phantoms with line pair test objects cannot test this upper limit.

Conclusion

There are several options for phantoms to test the capabilities of the multi-energy scanners. They typically cost NZ$25-30 000. Possibilities exist to create some home-made phantoms at a significantly cheaper price. Whether they are used for acceptance testing only, or for annual testing is a significant question for further discussion among diagnostic medical physicists.

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Assessment of Temporal Resolution in Fluoroscopy

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Introduction

Towards the end of 2024 our Cardiologists became increasingly vocal about poor image quality on our oldest lab – a 14 year old Siemens Artis Zee. Comparing static imaging performance with the Siemens ICONO revealed only subtle differences in detectability. This begged the question, are we missing something important by not evaluating dynamic imaging.

Method

A spinning plate test object was developed following Nema XR-21 specifications as closely as possible. This was used on the older Artis and the newer ICONO under a range of different fluoroscopic and angiographic protocols.

Results

Results are still being collected but we will present differences in temporal resolution between the 2 machines as well as difficulties in analyses of dynamic imaging. There have also been some interesting findings in how our solid-state dosimeter reports dose at varying dose rates.

Conclusion

Evaluation of temporal resolution in an important and overlooked aspect of fluoroscopic x-ray assessment. There are many challenges but in some specific cases it can provide valuable insight into real world clinical performance.

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Evaluation and Segmentation of AI-Denoised Propagation-Based X-ray Phase-Contrast CT Images of the Breast

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Introduction

Propagation-based X-ray phase-contrast computed tomography (PB-CT) [1] offers enhanced soft-tissue contrast, making it a promising modality for breast imaging in cancer detection. Though PB-CT can generate less noisy images at similar radiation doses compared to conventional modalities [2], image quality can still be affected by noise, especially in low-dose acquisitions. This research evaluates the impact of artificial intelligence (AI)-denoising on the segmentation of breast tissues in PB-CT images of mastectomy samples. We focused on segmenting glandular and adipose tissues, which constitute most of the breast and are clinically significant.

Method

PB-CT images of six fresh mastectomy samples were acquired at 4 mGy and 24 mGy mean glandular doses. An AI model trained on images of similar mastectomy samples was used to denoise 4 mGy images. Images captured at different doses were rigidly registered [3] (aligned) using Elastix [4] by minimising mean squared differences. Manual annotations were made using 3D Slicer [5] on strategically selected image slices per sample, to represent diverse tissue features and used to train nnU-Net [6] models, widely adopted AI models for medical image segmentation, for 4 mGy original, 4 mGy AI-denoised and 24 mGy images using five cases and then evaluated for the remaining case.

Results

Segmentation accuracy was assessed using the Dice Similarity Coefficient (DSC) [7], which quantified the overlap between automated and manual reference segmentations, where a higher DSC indicates better performance. Preliminary results show that the original 4 mGy dataset yielded a DSC of 0.943 (adipose) and 0.842 (glandular), while DSCs for AI-denoised 4 mGy dataset were higher- 0.979 and 0.938, respectively.

Conclusion

These findings demonstrate that AI denoising can enhance segmentation accuracy of adipose and glandular tissues. Evaluation is in progress, and we are planning to use this improved segmentation accuracy in our further studies, including dosimetry and breast density calculations.

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Investigation into the automatic optimisation of parameter (AOP) DOSE- mode on General Electric (GE) Pristina mammography machines

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Introduction

The signal difference to noise ratio (SDNR) is failing the achievable limit, as required by BreastScreen Aotearoa National Policy and Quality Standards (NPQS) standards for 4 cm, 6 cm and some 2 cm PMMA phantom thicknesses on GE Pristina machines for AOP DOSE-. An image quality assessment, using a Pro-MAM Gold MK II phantom, was undertaken to compare Pristinas on DOSE- and STD with Hologic 3Dimension and Siemens Revelation machines. The latter two machines easily pass the achievable SDNR requirement.

Method

An investigation into the failure of the Pristina SDNR was undertaken using a phantom-based subjective image quality assessment. A Pro-Mam Gold MK II phantom was imaged using the following mammography machines and AOP settings, in the case of Pristina machines:

1. General Electric Pristina (AOP DOSE- and AOP STD)
2. Hologic 3Dimensions
3. Siemens Revelation

Spot checks to verify the results from this study were performed by two other independent physicists.

Results

Of the machine types and AOPs tested, GE Pristina on STD was marginally better than the other machine types for overall gold disk details visible.

Machine Type	**Total number of gold disks visible**
GE Pristina DOSE-	177
GE Pristina STD	189
Hologic 3Dimensions	185
Siemens Revelation	178

Conclusion

GE Pristina machines use indirect digital detectors and have larger pixels. As a result, they have inferior spatial resolution compared to Hologic and Siemens machines which use direct digital detector technology. Additionally, the SDNR is significantly worse compared to both Hologic and Siemens machines. Why are these facts not reflected in the results from the Pro-MAM Gold MK II study? Possibly it is due to the GE Pristina-specific 34 kVp energy spectrum produced by a rhodium target and silver filter corresponding to the optimal energy range for the most frequent breast population.