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Exposure to Clinical Medical Physics Research at an Academic Radiation Oncology Department Through an Undergraduate Lens

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INTRODUCTION

- As a third-year undergraduate biology major with an interest in mathematics and engineering, I sought to bridge these fields to guide me toward biomedical engineering graduate school. I began supplementing my degree with engineering coursework while also seeking a research opportunity where biology and engineering intersect.
- I learned of a multidisciplinary opportunity in medical physics through an outreach initiative led by a medical physicist in the radiation oncology department at The University of Kansas Cancer Center. I contacted her, was introduced to the clinical environment, and, after demonstrating interest in her research project, was sponsored for the institution's research-focused educational experience fellowship
- The project examined gynecologic brachytherapy plans, comparing the tandem's distance to the nearest organ at risk (ROAR) against its distance to the furthest edge of the HRCTV (Rmax) at each dwell position, a geometric signal intended to flag when an interstitial needle may be needed. My role was to build and validate the code that extracted and computed the geometry from the treatment plans.

METHODS AND MATERIALS

- After completing HIPAA and Human Subjects Protection training, I was oriented to gynecologic brachytherapy and DICOM fundamentals through materials from my mentor, then trained to navigate the Oncentra Brachytherapy Planning System (Elekta, Veenendaal, Netherlands).

DICOM dataset extraction:
- Each patient's case was then de-identified and assigned a unique code so that all subsequent analysis worked from anonymized data.

Geometric analysis:
- I built a Python code to extract and compute the geometric features directly from the exported DICOM datasets. Using the Pydicom and NumPy libraries, I extracted the 3D dwell positions from the tandem and the contours of the HRCTV and OARs.
- Contour points were paired to each dwell position using a slice-matching tolerance, a threshold on the z-axis defining which points counted as lying on the same slice.

Synthetic control point injection:
- To increase sampling resolution, I built a separate code that interpolated synthetic midpoints between consecutive control points in the DICOM- RT plan file and wrote the combined sequence back into a copy of the plan.
- To preserve the plan's metadata, each synthetic midpoint was cloned from an existing control point.

RESULTS

- The analysis was applied across ≥90 patients, extracting dwell positions and contour geometry from each plan.
- The code computed Euclidean distance to generate geometric features characterizing the spatial relationships of the tumor HRCTV and OARs relative to the tandem. Patient-specific results were then exported to Excel for further analysis.
- Iterative verification against 3D Slicer confirmed that the computed geometry matched the true geometry.
- My work on this project has contributed to the submission of three abstracts to national scientific meetings.

Patient Cipher	Slice (mm)	Rmax (mm)	ROAR (mm)	Closest OAR	Rbladder	Rrectum	Rsigmoid	Rsmb	RLb
002FX1D-SCP	248.93	15.93	23.62	Small bowel	N/A	47.84	28.60	23.62	N/A
002FX1D-SCP	246.46	18.38	14.08	Small bowel	N/A	51.39	27.15	14.08	N/A
002FX1D-SCP	244.00	20.97	12.37	Small bowel	N/A	54.23	24.67	12.37	28.84
002FX1D-SCP	241.54	22.19	12.64	Small bowel	N/A	55.31	24.51	12.64	28.43
002FX1D-SCP	239.08	29.18	14.74	Small bowel	N/A	56.99	27.32	14.74	26.82
002FX1D-SCP	236.62	28.79	15.11	Small bowel	N/A	57.74	27.15	15.11	27.06
002FX1D-SCP	234.15	33.14	16.38	Small bowel	N/A	59.21	27.77	16.38	28.26
002FX1D-SCP	231.69	33.12	17.37	Small bowel	N/A	60.94	29.09	17.37	28.20
002FX1D-SCP	229.23	33.43	19.09	Small bowel	N/A	60.32	N/A	19.09	28.40
002FX1D-SCP	226.76	34.24	19.51	Small bowel	N/A	59.06	N/A	19.51	29.24
002FX1D-SCP	224.30	35.77	22.07	Small bowel	N/A	39.78	N/A	22.07	30.31
002FX1D-SCP	221.83	37.08	19.94	Small bowel	N/A	39.33	N/A	19.94	33.70
002FX1D-SCP	219.37	39.47	20.30	Small bowel	N/A	37.15	N/A	20.30	32.36
002FX1D-SCP	216.91	39.27	19.09	Bladder	19.09	34.44	N/A	31.59	33.17
002FX1D-SCP	214.44	36.40	19.93	Bladder	19.93	33.98	N/A	37.11	34.07
002FX1D-SCP	211.97	36.65	20.19	Bladder	20.19	33.95	N/A	39.79	34.33
002FX1D-SCP	209.50	39.20	18.62	Bladder	18.62	28.94	N/A	N/A	37.84
002FX1D-SCP	207.02	39.03	18.83	Bladder	18.83	28.39	N/A	N/A	39.26
002FX1D-SCP	204.54	34.80	18.73	Bladder	18.73	25.36	N/A	N/A	45.65
002FX1D-SCP	202.06	33.80	20.07	Bladder	20.07	24.44	N/A	N/A	N/A
002FX1D-SCP	199.58	33.76	18.19	Bladder	18.19	24.26	N/A	N/A	N/A

Table 1. Representative structure of the per-slice geometric output generated for each plan.

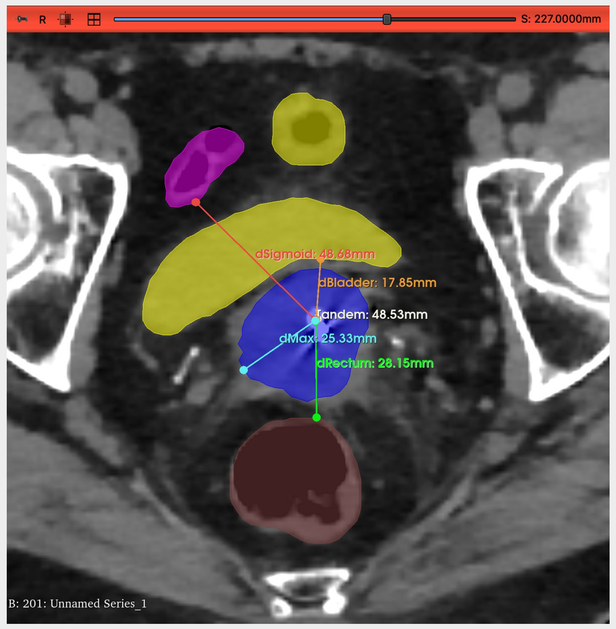

Figure 1. Euclidean distances from Tandem to the closest surface point of each OAR and the furthest edge of HRCTV.

DISCUSSION

The KEE program mentor (medical physicist) provided educational materials to familiarize me with brachytherapy and DICOM fundamentals and trained me to navigate the Oncentra TPS.

I subsequently applied my Python knowledge to extract the required datasets. Accurate handling of patient data proved challenging and required troubleshooting. Although the learning curve led to occasional errors, my mentor fostered open communication, enabling issues to be identified and resolved efficiently.

Regular research meetings between the collaborators; the mentor and the radiation oncologist supported this process by providing structured opportunities to review progress and plan next steps and enhanced my understanding of radiotherapy and its clinical applications.

The successfully extracted data from (≥90) patients and the geometric features analyses generated through this valuable experience earned the team three accepted abstracts to the two biggest national scientific meetings in the field of Radiation Therapy: The American Association of Physicists in Medicine (AAPM) annual conference and the American Society of Radiation Oncology (ASTRO) annual meeting.

CONCLUSIONS

- The most valuable part of this experience was learning how to sharpen my research approach. Early versions of the code ran smoothly but inaccurately computed the geometry, and to catch these errors, I had to learn to always question my assumptions and validate my data at every step.
- Regular research meetings with my mentor and the radiation oncologist helped me build a clearer understanding of how the treatment plan files are organized and how the underlying geometry is stored in the data. This understanding allowed me to trace problems in the code faster over time and improve the accuracy of the analysis.
- Being also introduced to Radiobiology has opened my mind to possibilities of diverse career pathways through consultation with the department radiobiology professor which solidified my interest in a career integrates biomedical engineering with radiation oncology.

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