Early Prediction of Peg Feeding Tube Placement In Head and Neck Cancer Using Dosiomic Features: Beyond Clinical Factors

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ABSTRACT

Purpose: Patients with head and neck (H&N) cancer frequently require percutaneous endoscopic gastrostomy (PEG) tube placement to maintain adequate nutrition during treatment. Current PEG placement decisions are primarily based on patient-specific clinical factors, although dosiomic features derived from radiation dose distributions may provide additional predictive value. This study aims to develop a predictive model for PEG tube placement by integrating dosiomic and clinical features.

Methods: We developed a novel Physics-informed Neural-Network (PNN) decision-making tool considering clinical and dosiomic features from 65 H&N patients who received radiation therapy dose ranging from 60-70Gy in 33-35 fractions. Thirty-two patients underwent PEG tube placement reactively. We incorporated 13 impactful clinical features: Age, Performance status, Weight loss at first OTV, Weight loss at last OTV, Tumor (T-stage), Neck Involvement, Level1 to Level5 (index), Bi-neck (index),Pre-treatment Dysphagia. Additionally, we extracted six dosiomic features from dose-volume histograms: Mean doses to oropharynx, Hypopharynx, Oral Cavity, Cervical Esophagus, Pharyngeal Constrictor, and Parotid Gland combined.

Results: Designed PNN model was evaluated using clinical features, dosiomic features, and their combination. Model based on clinical features alone achieved mean AUC of 0.70±0.02. Incorporation of dosiomic features improved discriminatory performance (mean AUC = 0.75±0.15). Importantly, the combined clinical-dosiomic model demonstrated the highest performance, with mean AUC of 0.78±0.09,sensitivity of 0.85±0.18, and specificity of 0.72±0.22. Results indicate that integrating dosiomic features with routinely available clinical data provides a measurable improvement in predictive performance, yielding a 4-11% increase in AUC compared with models using individual feature groups.

Conclusion: This study demonstrates the added value of dosiomic features in the development of a decision-support tool for PEG tube placement. The integration of dosiomic information with clinical data has the potential to improve patient-specific risk stratification. Nevertheless, further validation using large, multicenter cohorts is required to confirm the robustness and generalizability of the proposed approach.

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INTRODUCTION

- Head and neck cancer patients frequently experience dysphagia, odynophagia followed by the curative treatment [1].
- Mucositis typically takes weeks to months to heal after completion of therapy.
- Percutaneous Endoscopic Gastrostomy (PEG) tubes provide adequate nutrition for patients at high risk of inadequate oral intake [2].
- Current PEG placement decisions are primarily based on patient-specific clinical factors.

Aim: This study developed a Physics-informed Neural Network (PNN) model for predicting PEG tube placement by integrating dosiomic and clinical features.

METHODS AND MATERIALS

- **Data cohort →** Study includes 65 Head and Neck patients treated at SUNY Upstate Cance Centre (as presented in Table 1).
- **Prediction Model →** A novel Physics-informed Neural Network (PNN) architecture (as shown in Fig. 1).
  - Model incorporates the physics-based mean square error residual loss function ($L_{Physics-informed}$) and the binary cross entropy objective function ($L_{Binary-cross-entropy}$)

$$L_{Binary-cross-entropy} = -\frac{1}{N}\left(t_i \log(y_i) + (1-t_i)\log(1-y_i)\right)$$

$$L_{Physics-informed} = \frac{1}{N}\sum_{i=1}^{N}\left(y_i - y_i^{physics}\right)^2$$

$$y_i^{physics} = \sin\left(\sum_{j=1}^{n} x_{ij}\right) + \sqrt{\frac{1}{n}\sum_{j=1}^{n}|x_{ij}|}$$

t_i → target of i^{th} sample; y_i → output of i^{th} sample; N → total number of samples; x → input feature array; n →number of features

- **Input Features →**
  - **Thirteen impactful clinical features:** Age, Performance status, Weight loss at first OTV, Weight loss at last OTV, Tumor (T-stage), Neck Involvement, Level1 to Level5 (index), Bi-neck (index),Pre-treatment Dysphagia.
  - **Six dosiomic features from dose-volume histograms:** Mean doses to oropharynx, Hypopharynx, Oral Cavity, Cervical Esophagus, Pharyngeal Constrictor, and Parotid Gland combined.

RESULTS

- Patients received radiation therapy with prescription dose ranging from 60-70 Gy in 33-35 fractions.
- Among 65 patients, 32 patients underwent PEG tube placement reactively.
- The designed PNN model with clinical features achieved a mean AUC of 0.70 (±0.02), whereas the model with adding dosiomic inputs exhibited improved performance, as mean AUC of 0.75 (±0.15).
- Models with individual features exhibited lower specificity, indicating diminished ability to correctly predict both classes (as shown in Fig. 2).
- The designed PNN-model with clinical and dosiomic features demonstrated an improved performance with the increment of up to 11% in AUC, 16% in specificity, and 7% in weighted avg F1-score.

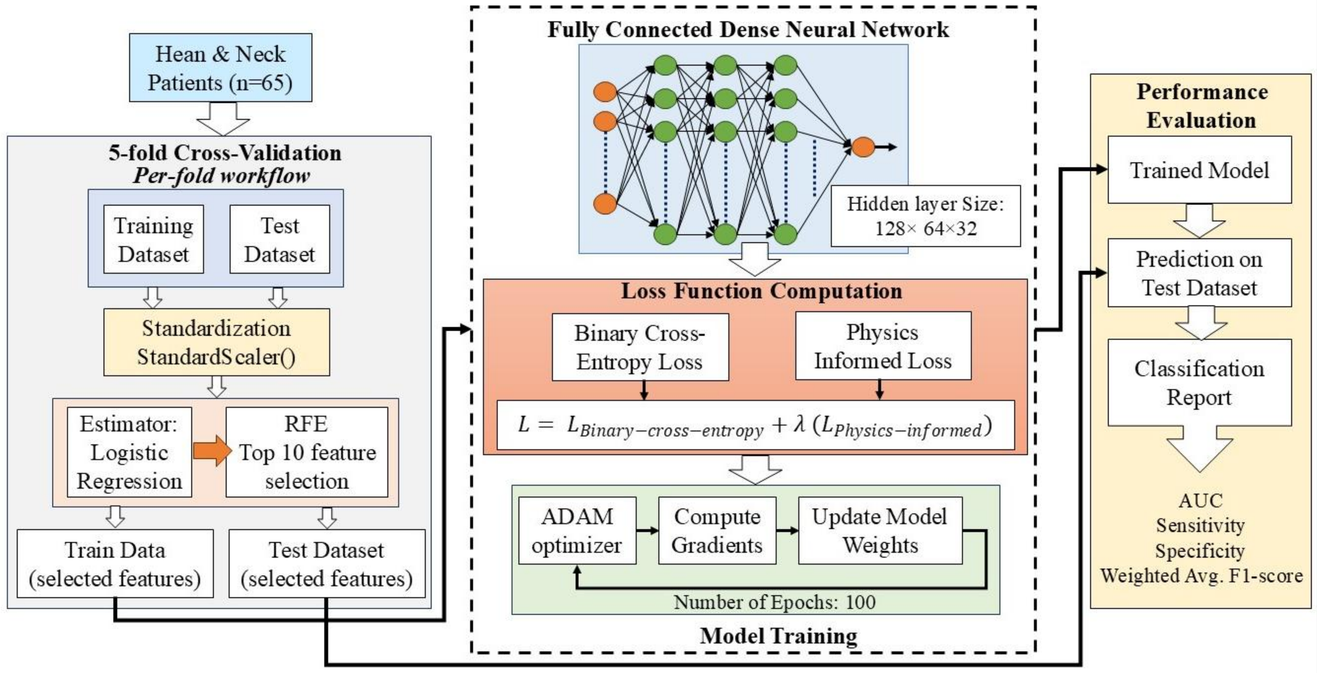

Figure 1: The proposed PNN-based PEG feeding tube prediction model for Head & Neck cancer patients.

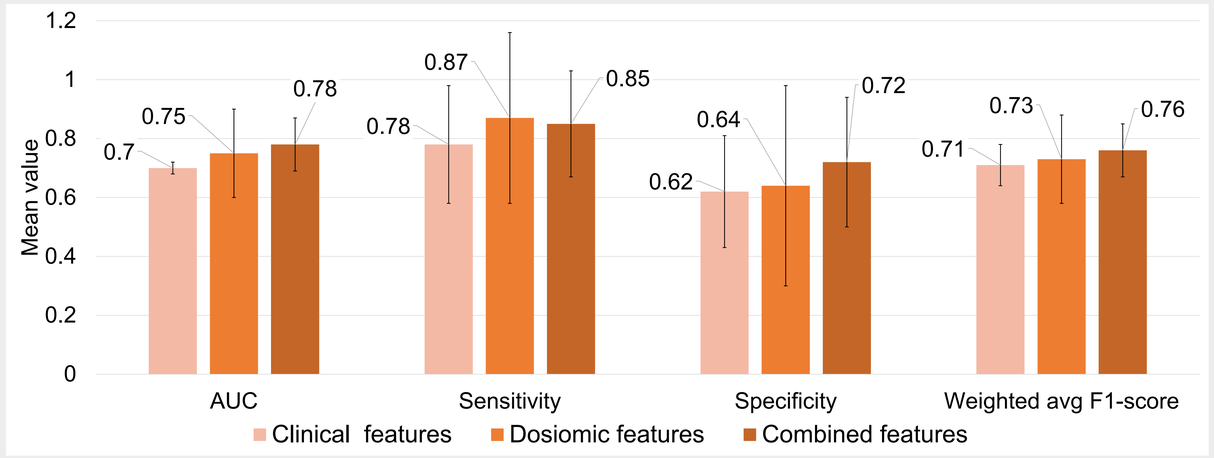

Figure 2: The performance analysis of PNN-based PEG feeding tube prediction models.

Table 1: Clinical and dosiomic features of 65 head and neck cancer patients.

Feature Group	Feature Variables	Median (range) or (%)
Clinical Features	Age @ Consult	65 (42-93)
	Weight Loss at First OTV	0.41 (-13.51-11.79)
	Weight Loss at Last OTV	7.8 (-13.51-27.9)
	Performance Status	0 (55.4%), 1 (30.8%), 2 (7.7%), 3(4.6%), 4 (1.5%)
	Tumor T-stage	T0 (1.5%), T1 (24.6%), T2 (30.8%), T3 (23.1%), T4 (20%)
	Neck Involvement Overall	Yes(72.3%), No (27.7%)
	Neck Involvement Level 1	Yes(9.2%), No (90.8%)
	Neck Involvement Level 2	Yes(61.5%), No (38.5%)
	Neck Involvement Level 3	Yes(23.1%), No (76.9%)
	Neck Involvement Level 4	Yes(9.2%), No (90.8%)
	Neck Involvement Level 5	Yes(6.2%), No (93.8%)
	Bilateral Neck Treated	Yes(81.5%), No (18.5%)
	Pre-Treatment Dysphagia	Yes(27.7%), No (72.3%)
Dosiomic Features	Mean Dose to Oral Cavity (cGy)	4518.5 (41.8-7425.4)
	Mean Dose to Oropharynx (cGy)	5666.5 (910.2-6888.4)
	Mean Dose to Pharyngeal Constrictor (cGy)	5285.1 (1684.6-6552.6)
	Mean Dose to Hypopharynx (cGy)	4679 (119-7100.6)
	Mean Dose to Parotid Gland (cGy)	2713 (74.7-4814.8)
	Mean Dose to Cervical Esophagus (cGy)	2786.3 (23.8-5343.8)

CONCLUSIONS

- This study underscores the impact of dosiomic features in developing a decision-making tool for PEG tube placement.
- The integration of dosiomic with clinical information can improve patient-specific risk stratification by providing complementary predictive information.
- The proposed PNN model may facilitate early detection of patients requiring PEG support, enabling individualized treatment and improved supportive care.
- **Future study:** Validation using large, multicenter cohorts is required to confirm the robustness and generalizability of the proposed approach.

REFERENCES

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2. M. Wei, E. Ho, and P. Hegde, An overview of percutaneous endoscopic gastrostomy tube placement in the intensive care unit. *J. Thorac. Dis.*, 2021;13(8):5277-5296.