Enhancing Non-Small-Cell Lung Cancer Patients' Urgent Care Visit Prediction after Combined Modality Therapy with Patient-Reported Outcome and Wearable Sensor Data

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ABSTRACT

Purpose: Previous studies in predicting the risk of urgent care visits for non-small-cell lung cancer (NSCLC) patients receiving combined modality therapy (CMT) have generally focused on pre-treatment risk factors. Our study aimed to develop a risk prediction model with patient-reported outcome (PRO) data and wearable sensor data.

Methods: Participants included 58 patients with NSCLC treated with CMT at Moffitt Cancer Center. We collected demographic, clinical, and PROs (PROMIS-57) data before starting CMT and abstracted data on usage of urgent care within 60 days after starting CMT. We also collected wearable sensor data from Fitbit activity trackers during this 60-day period. The follow-up period was split into two 30-day periods. For clinical variables, we included the most extreme value within each 30-day period but before the first urgent care visit. For PROs, changes since baseline but before the first urgent care visit were included. First, we generated a Bayesian network (BN) predicting risk of urgent care visit using only demographic and clinical data available before starting CMT and a second BN including these data during-CMT. Next, we generated an enhanced pre-treatment BN that added pre-CMT PRO data. Lastly, we created an enhanced during-treatment BN that added wearable sensor and clinical data assessed during-CMT. Cross-validation and area under the receiver operating characteristic (AU-ROC) curve were used to evaluate the predictive performance of each BN.

Results: Participants were mostly female (57%), White (88%), and non-Hispanic (95%) with average age 69 years (range = 35-89). The enhanced pre- and during-treatment BNs significantly outperformed the BNs with only on pre-CMT ($p < 0.001$) and during-CMT ($p = 0.002$) clinical and demographic data respectively.

Conclusion: Wearable sensor and PRO data before and during CMT can significantly improve prediction of NSCLC patents' urgent care visit. Future studies should aim to validate this model in independent and external datasets.

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INTRODUCTION

Patients receiving **combined modality therapy** (CMT) for **non-small cell lung cancer** (NSCLC) are at high risk of toxicities that can lead to unplanned healthcare use, including **urgent care** (UC) **visits**. Patient toxicities are historically under-detected, and the field of predicting emergent toxicities at the patient-level remains nascent. Improved detection, prediction, and prevention of toxicities could improve patient outcomes and reduce healthcare system burden. Patient-generated health data (PGHD), such as patient-reported outcomes (PROs) and wearable sensor data (WSD), may offer important insights.

Innovation/Impact: Patients receiving CMT for NSCLC experience high rates of toxicities with a significant impact on patient outcomes. The innovation of this study is

- Test the importance of collecting PRO data and WSD in addition to clinical data in predicting healthcare utilization, specifically UC visits via Bayesian networks (BN) approach.
- Underscore the importance of integrating multidimensional data sources to enhance predictive modeling capabilities and refine risk stratification strategies.
- Emphasize the potential of the explainable machine learning approach to substantially improve patient outcomes and enhance the quality of cancer care delivery.

METHODS AND MATERIALS

Patients were recruited at **Moffitt Cancer Center** (MCC) and enrolled from March 2021 to March 2022. The study protocol was approved by MCC's Institutional Review Board (Pro00048158). Eligible patients were:

1) ≥18 years old;
2) expected to begin CMT (i.e., chemotherapy, immunotherapy, and/or targeted therapy) for NSCLC;
3) within Eastern Cooperative Oncology Group (ECOG) performance status scores of 0–2;
4) without severe, untreated neurological, psychiatric, or physical limitations precluding participation;
5) able to provide informed consent. No participation incentives were provided.

Participants were enrolled within seven days of initiating CMT (pre-CMT) and monitored for 60 days after starting CMT (during-CMT) while wearing a Fitbit device to collect WSD (i.e., daily physical activity, sleep patterns, heart rate). At pre-CMT and 60-day follow-up, participants completed the Patient-Reported Outcomes Measurement Information System 57-item Profile (PROMIS-57 v2.1) measuring quality of life and well-being (i.e., depression, anxiety, physical function, pain interference, fatigue, sleep disturbance) and global pain intensity. MCC's Collaborative Data Services Core abstracted medical record data, including demographic and clinical variables (e.g., albumin, calcium) and UC utilization. Changes in albumin, calcium, and WSD from pre-CMT to an instance of UC visit were calculated. **Table 1** details measures of demographic, clinical, PRO, and WSD pre- and during-CMT.

Table 1. Available features of NSCLC patients before and during CMT in the training dataset

	Pre-CMT	During-CMT
Demographic and Clinical Data	Age, sex, marital status, area deprivation index (ADI)-national percentile of block group, ADI-state-specific decile of block group, height, weight, body mass index (BMI), cancer stage, adenocarcinoma, squamous cell carcinoma, large cell carcinoma, albumin, calcium, Eastern Cooperative Oncology Group (ECOG) and Karnofsky performance status	Chemotherapy, radiotherapy, immunotherapy, targeted therapy, weight, weight loss (most dramatic), albumin, calcium, ECOG and Karnofsky performance status
PROs or WSD	PROs: PROMIS-57 scores, including global pain raw score (0-10) and PROMIS T Scores (0-100) for Physical Function, Anxiety, Depression, Fatigue, Sleep Disturbance, Social Roles, and Pain Inference	WSD: Change in Fitbit-measured steps, resting heart rate, active calories, active minutes, sedentary minutes, total time in bed, total time asleep, sleep efficiency

RESULTS

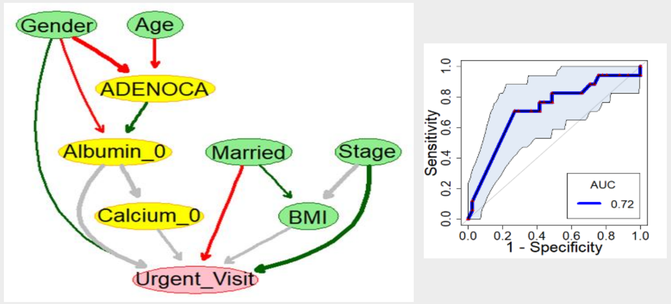

Figure 1. Pre-CMT UC visits predictive model without PRO data and its performance.

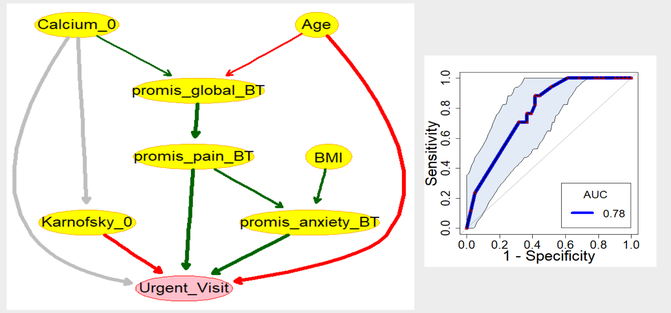

Figure 2. Pre-CMT UC visits predictive model with PRO data and its performance.

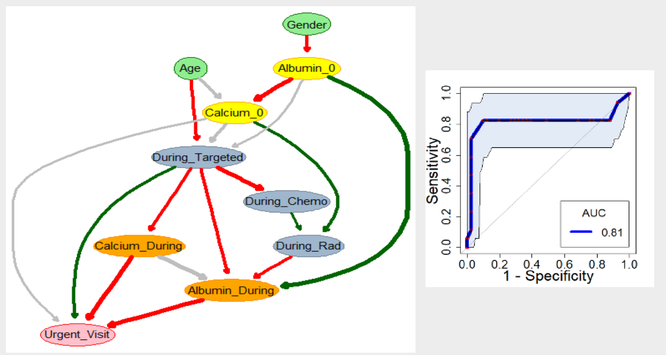

Figure 3. During-CMT UC visits predictive model without WSD data and its performance.

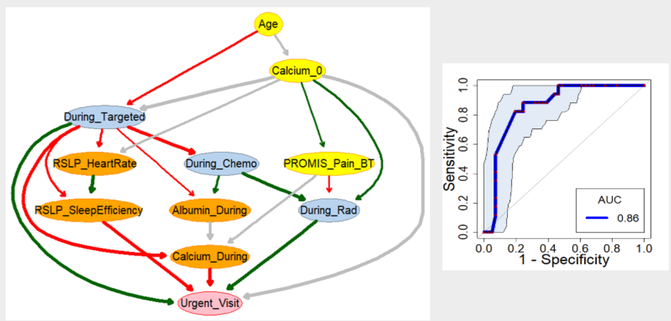

Figure 4. During-CMT UC visits predictive model with WSD data and its performance.

The BN shown in **Figure 1** used only demographic and clinical data at pre-CMT – age, sex, marital status, cancer stage, body mass index (BMI), adenocarcinoma diagnosis (ADENOCA) (yes/no), albumin, and calcium – with an AUC predictive performance of 72% (95% CI: 0.57-0.80). In the BN, green or red arcs between two nodes denote positive or negative monotonic associations, while gray arcs indicate mixed or non-monotonic associations. The BN shown in **Figure 2** incorporated pre-CMT PRO data and included age, BMI, Karnofsky performance status, PROMIS Global Pain, and PROMIS Pain Interference with a predictive performance of 78% (95% CI: 0.66-0.88).

The BN shown in **Figure 3** incorporated during-CMT demographic and clinical data and included age, sex, pre-CMT albumin, pre-CMT calcium, albumin and calcium changes from pre-CMT to UC visit, and receipt of targeted therapy, chemotherapy, and/or radiation therapy with a predictive performance of 81% (95% CI: 0.63-0.89). The BN shown in **Figure 4** incorporated during-CMT clinical data and WSD and had a predictive performance of 86% (95% CI: 0.76-0.95). DeLong's tests revealed that the enhanced BNs for pre-CMT (Figure 2) and during-CMT (Figure 4) significantly outperformed the BNs for pre-CMT (Figure 1) ($p = 0.002$) and during-CMT (Figure 3) ($p < 0.001$), respectively.

DISCUSSION

Multidimensional data sources, including demographic, clinical, PRO, and WSD can enhance ML predictive models to elucidate complex, interactive factors influencing healthcare utilization during the first 60 days of CMT. Use of explainable ML to predict and prevent treatment toxicities and healthcare utilization could improve patient outcomes and enhance the quality of cancer care delivery.

CONCLUSIONS

Study findings support the utility of BN models that incorporate PGHD (i.e., PRO, WSD) with demographic and clinical data for predicting UC visits among NSCLC patients undergoing CMT. Our models show promising predictive performance and provide critical insights into the complex interplay of factors influencing healthcare utilization during the first 60 days of CMT for NSCLC. Initial models trained solely on demographic and clinical data demonstrated moderate predictive accuracy for UC visits. Subsequent incorporation of PROs and WSD yielded enhanced models with significantly improved performance.

Published Paper

Gonzalez BD, et.al., Using Bayesian Networks to Predict Urgent Care Visits in Patients Receiving Systemic Therapy for Non-Small Cell Lung Cancer. JCO Clin Cancer Inform. 2025 Sep;9:e2400315. doi: 10.1200/CCI-24-00315.

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