# Dosimetric Impact of Using Machine Learning-Predicted Hybrid Interstitial Needle Arrangements for High-Dose-Rate Cervical Brachytherapy


Kailyn Stenhouse[1,2], Michael Roumeliotis[3], Kevin Martell[4], Robyn Banerjee[4], Tien Phan[4], Corinne Doll[4], Philip Ciunkiewicz5, Svetlana Yanushkevich[6], Sarah Quirk[7], Philip McGeachy[1,2,4]

[1] University of Calgary / Department of Physics and Astronomy, Calgary, AB.
[2] Tom Baker Cancer Centre / Division of Medical Physics, Calgary, AB.
[3] Johns Hopkins University / Department of Radiation Oncology and Molecular Radiation Sciences, Baltimore, MD.
[4] University of Calgary / Department of Oncology, Calgary, AB.
[5] University of Calgary / Department of Biomedical Engineering, Calgary, AB.
[6] University of Calgary / Department of Electrical and Software Engineering, Calgary, AB.
[7] Brigham and Women's Hospital / Department of Radiation Oncology, Boston, MA.


## Impact / Innovation

- High-dose-rate brachytherapy (**HDR-BT**) using hybrid interstitial (**IC/IS**) applicators is crucial for cervical cancer patients with large/irregular tumours
- Needle arrangement impacts organ-at-risk and tumour dose, correlated with toxicity and local recurrence[1,2]
- Needle selection is complex, relying on physician expertise,[3] highlighting the need for **predictive models**

**Goal** – Quantify the **dosimetric impact of machine learning predicted needle arrangements** to assess clinical benefits of model in a prospective study

## Materials & Methods

### *Patient Cohort*

- 10 cervical cancer patients receiving HDR-BT (December 2020 – October 2022)
- Treated using intracavitary (**IC**) or hybrid interstitial (**IC/IS**) ring or semi-lunar ovoid applicators – Vienna or Venezia (**Figure 1**)

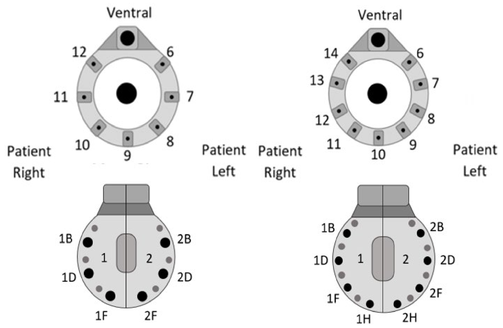


**Figure 1.** Needle positions for 26 mm (top left) and 30/34 mm (top right) Vienna applicator and the 22 mm (bottom left) and 26/30 mm (bottom right) Venezia applicator

### *Machine Learning (ML) Prediction*

- Model predicts IC or IC/IS implant based on target volume geometry (**HR-CTV**)
- Arrangement of needles predicted for IC/IS cases
- Performance metrics compare ML predictions to clinical treatment plan needles

### *Dosimetric Assessment*

- Dosimetric differences between ML-predicted and clinical needle arrangements assessed for three treatment fractions
- Target coverage matched to clinical plan, differences in organs-at-risk doses assessed

## Results

### *Patient Cohort*

- 5 of the 10 patients had ML-predicted IC/IS applicator, in agreement with treatment applicator
- These were eligible for replanning to compare needle arrangement dosimetry

### *Machine Learning Performance (Table 1)*

- Average agreement between ML-predicted and clinical needles ~80% for all metrics
- 40% of patients had **full agreement** between ML-predicted and clinical needles

| Performance Metric | Patient 1 | Patient 2 | Patient 3 | Patient 4 | Patient 5 | Average |
|---|---|---|---|---|---|---|
| Accuracy | 66.7% | 100% | 57.1% | 87.5% | 100% | **82.3%** |
| Balanced Accuracy | 66.7% | 100% | 58.3% | 87.5% | 100% | **82.5%** |
| Precision | 80.0% | 100% | 66.7% | 80.0% | 100% | **85.3%** |
| Recall (Sensitivity) | 66.7% | 100% | 50.0% | 100% | 100% | **83.3%** |
| Specificity | 66.7% | 100% | 66.7% | 75.0% | 100% | **81.7%** |

**Table 1.** Performance metrics for machine learning model needle arrangement prediction compared to clinical needle arrangement

| Patient # | Bladder D2cc (cGy) | | Rectum D2cc (cGy) | | Sigmoid D2cc (cGy) | | Bowel D2cc (cGy) | |
|---|---|---|---|---|---|---|---|---|
| | Fx 1 | Fx 2 & 3 | Fx 1 | Fx 2 & 3 | Fx 1 | Fx 2 & 3 | Fx 1 | Fx 2 & 3 |
| 1 | -48.0 | -17.4 | -51.4 | -8.0 | -94.1 | -9.8 | -88.1 | -48.0 |
| 2 | 4.7 | 7.0 | -4.0 | 3.8 | -43.3 | 4.1 | -6.4 | 4.7 |
| 3 | -95.4 | -12.5 | -62.3 | 8.4 | -55.3 | 9.5 | -9.7 | -95.4 |
| 4 | -10.6 | -4.0 | 19.5 | -2.6 | -0.6 | 2.9 | -0.1 | -10.6 |
| 5 | -53.3 | -28.5 | -31.3 | 4.1 | -6.1 | 1.9 | -12.6 | -53.3 |
| **Average** | **-40.5** | **-11.1** | **-25.9** | **1.1** | **-39.9** | **1.7** | **-23.4** | **-40.5** |

**Table 2.** Differences between ML-predicted needle replan and the clinical plan dosimetry. A negative value (shown in green) indicates a **reduction** and a positive value (shown in red) indicates an **increase** in organ-at-risk doses when using the ML-predicted needles.

### *Dosimetric Comparison (Table 2)*

- Dosimetric differences between ML and clinical plans were most significant for **first fraction**
- Largest changes occurred when:
  1. Needles not used clinically until the second and third fractions
  2. Fewer needles were used for the first fraction
- Using the ML-predicted needles resulted in average organ-at-risk doses **improving**
- Factors impacting dosimetry, from most to least important appear to be:
  1. Use of hybrid interstitial needles
  2. Number of needles used
  3. Arrangement of needles

## Conclusions

- ML-predicted needle arrangements have **greatest dosimetric improvement for first fraction**
- For the following fractions, differences between the ML-predicted and clinical needle arrangements had minimal impact on plan quality, leading to **comparable plans**
- Further work assessing model performance across a large cohort of patients in a multi-centre setting is required

**The presented machine learning-based decision support tool shows strong predictive capabilities in a prospective setting, supporting the utility of such a model in a clinical setting.**


**References**

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**EMAIL:** kjstenho@ucalgary.ca