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2025 Canadian Undergraduate Medical Physics Conference Abstract Book

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Abstract
The Canadian Undergraduate Medical Physics Conference (CUMPC) is a free virtual conference that provides a professional platform for undergraduate students across Canada to present their medical physics research projects. Following this year's theme, Empowering the Next Generation of Medical Physicists, CUMPC offers an opportunity to introduce undergraduate students to medical physics while also providing graduate students and trainees with valuable leadership experiences and networking opportunities through the organizing committee. In addition to the student presentations, a series of panels provides a space to explore careers, share research knowledge, and network with peers, graduate students, and professional physicists. Students are invited to submit abstracts, which are evaluated and returned with professional feedback for future improvements. Selected students are invited to make an eight-minute presentation during the two-day event. Oral presentations are judged by a panel of research, clinical, and industry professionals, where three winners per presentation category are ultimately selected. To learn more about CUMPC, please visit our website at https://cumpc.ca.

Keywords: medical physics; physics; imaging; therapy; nuclear medicine; undergraduate research conference

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Conference Abstracts

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Artificial Intelligence and Image Processing

Refinement of Automatic Curved Catheter Localization Using a Deep Learning and Feature-Based Approach in High-Dose-Rate Prostate Brachytherapy

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Introduction: Prostate cancer is the most common cancer among Canadian men. High-dose-rate (HDR) brachytherapy (BT) is a method to treat prostate cancer by temporarily implanting transperineal catheters into the prostate and using radioactive isotopes positioned inside the catheters to kill malignant cells. Catheter localization is often performed intraoperatively using

three dimensional transrectal ultrasound (3D TRUS). Imaging artifacts, such as shadowing, complicate manual localization, increasing procedure times and patient risk. Recent deep learning efforts have aimed to automate catheter segmentation but often assume rigidity or overestimate curvature, failing to capture realistic bending of flexible catheters. This study aimed to improve automatic localization of flexible catheters in 3D TRUS images of prostate brachytherapy patients by using a deep learning and feature-based curvature-constraining approach to better model realistic curvature.
Methods: The training, validation and testing datasets consisted of 67, 15 and 15 patients, respectively. Based on prior studies, a 3D U-Net architecture was applied to 3D TRUS images to generate point-cloud predictions, and a 3D Hough transform with curve fitting was applied. To refine curved predictions, the points were refit and smoothed using a Savitzky-Golay filter to reduce curvature overestimation. As ongoing work predicted catheters will be compared with ground truths annotated by medical physicists.
Results: The average Dice coefficient will be calculated to compare overlap, along with average shaft and tip position differences between predicted and ground truth catheters. Mean, 95th percentile and maximum curvature will also be calculated. These values will be compared for the algorithm with and without curvature constraints.
Conclusion: Further improvement of localization of curved catheters is necessary to reduce error and improve the success of HDR prostate BT. Automating segmentation of curved catheters can shorten patient time under anesthesia and reduce human variability and uncertainties in the clinical workflow, improving patient outcomes.

AI Based Organs and Applicator Segmentation in Cervical Brachytherapy: CT Image Data Preparation
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Introduction: Automatic segmentation of organs at risk and applicators on computed tomography (CT) images could greatly facilitate treatment planning for cervical cancer brachytherapy. nnU-Net, with its state-of-the-art segmentation capability, is ideally suited to this task, but it requires standardized inputs. This project aims to develop a user-friendly pipeline to prepare CT scans for nnU-Net, combining robust data cleaning, format conversion, and computer-science best practices under a framework of responsible AI.
Methods: 201 cervical cancer brachytherapy computed tomography (CT) scans acquired from 60 CRCHUM patients were used. A fully automated, end -to-end pipeline ingests raw anonymized DICOM folders, converts files to NIfTI volumes, generates multilabel RTSTRUCT segmentation masks, and performs continuous data integrity checks. The converted dataset was partitioned into training, validation, and testing sets by patient ID (rather than by scan) to avoid data leakage. The pipeline is interactive, allowing users to skip previously completed steps or customize specific processing needs, and is organized into well -documented, modular components with automated logging for full traceability. This enables in -house cervical brachytherapy CT datasets to be directly consumed by nnU-Net v2.
Results: Of 201 scans, 183 (91 %) were prepared successfully; 18 were excluded due to corrupted RTSTRUCTs (17) or inconsistent slice dimensions (1). The converted scans passed the nnU-Net v2 integrity check, confirming full compliance with its input requirements. Its runtime and memory usage were also optimized during development, contributing to the successful processing of a large dataset without requiring manual intervention.
Conclusion: The preprocessing pipeline successfully standardizes raw DICOM CT data for nnU- Net v2, removing a key barrier to automatic segmentation in cervical cancer brachytherapy. Combined with nnU -Net, it provides a user-friendly workflow for segmentation training with minimal manual intervention, and its flexibility makes it easily reusable for future applications.

Towards a Transfer Learning Approach for Automatic Segmentation of Intracavitary Brachytherapy Applicators in Ultrasound Images
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Introduction: Gynecological cancers are one of the most prevalent cancers affecting women worldwide. A treatment for these cancers is intracavitary brachytherapy. This involves inserting a tandem into the uterus while an additional structure (ovoid or ring) rests against the cervix, both allowing temporary positioning of a radioactive source. Ultrasound (US)

imaging can provide low-cost, accessible intraoperative guidance, however, acoustic shadowing from the applicator is a challenge in three-dimensional (3D) transabdominal (TAUS) and transrectal (TRUS) ultrasound images. A strategy to recover the complete field-of-view containing key features for treatment is the fusion of these TAUS and TRUS images. Our proposed automated fusion pipeline, requires localizing the applicator in each US perspective to provide a rigid body for registration. Manual localization is a difficult task, limiting clinical feasibility, thus there is need for automation. This study explores transfer learning via a deep learning -based needle segmentation algorithm to automatically localize the linear needle-like tandem of the applicator in TAUS and TRUS images.
Methods: The algorithm to be tested is a 3D U-Net that was pre-trained on prostate brachytherapy TRUS images. The network will be fine-tuned using gynecological intracavitary brachytherapy images. Fine-tuning the network involves freezing specific layers and re-training remaining layers on the new dataset.
Results: Segmentations of the tandem are anticipated to be successful after re-training, due to similarities with needles in the pre-training dataset. The predicted segmentations will be compared to ground truths by Dice similarity coefficient (DSC) and median distance (MD) between tandem tips and shafts. Target values for the DSC and MD are (>80%) and (<2mm), respectively.
Conclusion: Localizing the applicator is vital for optimizing treatment and automatic segmentation would enable clinically feasible automated registration of multi -perspective US images. Thus, this work has potential to enable accessible and low -cost 3D visualization and planning of gynecological brachytherapy in resource-constrained settings.

Predicting Optimal Region-of-Interest Placements for Surface-Guided Radiation Therapy

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Introduction: Surface-Guided Radiation Therapy (SGRT) is a growing motion management technique that monitors a patient's position and movement during radiotherapy. Three ceiling-mounted cameras are used to reconstruct the patient's surface for set-up. A user-defined region- of-interest (ROI) is then used to monitor the patient's motion during treatment. However, ROI placement can impact system efficacy due to camera obstruction from the linear accelerator (Linac). The purpose of this work was to develop a software to predict camera obstruction, guiding clinicians in ROI placement for SGRT.
Methods: The software took the patient body contour generated from their computed tomography (CT) images as input to define the surface points. Vector rays from the surface points to the cameras were generated and checked for intersection with the Linac head. Point blockage due to other parts of the patient's body was similarly flagged based on ray intersection with obstructing structures. Additionally, blockage information was used to identify unobstructed surface regions. ROI placement efficacy was tested with two ROIs on an in -house chest phantom: one with expected obstruction and one with no obstruction. The Linac was then rotated through 360° to test SGRT efficacy with each ROI.
Results: The software predicted that the chest center would be unobstructed throughout treatment, while obstruction was expected in the upper right of the pectoralis major within an arc range of 3° – 105°. When the ROI was drawn on the center of the chest, the system remained functional for the entirety of the 360° rotation, while the obstructed ROI caused an interruption of monitoring from 19° - 96°, consistent with software predictions.
Conclusion: We created a novel software capable of predicting optimal ROI placement for SGRT, improving the stability of intrafraction surface monitoring for external beam radiotherapy. Future work includes optimization of placements of cameras to avoid obstructions entirely.

Prediction of the Cardiac Dose During Breast Cancer Treatment Using Artificial Intelligence Tools to Sort Out the Patients Eligible for DIBH Treatment

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Introduction: Deep inspiration breath hold (DIBH) is a breathing maneuver used during breast cancer treatments to reduce the cardiac dose without diminishing the impact on the target. As DIBH requires more time during the planning, and as not every patient is suitable for DIBH, it raises the question of whether it should be prioritized over free breathing. At our institution, we have no robust, reproductible, quick and reliable way to sort which patients would benefit from DIBH. The purpose of this study is to develop such a tool using artificial intelligence and study its efficiency.
Methods: Three cohorts were studied: patients with left breast cancer (80 patients: 65 training, 15 validation); patients with left breast cancer that required treatment of the internal mammary lymph node (IMN) (63 patients: 50 training, 13 validation); patients with right breast cancer that required treatment of the IMN (45 patients: 36 training, 9 validation). For each cohort, RapidPlan, a Varian knowledge -based auto planning software, was used to predict the mean cardiac dose, which is used to sort out eligible patients for DIBH. A HD-Unet architecture was used for the same purpose, serving as a comparison and validation tool.
Results: Using RapidPlan, it was found that the mean difference between the predicted dose and the actual dose was 0,4 Gy for left breast cases (maximal error: 1,0 Gy) and 0,5 for both breasts with the IMN involved (maximal error: 1,1 Gy). We are expecting numeric results from the HD- Unet, and a comparison of the two tools by the end of this project.
Conclusion: Preliminary results demonstrate potential for using RapidPlan as a clinical tool to sort patients that would benefit from DIBH. Further validation is needed and a comparison with the HD-Unet architecture will be done by the end of the project to ensure the performance of the software.

Comparing MRI Intensity Normalization Techniques for Machine Learning

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Introduction: Diagnosing prostate cancer on *in vivo* T2-weighted (T2w) MRI is affected by moderate interobserver variability. Registering 2D histopathology images to 3D MRI can create a tool to better train radiologists, but this task requires specialized training, limiting access to large paired datasets. Machine learning (ML) can be used to generate synthetic T2w MRIs from histopathology images to facilitate registration of these images. Voxel intensities of T2w MRIs must be normalized to be used effectively in ML, but the optimal normalized method is unknown. Therefore, this study aimed to explore how different MRI normalization techniques impact the performance of a ML model in creating synthetic T2w prostate MRIs.
Methods: A total of 250 histopathology-MRI pairs were collected from 68 prostate cancer patients. The images were randomly split into training (n=168), validation (n=41), and testing (n=41) cohorts. T2w voxel intensities were normalized using z-score, 3-Sigma, or histogram normalization. An ML model was created to generate synthetic T2w MRIs from an input histopathology image. Structural Similarity Index Measure (SSIM) and Mean Squared Error (MSE) were calculated as image quality metrics for the synthetic T2w MRIs.
Results: The mean SSIM values for z-score, 3-Sigma, and histogram normalized were 0.9140, 0.9139, 0.8440, respectively. The mean MSE values for z-score, 3-Sigma, and histogram normalized were 0.0054, 0.0052, 0.0217, respectively. The SSIM and MSE for z-score and 3-Sigma normalization methods were not significantly different ($p>0.9$). Quantitative metrics for z-score and 3-Sigma were higher compared to the histogram normalized images ($p<0.001$).
Conclusion: Among MRI normalization methods, z-score and 3-sigma approaches outperform histogram normalization, providing an optimal approach for the generation of synthetic T2w MRI. These synthetic images will better enable the registration of prostate MRI to histology, supporting the large-scale training of ML models.

Is Magnetic Resonance Imaging Necessary for Producing Clinically Appropriate Hippocampal Contours with the Introduction of AI Generated Computed Tomography-Based Auto-Contours?

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Introduction: Whole-brain radiotherapy (WBRT) is standard-of-care for treating brain metastases; however, side effects from hippocampal irradiation have led to the development of hippocampal avoidance (HA)-WBRT. To prepare an HA-WBRT plan, a radiation oncologist (RO) manually contours the hippocampi, often requiring fused magnetic resonance (MR) and computed tomography (CT) imaging. This study evaluates clinical acceptability of hippocampal contours generated by AI auto-contouring using CT alone, compared to standard-of-care MR techniques.
Methods: Sixteen HA-WBRT patients were included and four contour sets were generated for comparison:

1. Consensus "ground truth" contours using the Simultaneous Truth and Performance Level Estimation (STAPLE) algorithm, based on seven ROs' MR-fused CT contours.
2. CT-based Limbus AI auto-contours (Limbus AI Inc., v1.7.0).
3. MR-based Limbus AI auto-contours.
4. Clinical contours by the treating RO (with MR-fused CT and Limbus AI).

Each set included contours for the left and right hippocampi and their 5mm planning organ- at-risk volumes (PRVs). Comparisons used the Dice Coefficient and qualitative assessments of over-/under-contouring.
Results: Clinical-based hippocampal and PRV contours achieved a mean Dice score of 0.64 and 0.82 when compared with STAPLE, defining a standard of acceptability. Limbus MR contours achieved a mean Dice of 0.66 (hippocampal) and 0.82 (PRV), while Limbus CT contours achieved 0.57 (hippocampal) and 0.78 (PRV), both compared with STAPLE. Limbus CT contours showed a decrease in mean Dice of 11% from the standard comparison for hippocampal structures and 4.5% for PRV structures. Despite this decrease, Limbus CT over-contouring, when compared with STAPLE, appeared in 12/16 cases, suggesting adequate sparing of both hippocampi.
Conclusion: Limbus CT contours were clinically acceptable compared to MR-based 'ground truth' segmentations. Implementation of this AI auto-contouring software would enable HA- WBRT planning without an MR scan, streamlining clinical care. Future work may focus on dosimetric analysis of Limbus AI or expand to alternative AI auto-contouring software.

Methodological Approaches for the Analysis of Prostate Cancer Histopathology Images Using Artificial Intelligence

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Introduction: Prostate cancer is one of the most diagnosed cancers affecting men. Histopathological analysis of biopsy tissue is essential for diagnosis and cancer grading in clinical practice. The digitization of whole slide images (WSIs) combined with artificial intelligence has the potential to assist pathologists and reduce inter-observer variability. Such approaches can increase the accuracy of cancer staging, guide appropriate treatments, and improve patient outcomes. This study aims to develop a fast and reliable deep learning-based pipeline for prostate tissue analysis.
Methods: The dataset used in this study consisted in WSIs from 2000 prostate cancer patients who underwent radical prostatectomy, along with their associated primary and secondary Gleason scores. The training (n = 1750) and test (n = 250) sets were randomly created while preserving the original Gleason score distribution. For each histopathological image, a tissue mask was generated using Otsu's thresholding method. Image patches (256×256 pixels, 0.5 μm/pixel) were then extracted and stain normalized on an AMD Ryzen 5000 workstation. Nucleus instance segmentation and classification (neoplastic epithelial, inflammatory, connective, dead and non - neoplastic epithelial) was performed without manual annotations using the Hover -Net model trained on the PanNuke dataset. Following a literature review, the UNI vision transformer foundation model, trained across 20 major tissue types, including prostate tissue, was chosen for fine-tuning in prostate-specific segmentation tasks.

Results: Preprocessing time per slide averaged 30 minutes. Time varied with tissue area and image size. Approximately 10,000 patches per WSI were stored in HDF5 files averaging 3 GB each. Visual inspection confirmed consistent stain normalization across patches.
Conclusion: Results demonstrate the potential of computational pathology to assist clinicians in cancer staging. Further work includes optimization of the patch extraction pipeline to reduce processing times, adaptation of UNI for generating accurate segmentation maps and applying these segmentations to develop an automated Gleason grading system.

A Deep Learning Approach to Reducing Skin Reflections in Microwave Breast Imaging

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Introduction: Breast cancer is one of the most prevalent cancers globally, accounting for around 700,000 deaths every year. Microwave Breast Imaging (MBI) proposes a low-cost and non-ionizing detection technique that leverages the contrast in dielectric properties between different tissues. Skin, however, has a strong response that diminishes the signals from deeper structures. Existing solutions often rely on idealized conditions. This work explores deep learning techniques to suppress the skin contribution in MBI signals, enhancing the potential for accurate tumour detection.
Methods: The UM-BMID database was used, containing S_{11} measurements from 1-8 GHz for 505 paired samples: one with the skin response and one with the skin removed via a differential imaging technique. Signals were transformed to the time domain and clipped to the first 200 time steps, where the skin response is most prominent. Two U-Net models were trained to remove the skin response, one using mean square error (MSE) for the magnitude of the signal, and the other using circular MSE for phase to account for its cyclic nature.
Results: The magnitude U-Net model successfully reduced the skin response, achieving an MSE of 6×10^{-8} and a correlation coefficient of 0.84 with the ground truth, indicating high fidelity in reconstruction. In contrast, the phase model showed less favourable results, with a circular MSE of 2.2 and a correlation of 0.29, reflecting a poor agreement and highlighting the complexity of learning cyclic phase information.
Conclusion: This study demonstrates the potential of deep learning algorithms to suppress the skin response in MBI signals. Although the results for the magnitude component were promising, challenges remain when addressing the phase information. Future work could focus on improving phase reconstruction and exploring the direct implementation of these algorithms in the frequency domain, thereby contributing to more accurate and reliable tumour detection.

Brachytherapy

Texture Analysis for Permanent Implant Prostate Brachytherapy Dose Distributions

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Introduction: Permanent implant prostate brachytherapy (PIPB) involves intricate dose distributions due to numerous implanted radioactive sources. However, commonly-used clinical metrics (e.g., D90, DHI: dose homogeneity index) ignore the spatial arrangement of doses, providing limited information about their distribution. In contrast, texture analysis can detect and quantify spatial patterns. The objective of this project is to quantitatively characterize 3D patient-specific absorbed dose distributions of low dose rate PIPB determined via Monte Carlo (MC) simulation using Haralick and Grey Level Size Zone Matrix (GLSZM) texture analysis.
Methods: A retrospective study of 19 125I PIPB patients was conducted using TG-186 (realistic tissue, with interseed attenuation (ISA)) and TG-43 (all water, no ISA) MC simulations. Five Haralick features were calculated using Löfstedt et al.'s modified approach and seven GLSZM features using the pyradiomics package. Textural features were compared to traditional clinical measures (D90, DHI, seed density in PTV).
Results: GLSZM and Haralick features were generally well-correlated with DHI (R2 for GLSZM ranging from 0.39–0.81 for TG43 and 0.31–0.77 for TG186). With the exception of correlation (COR), Haralick features showed strong associations (R2 from 0.66–0.82 for TG43 and 0.28–0.86 for TG186). Implants with higher DHI showed higher large area emphasis, homogeneity, and trends consistent with feature definitions and dosimetric principles. GLSZM features also correlated with seed density in the prostate (R2 from 0.35–0.93 for TG43 and 0.24– 0.84 for TG186). Haralick and GLSZM features in combination seemed to detect abnormalities in dose distributions such as cold spots or microcalcifications.

Conclusion: The results suggest that supplementing existing analysis techniques with Haralick and GLSZM textural analysis provides an enhanced approach to quantitatively characterize patient specific 3D absorbed dose distributions in terms of meaningful measures. Future directions could include expanding the analysis to a wider patient cohort and investigation of clinical outcomes.

Towards Automatic Registration of Three-Dimensional Transrectal and Transabdominal Ultrasound Images for Intraoperative Gynecological Brachytherapy Visualization

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Introduction: Gynecological cancer is among the most prevalent cancers worldwide, with high occurrences in resource-constrained regions. Brachytherapy is an effective targeted treatment that exposes tumours to radiation. The source is typically positioned via an intracavitary applicator temporarily placed inside the vagina/uterus, sometimes accompanied by needles to achieve desired dose distributions. Identification of applicators is vital to ensure successful treatment; however, under ultrasound imaging, applicators cause acoustic shadowing, obscuring critical features. Although manual registration of three-dimensional (3D) trans-abdominal ultrasound (TAUS) and trans-rectal ultrasound images (TRUS) is promising to recover visualization, it is difficult and clinically infeasible. This proof-of-concept study towards automatic TRUS-to-TAUS registration evaluated whether applicator-model-based Iterative Closest Point registration (ICP_{REG}) is feasible to align these image coordinate systems.
Methods: A ground truth registration (GT_{REG}) transform was created by manually aligning 3D TRUS and TAUS images of a gynecological phantom containing an applicator and three visible needles. To minimize localization uncertainty and isolate the ICP_{REG} transform for comparison to GT_{REG}, all available features were used to manually localize the rigid applicator model in both images. ICP_{REG} established a transformation between the TRUS and TAUS applicators. Target Registration Error (TRE) was calculated between the transformed TRUS and TAUS images using localized needle tips.
Results: ICP_{REG} achieved a mean surface distance of $1.4 \times 10{-}5$ mm between the transformed applicators, demonstrating successful algorithmic alignment of the models. The TRE between the TRUS and TAUS images after ICP_{REG} was 2.1 mm, matching the TRE between the two ultrasound images using the GT_{REG}, indicating that ICP_{REG} produced an equivalent registration.
Conclusion: The minimal difference between the TREs demonstrates that ICP_{REG} of applicator models is feasible for automatic TRUS-to-TAUS registration, enabling comprehensive visualization of applicators and nearby organs-at-risk. This is a promising step toward creating an accessible, clinically-viable imaging solution that decreases intraoperative uncertainty and associated patient risks.

Comparison of High-Dose-Rate Prostate Brachytherapy Dosimetry Using Manually and Automatically Delineated Structures in Trus Imaging

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Introduction: Prostate cancer accounts for 22% of all new cancer diagnoses among Canadian men in 2024, highlighting its clinical and societal impact. Brachytherapy is a form of radiotherapy where sources are placed directly inside or near tumours and is a well-established option for localized cases. High-dose-rate prostate brachytherapy (HDR-BT), often performed under three-dimensional (3D) transrectal ultrasound (TRUS) guidance, involves temporarily inserting catheters through the perineum. 3D TRUS imaging enables immediate refinement of catheter placement and anatomical delineation for intraoperative planning. HDR-BT dose delivery depends on accurate and precise contours of prostate and organs-at-risk (OAR), as errors lead to significant dosimetric deviations. This study investigates the dosimetric consequences of using deep learning– based auto-segmentation compared to manual delineation in 3D TRUS-guided HDR-BT.

Methods: TRUS images from 100 prostate cancer patients previously treated with HDR-BT were retrospectively analyzed. A clinical expert performed manual segmentations of the prostate for dosimetric evaluation. A U-Net algorithm will be used to generate auto-segmentations of the prostate. Standard dose metrics, including D90, V100, and V150 for the prostate, and D2cc and maximum dose for the rectum and urethra, were extracted. Dosimetric comparisons of the metrics between the manual and auto-generated segmentations will be performed.
Results: Agreement between manual and automated prostate segmentations will be evaluated using the Dice similarity coefficient. A Dice score greater than 0.85 for the prostate segmentations and dose deviations within ±5% will be deemed clinically acceptable.
Conclusion: This study outlines a framework for evaluating automated prostate segmentation in 3D TRUS-guided HDR-BT. Manually delineated structures from delivered clinical plans serve as ground truth for comparison. The ongoing work will compare prostate dose metrics between manual and automated segmentations to assess whether automated contours can improve segmentation efficiency while maintaining clinically acceptable dose coverage.

Conception and Characterization of a New Configuration of In-Vivo Scintillation Detector for Brachytherapy

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Introduction: Brachytherapy is a very efficient procedure for cancer treatments. However, errors related to transfer tube inversion and uncertainty in catheter reconstruction can affect treatment accuracy, justifying the importance of real-time dose monitoring. This study aims to develop and characterize a new in-vivo detector (IVD) configuration, combining Plastic (PSD) and Inorganic (ISD) scintillators, and evaluating its performance in terms of signal-to-noise ratios (SNR).
Methods: Three detectors were used: PSD PRB-0057 (1 ×1 mm scintillating fiber, Medscint, Québec, Canada); 3 ×1 mm BCF-12; and 0.5 ×0.5 mm Gd_2O_2S:Pr,Ce,F. All scintillators were coupled to 1 mm × 8 m optical fibers. Detectors were positioned at 1.8 cm from an Iridium -192 flexisource (Elekta, Netherlands; S_K= 31291, 29566 and 29571 U) in a 48 × 48 × 48 cm^3 water tank, respecting TG-43 conditions. A robotic arm moved the detectors up to 5.8 cm from the source in 0.5 cm steps every 40 seconds along the source transverse plane (θ =90°). Light-yield spectra were acquired at 1 Hz with a Hyperscint-RP200 spectrometer (Medscint) to derive SNRs.
Results: The highest SNR values were obtained from the ISD, varying from 33.01 at 1.8 cm to 8.31 at 5.8 cm from the source, corresponding to dose rates of 2.85 and 0.27 cGy/s according to TG-43. SNRs from Medscint and BCF -12 detectors also decreased with distance, ranging from 28.44 and 18.02 (3.02 and 2.85 cGy/s) at 1.8 cm to 6.06 and 5.61 (0.29 and 0.27 cGy/s) at 5.8 cm. The Rose criterion (SNR > 5) is respected for all detectors up to 5.8 cm.
Conclusion: Results show a good performance of both ISD and PSD, coupled to the Hyperscint - RP200 dosimetry platform, down to 0.13 cGy/s. To conceive and characterize a hybrid IVD, the following steps involve characterizing the ISD's dependencies and optimizing a single-fiber ISD/PSD prototype for time-resolved IVD.

Retrospective Study of Dosimetric Differences Between TG43 and TG186 Formalisms in the Presence of Calcifications in Prostate LDR Brachytherapy

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Introduction: Permanent implant brachytherapy utilizes low-energy photons, achieving a curative low-dose rate (LDR) on the prostate while sparing nearby organs. Current clinical dose calculations use TG43 formalism, approximating the patient body as water, which works for high-energy photons. However, photoelectric cross-sections dominate low-energy photon interactions, making tissues with different atomic number than water, like calcifications, impactful. Therefore, TG186 formalism, which takes into consideration tissue compositions, becomes favorable. This work's objective is to analyze

dosimetric differences between TG43 and TG186 dosimetry for LDR brachytherapy treatments at the CHU de Québec - Université Laval.
Methods: From a database of 956 patients, 74 were discarded due to missing data. Then, 273 patients were identified having calcifications of over 10% calcium. Monte-Carlo (MC) simulations reproduced the treatment using EGS-Brachy, and TG43 and TG186 patient-specific dose distributions were computed. Dosimetric values were extracted for both formalisms on this dataset. Prostate and calcification volumes were extracted from the patient geometry. Then, the difference between both formalisms' dosimetries was computed.
Results: The difference in prostate D90 between TG43 and 186 formalisms (TG43- TG186) exhibited a linear relationship as a function of calcification percentage in prostate volume with an R^2 of 0.853, showing an increase of 3.67 ± 0.09 Gy per percent. Urethra D0.1cc yielded an R^2 of only 0.566 with an increase of 4.2 ± 0.2 Gy per percent, which is less indicative than prostate D90.
Conclusion: TG43 and TG186 formalisms were compared using MC codes on patient data from CHU de Québec in LDR brachytherapy. Linear relationships were established when investigating the difference between both formalisms for the prostate D90 and urethra D0.1cc as a function of calcification percentage in prostate volume. Recalculations will be done when the database is updated (Summer 2025).

Advanced Imaging and Neuro Applications

Myelinated Axon Diameters Measured in a Male and Female Mouse at Multiple Angles to Better Understand Magnetic Resonance Imaging Estimates

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Introduction: Axons are microstructural cells in the brain that are grouped together in fibre tracts to propagate electrical signals. Postmortem studies suggest that changes in axon diameter and fibre tract densities are linked to various neurological disorders. To understand when and how axon diameters change due to disease development, measuring axon diameters in vivo is crucial. Electron microscopy (EM), the gold standard for viewing microstructures, but imaging is ex vivo. A diffusion magnetic resonance imaging (MRI) model estimates axon diameters, although overestimations may occur due to its single-directional measurements. Therefore, our objective was to measure axons diameter s at various angle orientations using EM to assess how MRI's measurement direction impacts axon size estimates.
Methods: The dataset consisted of one female mouse and one male mouse, each containing ten 9.4 µm x 5.5 µm EM images. Using ImageJ, a 0.77 µm2 grid was overlaid onto the EM images set either horizontally and vertically or at ±45 ° angles for each image. When a grid line crossed a complete axon, a line was drawn along the grid line and recorded to represent its diameter at 0°, 90°, and ±45°.
Results: Mean (d) and weighted mean diameters (AxD) were calculated at each angle. For the male mouse, d ranged from 0.68 ± 0.02 µm to 0.73 ± 0.02 µm, and AxD ranged from 1.1 ± 0.2 µm to 1.2 ± 0.3 µm. For the female mouse, d ranged from 0.409 ± 0.009 µm to 0.50 ± 0.07 µm, and AxD ranged from 0.61 ± 0.03 µm to 0.75 ± 0.07 µm. Statistical analysis showed no significant differences between angled diameters for the mice, except at +45° for the female mouse, where a significant difference was observed.
Conclusion: Expanding our dataset is critical to determine if the angle of measurement significantly affects mean axon diameters.

Towards Modular, Physiologically Accurate Monte Carlo Diffusion MRI Simulations for Increased Accuracy in Axon Diameter Estimates

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Introduction: Diffusion Magnetic Resonance Imaging (diffusion MRI) offers a non-invasive, *in vivo* technique for studying axon microstructure in people with neurodegenerative diseases such as multiple sclerosis. Unlike post-mortem electron microscopy studies, diffusion MRI enables the estimation of axon diameters and the potential for longitudinal assessments of axon integrity in living people. However, current models used to interpret diffusion signals rely on accuracy limiting

assumptions, such as membrane impermeability and idealized cell geometries, leading to uncertainty. This study aims to develop a Monte Carlo diffusion MRI simulator designed to model water diffusion and spin dynamics within biologically realistic conditions more thoroughly.
Methods: A fully tensorized, GPU-enabled framework using Python was built to allow the implementation of multiple cellular geometries with adjustable boundary permeabilities. Complex environments with latticed cylinders or spheres can be created with the added ability to introduce nested membranous structures or intracellular compartments. Water molecules within the simulation undergo 3D Brownian motion and are paired with evolving magnetization vectors. Support of multiple gradient waveforms, including Oscillating Gradient Spin Echo (OGSE) sequences has also been implemented.
Results: Initial results show evidence of diffusion mechanics and support for simulations with greater geometric complexity. Future work includes the fitting of simulated signals to estimate axon diameters, and further validation of outputs against diffusion MRI of mouse brains and electron microscopy data. Extensions are planned to include mesh-based geometries for further geometric complexity and adaptation of fit models based on novel diffusion metrics derived from experimental data.
Conclusion: This work demonstrates an extensible, GPU-accelerated Monte Carlo simulator for modeling diffusion MRI within complex environments. It shows potential for validation of diffusion encoding schemes, as well as the development of improved physiological models for diffusion MRI signal interpretation.

Segmenting White Matter Microstructure in Electron Microscopy Images to Estimate Cellular Packing Fractions for Comparison With MRI Inferences

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Introduction: Imaging techniques capable of assessing brain microstructure, such as the sizes of axons, could facilitate earlier diagnoses and an improved understanding of conditions which alter tissue microstructure. Electron microscopy (EM), the gold standard in viewing brain microstructure, is performed *ex vivo*, limiting its use in living organisms. Magnetic resonance imaging (MRI), a non-invasive technique, could enable *in vivo* assessment of brain microstructure. The primary goal for the summer was to investigate which cells affect the cellular packing fractions (*f*) found from our MRI method by comparing results with *f* found from microstructural segmentation of EM images of the same subject. Intra-axonal space is expected to be the major component of *f*, however, due to the short T2 of myelin water, and the much smaller sizes of cells that are not myelinated axons, if those spaces affect *f*, they are expected only to add to the contribution.
Methods: One male mouse brain with 10 EM images (9.4 µm x 5.5 µm) was analyzed using 3D Slicer. Each image was manually segmented into myelin (*m*), intra-axonal space (*ax*), intracellular space of other cells (*ic*), and extracellular matrix (*ec*), their respective area and *f* were calculated.
Results: Mean *f* values were calculated from six EM images as: f_{ax}=0.51±0.03, f_{m}=0.32±0.04, f_{ic}=0.07±0.03, f_{ax+m}=0.83±0.05, f_{ax+ic}=0.58±0.04, $f_{ax+m+ic}$=0.90±0.04. MRI *f* for this sample was 0.3±0.2. The f_{ax} and MRI agree within error bars. Comparisons between techniques must consider tissue alterations from EM processing (e.g., cell shrinkage, bubbles, extracellular compartment shrinkage), which can lead to overestimated EM *f* values.
Conclusion: Future work should tailor MRI parameters to target expected axon sizes. Simulations may clarify EM-related shrinkage effects. Full analysis of this mouse and additional subjects are needed to assess generalizability.

Do Cells Other Than Myelinated Axons Contribute to MRI Estimates of Axon Sizes?

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Introduction: A new diffusion-MRI method inferring micron sized-axon diameters overestimates the intra-axonal volume fraction in the mouse corpus callosum (CC). MRI might be inferring the sizes of all cells, as cell walls and myelin restrict the

diffusion of water within tissues. The main goal was to determine whether the average diameter of all cells within the EM images of the CC differs significantly from the average diameter of only myelinated axons.
Methods: A female mouse CC 9.4µm x 6.6µm EM image was analyzed. The diameter of every fully visible cell was measured. Mean diameters were calculated for myelinated axons, all other cells, and all cells together.
Results: Mean diameter of the myelinated axons is 0.43±0.02µm, of all other visible cells is 0.146±0.005µm, of all visible cells is 0.24±0.03µm. All groups show significantly different axon diameters ($p<0.05$).
Conclusion: The cells that are not myelinated axons have diameters too small for MRI to resolve and are unlikely to influence axon diameter estimates. However, their abundance and the restricted diffusion of intracellular water within the cells likely affects the MRI-derived volume fraction. Further study of the volumes in EM is needed to compare with MRI results.

Development of a Python Graphical User Interface for Two-Photon Transcranial Imagery in Mice
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Introduction: Neuronal and cerebrovascular activity in transcranial mice can be examined using a two-photon microscope. This imaging technique allows deeper access into the studied tissue. A custom graphical interface, adapted to this type of imaging, may reduce the time needed to collect brain activity data. It could also improve the speed of image processing and facilitate the integration of complementary analysis. The data shown and collected by the graphical interface is useful to study pathologies and behaviors in mice.
Methods: The graphical interface communicates with ThorLabs' Bergamo II Series Multiphoton Microscope by its Electronic Control Unit and its Alazar data acquisition card. The interface is written entirely in Python and tested on easily available phantoms made from fluorescent pollen. The images obtained are compared against those produced by ThorLabs' multiphoton image acquisition software, ThorImageLS.
Results: Testing shows that the user interface successfully communicates with the microscope's acquisition card and correctly processes its data, as images obtained are similar to those displayed in the ThorImage interface. The microscope's parameters and imaging settings, such as PMT gain, pixel numbers and zoom, can be easily manipulated by the user on the custom software. The GUI's frame rate can go higher than 15 fps. Z-stacks, crucial to mice brain imaging, can be captured. A one channel stack of 101 frames is obtained in 3 minutes and 44 seconds, a performance slightly slower than ThorImage's.
Conclusion: Initial results suggest that the graphical user interface is functional and, when optimized, could improve the efficiency and flexibility of two-photon imaging. The custom software permits further analysis, such as phosphorescence lifetime imaging microscopy. Further work will focus on the optimization of the interface and testing will be conducted during transcranial mice imaging sessions.

Radiation Therapy Planning and Technology

A Feasibility Study of Spatially Fractionated Radiotherapy (SFRT) for Canine Cancer Patients Using the Kilovoltage Optimized Accelerator Adaptive Dual-Robot Therapy System (KOALA)
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Introduction: Global disparities in access to radiation therapy remain a significant barrier to cancer treatment. KOALA (Kilovoltage Optimized AcceLerator for Adaptive therapy) is a novel, low-cost, dual-robot radiotherapy system currently being developed at our institution in an effort to improve affordability and adaptability. In this work, we investigated the capability of spatially fractionated radiotherapy (SFRT), a technique known to reduce normal tissue toxicity while preserving therapeutic effectiveness, delivered with KOALA.
Methods: An SFRT workflow was developed for KOALA's 225 kVp x-ray source, including the design and fabrication of angle-specific cutouts and a 3D-printed collimator holder to shape the beam along a defined treatment angle. SFRT was calculated with TOPAS Monte Carlo (MC) in a water phantom, a physical CT-derived canine head phantom for future measurements and a glioma-bearing canine patient. Dose distributions were assessed with radiochromic films placed on top of the collimator as well as within the canine phantom.

Results: Experimental peak-to-valley dose ratio (PVDR) measurements yielded a value of 25.0 ± 0.5 for film positioned on top of the collimator, greatly exceeding the therapeutic threshold of 5 in normal tissue. Simulated SFRT beamlet percent depth doses (PDDs) in the phantom at a depth of 4 cm ranged from 16.4 ± 0.3% to 31.2 ± 0.7% (23.0-40.3% for open beam delivery) with PVDRs ranging from 6.6 ± 0.2 to 4.7 ± 0.4, for collimator-to-skin distances varying from 0 to 10 cm. In the canine phantom, the simulated PVDR at a depth of 4 cm was 12.0 ± 3.0, with a corresponding peak PDD of 16.2 ± 1.5%.
Conclusion: Initial results support the feasibility of SFRT delivery using the KOALA system in a canine model due to the high spatial fractionation capabilities of the kilovoltage x-ray beams and the sufficient PDD at the tumor-relevant depth.

Development of a Beam Model for Monte Carlo Simulation of SBRT

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Introduction: Monte Carlo simulations of radiotherapy require a detailed linac model. Published procedures tune these models to 5x5 cm2 fields or larger which may not yield optimal accuracy for stereotactic body radiotherapy (SBRT) that uses smaller fields. Our objective was to establish whether tuning to a smaller field would yield a more accurate model for SBRT.
Methods: Dose measurements were acquired on the 10 MV FFF beam of an Elekta Agility linac. Simulations were performed using EGSnrc with the BEAMnrc and DOSXYZnrc usercodes. The energy and radial intensity distribution of the electron beam incident on the target were tuned to 5x5 and 2x2 cm2 fields in separate models. Calculated collimator openings were used as well as machine log files from the dose measurement sessions. Simulated and measured dose profiles were compared using gamma index analysis for a range of field sizes.
Results: The tuned electron beam energies were 12.4 MeV and 13.1 MeV, respectively, for the 5x5 and 2x2 cm2 field. Assessing the 2x2 tuned model's agreement with the film measurements gave gamma index pass rates of 88% and higher. The 2x2 tuned output factors for 1x1-5x5 fields deviated by 1-3% from the measured data sets, compared to up to 15% for the 5x5 tuned model which did not use log files. A systematic difference in field size of up to 1.3 mm occurred between measurements and simulations and was resolved by running simulations with the log files.
Conclusion: Our results show that tuning to a 2x2 cm2 field produces a better agreement with measured doses for small fields. Discrepancies between actual vs. planned collimator openings have large dosimetric impacts and log files corresponding to the measurements should be used as inputs for beam tuning. Our next step will be to analyze dosimetric accuracy of our model for patient plans.

Development of a Web-Based Radiation Survey Tool for Storing and Comparing Historical Radiation Levels Around LINAC, CT, and Brachytherapy Units

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Introduction: This project aimed to digitize the Radiation Survey used to collect annual measurements of background and operational radiation levels around LINAC bunkers, CT Sim units, and a brachytherapy unit at the Carlo Fidani Regional Cancer Centre. The primary goal was to create a centralized, web-based tool to streamline data entry, enable visualization, and support historical comparisons of radiation levels.
Methods: A front-end interface was designed to allow users to submit, view, and sort radiation survey entries. The data was stored and managed through QATrack+, an open-source quality assurance (QA) tracking system. The interface enables filtering by unit, submission year, and machine serial number. The survey included both predefined measurement locations and the ability for users to define additional customizable locations. An interactive diagram was incorporated into the interface, visually mapping these measurement locations onto schematics of the treatment units to assist with spatial context and data interpretation. All submitted radiation measurements were automatically converted to a consistent unit of μSv/hr to standardize the data and support reliable comparisons across time and equipment. A custom plotting tool was developed to generate scatter plots for each location, visualizing dose rate and background radiation trends over time and calculating average values. Additional features include dynamic grouping of entries and PDF export of individual survey reports.
Results: The tool enabled the submission and visualization of 11 years' worth of radiation survey data. Scatter plots display historical data and average values, allowing staff to compare current readings to trends and identify anomalies or gradual

changes. The system improved data integrity, reduced transcription errors, and enhanced accessibility. Integration with QATrack+ streamlined QA workflows and supported compliance tracking.
Conclusion: This project improved QA workflows by replacing static records with a centralized, interactive survey tool — enhancing efficiency, accuracy, and long -term usability in clinical radiation safety monitoring.

Optimisation and Validation of an Electron FLASH-RT Treatment Planning Interface Using Monte Carlo Dose Calculation and 3D Printed Heterogenous Mouse Phantom

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Introduction: FLASH radiotherapy (FLASH -RT) is a treatment modality in which radiation is delivered at ultra-high dose rates compared to conventional radiotherapy. This approach has been shown to spare healthy tissues while maintaining tumor control. Robust and reproducible FLASH- RT research is often limited by the lack of accurate dose calculation in preclinical settings. The aim of this work is to implement a treatment planning interface (TPI) for dose calculation of electron FLASH beams using Monte Carlo simulations, and to validate its accuracy through end-to-end testing.
Methods: A dual-nozzle 3D printer was used to print a realistic, heterogeneous mouse phantom adapted to include an alanine pellet and a Gafchromic film. Soft tissues were simulated by ABS, bones by PLA, and lungs by air. The printing settings were optimized to minimize air gaps and maximize the contrast between ABS and PLA on CT scan. A TPI originally designed for kilovoltage radiotherapy was repurposed for FLASH-RT dose calculation. The TPI allows to define beam orientation and field size based on a segmented CT scan and generates an input file for Monte Carlo dose calculation using EGSnrc. Simulation results are then uploaded and analysed for dose prediction in the TPI.
Results: The dose prediction workflow has been validated: the mouse phantom was successfully printed, scanned and uploaded in the TPI, where realistic dose profiles have been produced. ABS and PLA showed a difference of at least 40 HU on CT scan. Dose distributions predicted with Monte Carlo will be compared against the ones measured by the detectors.
Conclusion: Preliminary results show that 3D printing with PLA and ABS is appropriate to simulate arbitrary geometries that are closer to realistic models such as small animals. The TPI has potential to accurately predict dose delivered by FLASH-RT, this will be confirmed by the end of this project.

Lung Lesion Approximation for Improved Treatment Planning of Stereotactic Ablative Radiotherapy in Metastatic Cancer

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Introduction: Stereotactic ablative radiotherapy (SABR) delivers high-dose radiation and can be used to treat multiple lung lesions simultaneously, offering survival benefits for patients with metastatic disease. However, creating a safe and effective multi-lesion treatment plan can be complex and time-consuming, sometimes requiring multiple iterations of prescription selection and plan creation, which can lead to radiation treatment delays. Additionally, radiation oncologists may be uncertain about whether a suitable treatment plan for a patient and therefore request that planning pipeline be undertaken. It may be the case that a patient is ineligible for SABR, and therefore the patient's alternative therapies are delayed. We previously developed an artificial intelligence model for real-time dose prediction in lung SABR, which can potentially reduce planning time. However, the model still requires segmentations of the tumours as input, which are time consuming for radiation oncologists to generate. We hypothesize that sphere approximations of tumours will enable accurate dose predictions, expediting treatment eligibility assessments and dose escalation analysis.
Methods: This study utilizes 125 multi-lesion treatment plans. The artificial intelligence model was trained using 80% of the plans, which included CT scans, an initial dose estimation, and anatomical structure segmentation as inputs, For the remaining 20% of plans, which were used for evaluation, the planning target volumes (PTVs) were replaced with spherical approximations determined by three methods: average centroid distance, maximum centroid distance, and volume-matched radius. The dose predictions using spherical approximations were compared to those using the original PTVs by evaluating

the maximum dose to organs at risk (OARs), mean absolute error (MAE), gamma pass fraction, and percentage of lung volume receiving ≥ 20 Gy (lung V20). Statistical significance was assessed with a two one-sided t-test (TOST).
Results: The maximum dose to OARs, MAE, gamma pass fraction, and lung V20 were highly consistent across all spherical approximation methods and predictions made using true PTVs, and all closely matched the ground truth dose distribution. Non-inferiority was confirmed using TOST.
Conclusion: The strong similarity in dose prediction performance between spherical approximations and PTVs supports streamlining segmentation for patient eligibility assessment.

Quantification of Respiratory-Induced Errors in Stereotactic Ablative Body Radiotherapy for Lung Cancer Using 4D CT Imaging

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Introduction: Currently, stereotactic ablative body radiotherapy (SABR) is standard-of-care for inoperable early-stage lung cancer patients. However, treatments are planned on a static, time-averaged computed tomography (CT) scan, which assumes instantaneous delivery of the radiation that does not account for tumour motion. For treatment deliveries using Volumetric Modulated Arc Therapy (VMAT), the resulting interplay between tumour motion and nonuniform photon fluence can lead to suboptimal dose distributions. This retrospective study quantifies the discrepancies between prescribed dose distributions planned on 3D-CT to actual tumour coverage derived from 4D-CT imaging.
Methods: Eight patients with early-stage non-small cell lung cancer (NSCLC) previously treated with free-breathing SABR were analyzed in this study. An in-house MATLAB script generated six sub-plans corresponding to each phase of the patient's natural breathing cycle. These subplans were used to recalculate phase-specific dose distributions across the full 4D-CT dataset in the treatment planning system Eclipse v15.6 (Varian Medical Systems, Palo Alto, USA), to simulate dose delivery with respiratory motion. The dose distributions were then summed onto the end-inhale and end-exhale CT scans. Dose-Volume Histograms were generated for both original and recalculated plans and evaluated with D95, the minimum dose received by at least 95% of the tumour.
Results: Among the eight patients analyzed, the observed D95 ratio (recalculated D95/original D95) for both end-inhale and end-exhale accumulated dose varied across cases, from 0.86 to 1.08. Notably, two cases exhibited substantial reductions in D95 (≤0.93), suggesting cold spots in tumour coverage, while patients with values over 1.05 indicate areas receiving higher-than-prescribed dose, potentially increasing the risk of tissue toxicity.
Conclusion: The results of this study indicate both potential underdosing and overdosing due to respiratory motion, reflecting interplay effects on dose accumulation using 4D-CT based planning. By incorporating respiratory motion, 4D-CT-based dose analysis can be utilized for quantifying dose discrepancies and enabling more precise evaluation of interplay effects in VMAT SABR treatment planning.

Evaluating the Impact of a 0.5t Magnetic Field on Radiation-Induced DNA Damage Repair in Normal Fibroblasts Using a Biplanar Linac-MR

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Introduction: Image-guided radiotherapy allows to maximize dose to tumour while minimizing dose to surrounding normal tissue and, consequently, treatment side effects. Recently, MR-Linacs (MRI integrated with a linear accelerator) have become clinical, with the ultimate goal of real-time tumour tracking. Using a magnetic field for tumour tracking during radiotherapy introduces a new factor that could impact tissue responses. Our previous findings indicate that the presence of a 0.5T magnetic field on the Alberta Linac-MR, developed at the Cross Cancer Institute, does not significantly alter the DNA damage induced in skin fibroblasts. Next, we determine whether the magnetic field impacts DNA repair kinetics and the tissue response.
Methods: To establish whether the magnetic field of the Alberta Linac-MR could impact DNA damage repair, we build an experimental setup to uniformly expose fibroblast cells to 0T or 0.5T for 3h, while keeping their pH at 7.3 and the temperature at 37ºC. The cells were irradiated with 2Gy at 2cm depth in a solid water phantom. Irradiated cells were fixed at

30-minute intervals up to 180-minutes post-irradiation, then stained by immunocytochemistry for γH2Ax foci, indicators of DNA double-strand breaks (DSBs).
Results: Using a MR-safe incubator, we were able to keep cells in the magnetic field post irradiation. The pH constancy was achieved with a HEPES buffer and the temperature fluctuation was less than 1 °C. A high throughput immunocytochemistry procedure was established that precisely labelled DSBs. A semiautomated protocol was developed for confocal microscopy to analyze large and quantify fluorescent foci in hundreds of cells to derive DSB repair kinetics.
Conclusion: We now have a robust system to measure the repair kinetics of radiation-induced DSBs in fibroblasts irradiated with the Alberta Linac-MR. Next we will compare the repair kinetics in fibroblasts derived from various donors for their influence by the static magnetic field.

Translational Science and Experimental Techniques

Characterizing the Immune and Biochemical Radiation Response in Prostate Cancer via Raman Spectroscopy

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Introduction: Prostate cancer is the most frequent cancer diagnosis and the third leading cause of cancer-related deaths in Canadian men. It is commonly treated with radiation therapy — however, dosage is based solely on previous general population statistics, neglecting the variability between patients. Tumour-infiltrating immune cells have been linked to tumourigenesis, yet are also critical for tumour regression. Understanding the influence of tumour-infiltrating immune cells could enable the optimisation of clinical treatments such as radiotherapy. This study aims to assess the individual-to-individual variation in immune infiltration and identify the corresponding metabolites integral to cellular processes.
Methods: Biopsies taken from patients receiving monotherapy HDR-BT were snap-frozen in OCT medium and sectioned for staining and Raman spectroscopy acquisition. H&E slides are stained first and used to identify malignant and benign regions, from which Raman spectra is taken. One biopsy section contains multiple spectral regions each containing 50-500 spectra. Immunofluorescence is performed in parallel with the previous processes. Pre-conjugated antibodies are used to stain for macrophages, T-cells, and cytotoxic cells.
We aim to collect data from the biopsies of 20 patients, pre- and post-first-fraction HDR-BT. We'll use machine learning techniques to model immune infiltration using Raman spectral data. The Raman spectra are decomposed into 36 scores of metabolites, using group and basis restricted non-negative matrix factorisation. A Random Forest model will be trained to classify spectra into malignant and benign categories, as well as treatment stage (pre- or post-HDR-BT).
Results: Data collection and analysis is in progress. We aim to confirm previous results showing a 2.5x increase in macrophage count and 2x decrease in cytotoxic cells post HDR-BT. Our new dataset will be significantly larger and illustrate changes in malignant and benign subregions following a fraction of HDR-BT.
Conclusion: We aim to demonstrate the immune cell and biochemical changes within intermediate-grade prostate biopsies treated with HDR-BT.

Quantifying Breast Pair Alignment and Skin Subtraction Performance in Differential Microwave Breast Imaging

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Introduction: With one in eight women diagnosed with breast cancer in their lifetime, early screening is essential. Microwave Breast Imaging (MBI) is a non-invasive, low-cost, non-ionizing technique that capitalizes on the dielectric contrast in different breast tissues to detect abnormalities such as tumours. Skin, unfortunately, generates a strong response that masks deeper signals. Differential MBI aims to remove the skin response and enhance abnormality detection by only showing differences between a given breast pair. However, poor breast alignment leaves residual artifacts, hindering the usefulness of differential MBI. This work proposes a metric called Wide Differential Score (WDS) to assess breast alignment and skin response subtraction.
Methods: S 11 data were collected from a pre-clinical bed system. A cylindrical phantom, filled with an adipose tissue mimicking solution, was scanned over a 2-9 GHz bandwidth, with and without a tumour analog. Artificial positioning errors ranging from 1mm to 10mm were introduced to test the impact of poor alignment. For both scans, the maximum responses at all angles were identified, and the earliest extracted. Overlapping regions above a set threshold (e.g. 0.3–0.4 normalized intensity) defined the skin response region. The average intensity of the widest overlapping regions, normalized from 0–1, was reported as the metric.

Results: In well-aligned scans, low scores of 1.99×10^{-4} to 6.78×10^{-4}, consistent with clean subtraction, were obtained. Induced poor alignment yielded linearly increasing scores: WDS gave $R^2 = 0.9495$ and 0.9731 for tumour and non-tumour scans respectively, demonstrating sensitivity to poor alignment and skin artifacts.
Conclusion: WDS scored low for aligned scans and increased linearly with the introduction of poor alignment. This suggests that WDS offers an interpretable and reproducible evaluation of scan alignment and skin subtraction quality in differential MBI. Future research could explore using WDS to compare different differential MBI subtraction techniques.

Cancer Nanotechnology: Use of Gold Nanoparticles as a Better Drug Delivery Vehicle

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Introduction: Free chemotherapeutics have low tumour specificity. Gold nanoparticles (GNPs) have better specificity and can be used as drug carriers, passively accumulating in the tumour from the enhanced permeability and retention effect. Chemotherapeutic drugs can be tagged onto them to for better drug delivery. Our goal is to use GNPs as vehicles to deliver the chemotherapeutic drug paclitaxel (PTX) into tumour cells. Uptake and toxicity of GNP+PTX complex in pancreatic cancer cell line Mia PaCa-2 was evaluated.
Methods: Pancreatic cancer cell line Mia PaCa-2 was used in this study. Based on Transmission Electron Microscopy images, it was found that the diameter of GNPs used was 13.6 nm. The GNP+PTX complex was formed by conjugating a PTX molecule onto a thiolated PEG molecule, allowing for easy conjugation onto the nanoparticle surface. Toxicity of GNP+PTX complexes was measured with an immunofluorescence assay and uptake was evaluated with darkfield microscopy.
Results: High-performance liquid chromatography showed that there were 929 PTX molecules per GNP. The 50 percent inhibition concentration of GNP+PTX complex was 0.0069 ± 0.0007 nM in Mia PaCa-2 cells.
Conclusion: This study shows that GNPs can be used as highly effective drug delivery vehicles. Future work involves reducing the number of PTX molecules on the GNP surface by an order of magnitude to increase the concentration of GNPs usable for experiments. Due to gold's high atomic number, GNPs are being used as radiosensitizing agents. Paclitaxel acts by binding to β- tubulin in microtubules, contributing to microtubule stability and resulting in the spindle that separates the chromosomes to not be formed. Mitotic arrest results, leaving cells in the most radiosensitive stage of the cell cycle: G2-M. We believe this unique combination of GNPs and PTX has potential to achieve better therapeutic outcomes through radiosensitization.

Development of an Optical Tweezers-Based Assay for ECM Viscoelastic Characterization in Decellularized MSC Spheroids

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Introduction: The extracellular matrix (ECM) plays a crucial role in maintaining tissue structure and regulating cell behaviour, making its mechanical characterization essential for advancing regenerative medicine. To isolate and study the mechanical properties of the ECM independently from cells, we are developing an assay combining optical tweezers and microfluidics to measure viscoelasticity of decellularized mesenchymal stromal cell (MSC)-derived spheroids.
Methods: Our optical tweezer employs a 785 nm laser steered by mirrors focused through a high numerical aperture oil-immersion objective to trap 2.1 μm polystyrene beads. Trap stiffness calibration utilizes both the equipartition theorem and power spectral density (PSD) analysis, ensuring precise and validated measurements. To enable precise bead delivery into spheroids with minimal disruption, we built a bespoke microfluidic apparatus where compressed air actuates a pneumatic piston, driving bead suspensions through a micropipette. To synthesize 3D matrix, 35,000 human umbilical cord MSCs were seeded in agarose-coated 96-well plates and incubated for 4 days at 37°C, 5% CO_2, 5% O_2 in xenofree media. Spheroids were decellularized using 20 mM NH_4OH, 0.5% Triton X-100 plus protease inhibitors at 37°C for 30 minutes, followed by DNase I treatment (50 KU) for 30 minutes and stored at 4°C until use.

Results: We have successfully calibrated the optical trap stiffness, established a microfluidics system and optimized protocols to grow and decellularize MSC spheroids. Moving forward, we plan to use these tools to perform microrheological measurements by tracking the thermal fluctuations of trapped beads within the spheroid matrix. This will allow us to extract the complex shear modulus and characterize the viscoelastic properties of the extracellular matrix across relevant frequency ranges.
Conclusion: This assay will enable microscale characterization of 3D ECM scaffolds synthesized by primary human cells, allowing us to map these properties against native human tissues. This provides critical insights into the mechanical microenvironment and offers valuable information for designing endogenous scaffolds and optimizing regenerative therapies.

Development of Colorimetric Analysis Software for 2.2.2-Kryptofix Compliance Testing in ^{18}F-FDG Production

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Introduction: ^{18}F-fluorodexyglucose (^{18}F-FDG) is a glucose analog where the hydroxyl group in the C-2 position is substituted by the cyclotron produced ^{18}F radionuclide. This radiopharmaceutical is used in medical imaging, particularly in positron emission tomography (PET) scans which are crucial in cancer diagnoses and monitoring. The ^{18}F-FDG synthesis involves a nucleophilic substitution that requires 2.2.2-Kryptofix as a phase-transfer catalyst. However, Kryptofix residue quantities must be strictly regulated due to their toxicity. Current quality control processes employ spot testing where sample colors are compared to that of a standard prepared at maximal Kryptofix concertation of 0.5mg/V. This project aims to build a user interface able to determine whether a ^{18}F-FDG sample passes the Kryptofix concentration test through image analysis techniques.
Methods: A Python-based application was developed using the "Tkinter" library to create a graphical user interface, integrated with image processing features. The software employs colorimetric analysis by quantifying pixel intensity and performing statistical comparisons on user-defined cross-sections of the image. Software validation is performed using images with known sample and standard concentrations.
Results: The user-friendly interface aims to limit the subjectivity of human analysis for the determination of 2.2.2-Kryptofix contents in a sample and successfully determines the pass/fail status of the sample regarding regulatory standards of 0.5mg/V. The software generates reports documenting the analytical process required for regulatory compliance and quality assurance documentation which are crucial in a case of a test failure and a deviation situation.
Conclusion: Further improvements can be made to the software, to quantify the Kryptofix concentration in ^{18}F-FDG samples. The basic software architecture has also been adapted and modified to conduct other quality control tests in a radiopharmaceutical laboratory, with promising preliminary testing for bacterial colony counting and environmental monitoring.

Diagnostic Accuracy of Virtual Colonoscopy Compared to Traditional Colonoscopy for Detection of Colorectal Polyps: A Systematic Review and Meta-Analysis

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Introduction: Colorectal cancer is one of the leading causes of cancer-related mortality worldwide, and early detection through screening is critical to improving outcomes. Traditional colonoscopy is the current gold standard for detecting colorectal polyps and cancer, but it is invasive, leading to missed and incomplete appointments. Virtual colonoscopy (CT colonography) has emerged as a less invasive underutilised alternative, its diagnostic accuracy compared to traditional colonoscopy remains uncertain. This systematic review and meta-analysis aims to evaluate the diagnostic accuracy of virtual colonoscopy compared to traditional colonoscopy in asymptomatic adults for detecting colorectal polyps, using a paired study design to generate evidence that can inform future screening practices and clinical guidelines.
Methods: We systematically searched MEDLINE, EMBASE, and CENTRAL from inception to July 2025 for diagnostic accuracy studies involving asymptomatic adults undergoing both CT colonography and traditional colonoscopy. Pairs of reviewers independently screened titles and abstracts to identify eligible studies using pre-specified inclusion criteria. We will extract data on study design, participants, index and reference tests, and 2x2 diagnostic accuracy outcomes. Risk of bias

will be assessed using the QUADAS-2 tool. Meta-analyses will be performed using bivariate random-effects, with subgroup analyses by polyp size. This review was registered prospectively on PROSPERO (CRD420251110940).
Results: Title and abstract screening identified over 170 potentially eligible studies for full-text review, expanding substantially on the limited number of studies previously available in this field.
Conclusion: This ongoing comprehensive systematic review and meta-analysis will synthesize the available evidence comparing virtual and traditional colonoscopy for colorectal polyp detection. By incorporating newly identified studies and analyzing diagnostic accuracy, this review aims to inform clinical practice and screening policies.

Conflicts of Interest
The authors declare that they have no conflict of interest.

Authors' Contributions
ROL: Co-Chair for the 2025 CUMPC organizing committee, drafted the conference abstract booklet, and gave final approval of the published document.
GL: Co-Chair for the 2025 CUMPC organizing committee, drafted the conference abstract booklet, and gave final approval of the published document.

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