ORIGINAL ARTICLE

Financial risk and decision-making strategies for lung cancer: insights from Northern Thailand

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ABSTRACT

Lung cancer remains a significant health issue in Northern Thailand, driven by socio-economic factors and environmental pollutants that negatively impact patient outcomes. This study explores the relationship between financial risk, treatment accessibility, and survival rates among lung cancer patients. A total of 290 patients were analyzed concerning their demographics, treatment methods, financial burdens, and outcomes. Utilizing logistic regression and decision curve analysis, a prediction model for financial burden risk was developed, achieving an accuracy of 85.42%, with a sensitivity of 81.82%, and a specificity of 77.97%. Key factors contributing to financial toxicity included irregular income, prior financial difficulties, and inadequate reserve funds. Recommendations for managing patients based on financial risk categories are provided. Low-risk patients can benefit from financial counseling, affordable treatment options, and regular evaluations to mitigate unexpected expenses. Those classified as intermediate risk require timely financial planning, access to support services, and the optimization of healthcare coverage. High-risk patients should receive intensive encouragement through financial assistance programs, multidisciplinary care teams, and palliative care options to alleviate economic stress. The findings highlight the necessity for improved financial assistance policies and integrated care strategies that address financial security, promote environmental wellness, and foster community support, ultimately enhancing treatment adherence and patient outcomes.

Keywords:
financial toxicity, healthcare costs, lung cancer, Northern Thailand, prediction model

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INTRODUCTION

Lung cancer poses a persistent and growing health challenge in Thailand, with a rising number of cases documented over the past two decades. In 2021, lung cancer accounted for 17.9% of all cancer-related deaths in Thailand, highlighting its significant impact on public health [1-4]. This trend is reflected in the increasing incidence rates observed between 2012 and 2022 [1]. While national data provides a crucial overview, regional variations within Thailand are also important to consider. Early research indicated that Northern Thailand, specifically Chiang Mai Province, had some of the highest lung cancer incidence rates in Asia, with an age-adjusted rate of 37.4 per 100,000 women as early as 1999 [5]. This older data, while not the most recent, underscores the long-standing nature of the lung cancer challenge in the region. More recent national data confirm the increasing trend of lung cancer in Thailand, though specific regional data for Northern Thailand is less readily available.[1]

Established risk factors such as smoking remain a significant contributor to lung cancer incidence. However, in Northern Thailand, the interplay of multiple factors may be particularly relevant. Research from the late 1990s suggested that, in addition to smoking, chronic benign respiratory diseases, potentially associated with fungal infections, could play a role in the high incidence of lung cancer among women in the region.[1, 5-8] Furthermore, radon exposure, especially in upper-northern Thailand, has been identified as a significant risk factor, contributing substantially to lung cancer incidence and mortality.[1, 9] Air pollution, particularly PM2.5, is also recognized as a contributing factor to lung cancer development in Thailand, mirroring global trends.[1, 6, 7, 10]

Previous research has explored the impact of lung cancer on patients' lives, often focusing on clinical outcomes and treatment efficacy.[10-14] Furthermore, the financial burden associated with lung cancer treatment is increasingly recognized as a critical factor influencing patient outcomes globally. Diagnostic procedures, surgical interventions, chemotherapy, and radiation therapy often lead to substantial expenses, placing significant financial strain on patients and their families. This phenomenon, often termed "financial toxicity," may compel patients to make challenging choices, such as postponing or discontinuing treatment, thereby directly impacting their prognosis and survival prospects.[15-18] Studies have shown that patients experiencing severe financial hardship often prioritize immediate financial relief over long-term medical benefits, thereby jeopardizing their entire treatment journey.[16,17]

Despite documented impacts of financial toxicity on lung cancer patients, the specific financial challenges faced by patients in Northern Thailand, including contributing factors and their influence on treatment decisions and outcomes, remain understudied. Regional research primarily emphasizes clinical aspects, neglecting the complex interplay of socioeconomic factors, including financial toxicity, and their impact on patient care. Therefore, this study investigates the financial burden experienced by lung cancer patients in Northern Thailand, exploring the factors contributing to financial toxicity and its influence on treatment decisions and health outcomes. By examining these relationships, this research seeks to identify interventions and support systems to mitigate financial strain and improve access to equitable care.

METHODOLOGY

Study design and population

The financial burden faced by lung cancer patients in Northern Thailand was assessed through a cross-sectional analytical study conducted from August 2018 to July 2023. Participants were required to be 18 years of age or older, have a confirmed diagnosis of lung cancer (ICD10 code C34), and be receiving treatment at a government hospital in Northern Thailand. Patients who opted not to provide financial information were excluded from the study. Using the event-per-variable (EPV) method (20 events per variable across 8 variables, with a 78% incidence rate), it was determined that a minimum of 246 participants was necessary, with an additional 20% included to account for dropouts or non-responses.

Data Collection

Participants provided informed consent and completed questionnaires during their hospital visits. Healthcare providers conducted a survey addressing demographic, disease-related, and financial information. Data integration from hospital information systems and medical records was employed to supplement details related to the disease.

Financial Burden Assessment

A comprehensive questionnaire was designed to evaluate the financial challenges encountered by lung cancer patients in Northern Thailand, focusing on their financial circumstances following diagnosis and during treatment. Participants provided detailed information regarding their income, expenditures, out-of-pocket expenses for cancer treatment, and any additional financial difficulties they experienced. This data collection aimed to assess the financial impact of lung cancer on patients and to understand how financial barriers influenced their treatment accessibility and continuity.

Financial Barriers Leading to Treatment Noncompliance

The duration of treatment discontinuation due to financial constraints was analyzed using the Kaplan-Meier survival estimation method, with the log-rank test applied to evaluate any significant differences.

Ethical Consideration

This study received approval from the Ethical Committee of Lampang Cancer Hospital under document number 001/2562, ensuring adherence to ethical standards and the protection of participants' rights and confidentiality in accordance with the Declaration of Helsinki.

Statistical Analysis

A thorough statistical analysis was performed to assess all relevant factors. Descriptive analyses characterized the demographics, disease characteristics, financial conditions, treatment protocols, and associated expenses of participants. Logistic regression models, both univariate and multivariate, were employed to evaluate financial burden, with odds ratios (OR) indicating predictor-outcome relationships. The predictive performance was assessed through Receiver Operating Characteristic (ROC) curve analysis, where the Area Under the Curve (AUC-ROC) served as an indicator of accuracy. Feature selection was conducted using statistical methods and domain expertise to pinpoint key factors influencing financial burden. The reliability of the model was examined through calibration curves, Akaike's Information Criterion (AIC), and goodness-of-fit tests, while cross-validation was applied to ensure accuracy and minimize overfitting. Statistical significance was determined at $p<0.05$, employing two-tailed tests for all analyses.

RESULTS

Table 1. Patient Characteristics

Characteristics	Total n=290	Financial Burden n=231	No Financial Burden n=59	Testing Method	p-value
Gender, n (%)					
Female	77 (26.6)	60 (26.0)	17 (28.8)	Fisher's	0.741
Male	213 (73.4)	171 (74.0)	42 (71.2)	exact	
Age group, n (%)					
Less than 40 years	6 (2.1)	5 (2.2)	1 (1.7)	Fisher's	0.377
40-55 years	35 (12.1)	29 (12.6)	6 (10.2)	exact	
55-70 years	172 (59.3)	141 (61.0)	31 (52.5)		
Beyond 70 years	77(26.5)	56 (24.2)	21 (35.6)		
History of smoke and air pollution exposure, n (%)					
No	256 (88.3)	197 (85.3)	59 (100.0)	Fisher's	0.002
yes	34 (11.7)	34 (14.7)	0 (0)	exact	
Family History of Cancer, n (%)	146 (50.3)	117 (50.7)	29 (49.2)	Fisher's exact	0.885
History of cigarette smoking, n (%)					
No	94 (32.4)	65 (28.1)	29 (49.1)	Fisher's	0.003
<20 pack-year	173 (59.7)	149 (64.5)	24 (40.7)	exact	
>20 pack-year	23 (7.9)	17 (7.4)	6 (10.2)		
Occupation, n (%)					
No	45 (15.5)	33 (14.3)	12 (20.3)	Fisher's	<0.001
Government/enterprise officer	18 (6.2)	18 (7.8)	0 (0)	exact	
Company employee	10 (3.4)	7 (3.0)	3 (5.1)		
Business owner	18 (6.2)	18 (7.8)	0 (0)		
Daily employee	46 (15.9)	46 (19.9)	0 (0)		
Farmer	153 (52.8)	109 (47.2)	44 (74.6)		
Duration of living in Northern Thailand (years), n (%)					
5-10 years	7 (2.4)	1 (0.4)	6 (10.2)	Fisher's	<0.001
>10 years	283 (97.6)	230 (99.6)	53 (89.8)	exact	
Monthly Income, n (%)					
<9,000 THB	231 (79.6)	178 (77.1)	53 (89.8)	Fisher's	<0.001
9,000-15,000 THB	35 (12.1)	35 (15.1)	0 (0)	exact	
15,001-25,000 THB	12 (4.1)	12 (5.2)	0 (0)		
25,001-50,000 THB	6 (2.1)	6 (2.6)	0 (0)		
>50,000 THB	6 (2.1)	0 (0)	6 (10.2)		
Previous saving money, n (%)					
<10,000 THB	65 (22.1)	52 (22.5)	12 (20.3)	Fisher's	<0.001
10,001-35,000 THB	155 (53.5)	137 (59.3)	18 (30.5)	exact	
35,001-70,000 THB	18 (6.2)	6 (2.6)	12 (20.3)		
10,001-100,000 THB	30 (10.3)	24 (10.4)	6 (10.2)		
100,001-150,000 THB	11 (3.8)	6 (2.6)	5 (8.5)		
>150,000 THB	12 (4.1)	6 (2.6)	6 (10.2)		
Health care schemes, n (%)					
Universal coverage (UC)	230 (79.3)	189 (81.8)	41 (69.5)	Fisher's	0.026
Social security (SSS)	6 (2.1)	6 (2.6)	0 (0)	exact	
Government officer (OFC)	24 (8.3)	18 (7.8)	6 (10.2)		
Insurances	30 (10.3)	18 (7.8)	12 (20.3)		

Characteristics	Total n=290	Financial Burden n=231	No Financial Burden n=59	Testing Method	p-value
Previous financial burden, n (%)	173 (59.7)	161 (69.7)	12 (20.3)	Fisher's exact	<0.001
Private Health Insurance, n (%)	63 (21.7)	58 (25.1)	5 (8.5)	Fisher's exact	0.004
Insurance reimbursement (THB), mean (SD)	124,333 (5,342)	119,534 (5,350)	180,000 (0)	Independent t-test	0.002
Stage at diagnosis, n (%)					
Stage 2	11 (3.8)	5 (2.1)	6 (10.2)	Fisher's exact	0.002
Stage 3	120 (41.4)	90 (39.0)	30 (50.8)		
Stage 4	159 (54.8)	136 (58.9)	23 (39.0)		
Chemotherapy regimen, N (%)					
No CMT	35 (12.1)	18 (7.8)	17 (28.8)	Fisher's exact	<0.001
Ongoing CMT	255 (87.9)	213 (92.2)	42 (71.2)		
Number of cycles, median (IQR)	3 (1-4)	3 (1-4)	4 (0-6)	Wilcoxon rank-sum test	0.401
Surgical treatment, n (%)	17 (5.9)	5 (2.2)	12 (20.3)	Fisher's exact	<0.001
Radiation Therapy, n (%)	102 (35.2)	61 (26.4)	41 (69.5)	Fisher's exact	<0.001
Driver mutation, n (%)					
No or Unknown	241 (83.1)	194 (84.0)	57 (79.7)	Fisher's exact	0.369
ALK	2 (0.7)	1 (0.4)	1 (1.7)		
EGFR	47 (16.2)	36 (15.6)	11 (18.6)		
Targeted therapy, n (%)					
No	253 (87.2)	206 (89.2)	47 (79.7)	Fisher's exact	0.072
Ceritinib	2 (0.7)	1 (0.4)	1 (1.7)		
Erlotinib	11 (3.8)	6 (2.6)	5 (8.5)		
Gefitinib	24 (8.3)	18 (7.8)	6 (10.2)		
Significant weight loss, n (%)					
5-10%	71 (24.5)	42 (18.2)	29 (49.2)	Fisher's exact	<0.001
>10%	76 (26.2)	70 (30.3)	6 (10.2)		
Dietary modification, n (%)	217 (74.8)	163 (70.6)	54 (91.5)	Fisher's exact	0.001
Increase in dietary costs, n (%)	174 (60.0)	139 (60.2)	35 (59.3)	Fisher's exact	1.000
Out-of-pocket expense for cancer treatment (THB) per visit, median (min-max)	13,600 (200-37,300)	13,000 (200-37,300)	18,100 (200-35,400)	Wilcoxon rank-sum test	0.836
Transportation fare (THB) per visit, median (min-max)	500 (60-3,000)	500 (60-3,000)	800 (100-1,000)	Wilcoxon rank-sum test	0.272
Cost of patient's diet (THB) per month, median (min-max)	150 (100-1,000)	150 (100-1,000)	150 (100-500)	Wilcoxon rank-sum test	0.892
Cost of medical devices (THB) per month, median (min-max)	1,000 (100-10,500)	1,000	1,000	Wilcoxon rank-sum test	0.581
Loss of income (THB) per visit, n %)					
No	199 (68.9)	140 (60.9)	59 (100.0)	Fisher's exact	<0.001
1-300	54 (18.7)	54 (23.5)	0 (0)		
300-600	30 (10.4)	30 (13.1)	0 (0)		
600-2,000	0 (0)	0 (0)	0 (0)		
>2,000	6 (2.1)	6 (2.6)	0 (0)		

Characteristics	Total n=290	Financial Burden n=231	No Financial Burden n=59	Testing Method	p-value
Total increased extra-expense (THB) per month, median (min-max)	2,505 (100-38,500)	2,311 (100-38,500)	3,264 (344-3,600)	Wilcoxon rank-sum test	0.048
Total of Indirect-Cost (THB) per month, median (min-max)	2,646 (100-38,500)	2,492 (100-38,500)	3,264 (344-3,600)	Wilcoxon rank-sum test	0.982
Reduction in savings , n (%)	220 (75.9)	179 (77.5)	41 (69.5)	Fisher's exact	0.233
Reduction in family income, n (%)	267 (92.1)	214 (92.6)	53 (89.8)	Fisher's exact	0.431
Increase in family expenses, n (%)	254 (87.6)	207 (89.6)	47 (79.7)	Fisher's exact	0.047
Delayed treatment due to financial problems, n (%)	32 (11.0)	32 (13.9)	0 (0)	Fisher's exact	0.001
Treatment obstruction due to financial problems, n (%)	99 (34.1)	81 (35.1)	18 (30.5)	Fisher's exact	0.542
Discontinuation of treatment due to financial problems, n (%)	36 (12.4)	36 (15.6)	0 (0)	Fisher's exact	<0.001
Number of treatment failure, n (%)					
Never	173 (59.6)	144 (62.3)	29 (49.1)	Fisher's exact	0.019
Once	75 (25.9)	51 (22.1)	24 (40.7)		
Twice	42 (14.5)	36 (15.6)	6 (10.2)		
Overall survival time (months), median (min-max)	11 (5-85)	11 (5-85)	12 (9-30)	Wilcoxon rank-sum test	0.002
Survival $\geq$ 1 year, n (%)	130 (44.8)	89 (38.5)	41 (69.5)	Fisher's exact	<0.001

†Standard deviation (SD); Inter-quartile range (IQR), Thai baht (THB)

Table 2. The Predictive Performance of Predictors for financial burden in the Model

Predictor	OR††	95% CI	p-value	AUC-ROC	Coefficient	Score
Unstable income						
No	reference					0
Yes	39.4	7.6-204.0	<0.001	0.6672	3.67	5.5
Saving <100k						
No	reference					0
Yes	14.3	2.7-77.3	0.002	0.5672	2.66	4
Previous financial imbalance						
No	reference					0
Yes	10.0	4.7-21.3	<0.001	0.7468	2.31	3.5
Potential to family's income reduction after cancer diagnosis						
No	reference					0
Yes	2.0	0.6-6.5	0.257	0.5141	0.69	1

††Odd ratio (OR); area under the Receiver Operating Characteristic curve (AUC-ROC) = 0.9020.
p-value of Goodness-of-fit test 0.9821, Akaike's information criterion (AIC) 185.6

This research involved a cohort of 290 individuals diagnosed with lung cancer. Financial barriers significantly impacted treatment compliance among the study participants. Specifically, 32 patients (13.9%) experienced delayed treatment due to financial difficulties, while 99 patients (34.1%) reported interruptions in their treatment. Additionally, 36 patients (15.6%) indicated a potential to discontinue treatment entirely. Treatment failure was observed in 40.4% of the individuals, with an increased rate among those facing economic hardship (p=0.019). Patients grappling with financial limitations demonstrated reduced one-year survival rates and shorter overall survival durations compared to those without such barriers. Factors associated with financial strain included higher smoking rates, low-income occupations, limited savings, advanced cancer stages at diagnosis, participation in the Universal Coverage (UC) health scheme, prior financial hardships, undergoing chemotherapy, ineligibility for surgical or radiation therapy, significant weight loss, and substantial income loss during treatment. Logistic regression was employed to assess predictive factors, quantify their impact on outcomes using odds ratios (OR), and evaluate their predictive efficiency through the area under the receiver operating characteristic curve (AUC-ROC).

The factors outlined have been utilized to develop a predictive model for assessing the risk of financial burden during lung cancer treatment. In selecting predictors and constructing the model, both statistical significance and clinical relevance were taken into account. The primary objective of the model is to predict future financial burden risks associated with lung cancer, thereby enabling proactive risk reduction planning. As such, factors existing prior to diagnosis, such as unstable income (daily or monthly earnings), were included. It is noteworthy that there has been a previous financial imbalance with savings currently below 100,000 THB, and there is a possibility of decreased family income following a cancer diagnosis. The established comprehensive model was evaluated for reliability, yielding an AUC-ROC of 0.8542, an AIC of 205.6, and a GoF p-value of 0.6855.

The model has been transformed into a scoring system by calculating coefficients for each predictive factor, subsequently adjusting them into a basic score, as demonstrated in Table 2. Following this transformation, the scoring model achieved an AUC-ROC of 0.8542, an AIC of 199.6, and a GoF p-value of 0.6935. In financial risk management applications, a cut-off score of 8.5 was selected, resulting in an AUC-ROC of 0.8126 for distinguishing between low- and high-risk groups. The model exhibited a sensitivity of 77.97% and a specificity of 79.66%, with a positive predictive value (PPV) of 93.56% and a negative predictive value (NPV) of 52.27%. Additionally, it had a false-positive rate of 22.03%, a false-negative rate of 18.18%, and an overall correct classification rate of 81.03%. When applied to a population with a financial problem incidence of 79.7%, the model showed a sensitivity of 81.82% and a specificity of 77.97%.

To evaluate the model's calibration, a plot of the cumulative incidence function for competing risks (Figure 1A) was used, revealing that the Cumulative Incidence of Treatment Limitation (CITL) was 0.000. The slope of the calibration curve, calculated at 1.000, indicates a strong correlation between observed and expected risks, reflecting precise risk prediction. The AUC's predictive performance was 0.854, which denotes excellent discrimination. The calibration risk curve (Figure 1B) confirmed that the model's calibration performance was satisfactory, showing an acceptable alignment between observed

outcomes and predicted probabilities, thereby validating the model's reliability in predicting financial risks.

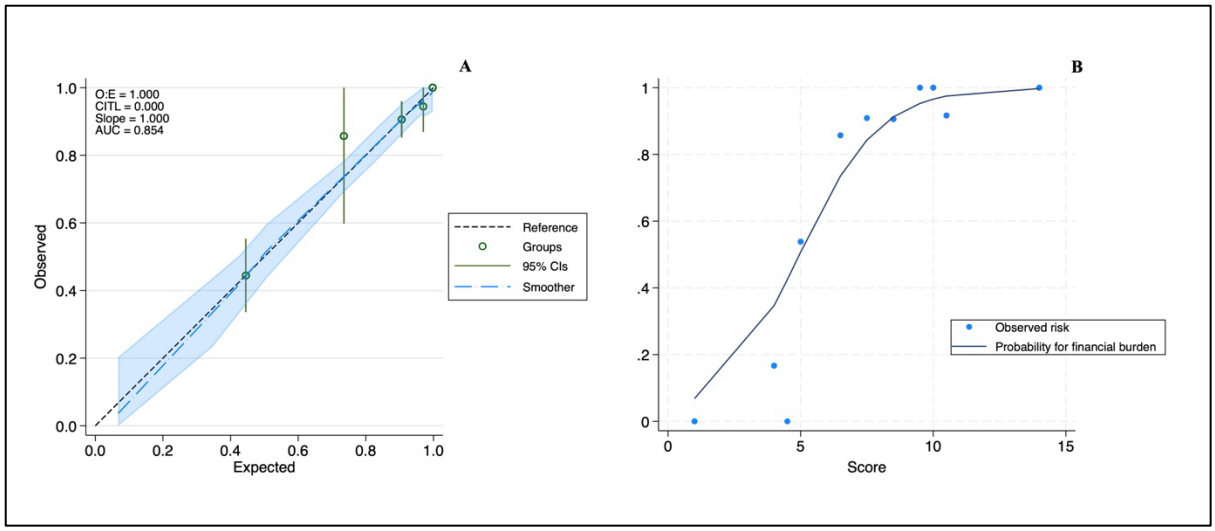

Figure 1. (A) The cumulative incidence function for competing risks indicates a Treatment Limitation Cumulative Incidence (CITL). (B) The calibration risk curve.

The cross-validation findings indicated that the Lasso model achieved a sensitivity of 77.5% (95% CI: 71.6%-82.7%) and a specificity of 79.7% (95% CI: 67.2%-89.0%). The AUC-ROC score was 0.79 (95% CI: 0.73-0.84), demonstrating robust discriminatory efficacy. Notably, the positive predictive value (PPV) was 93.7% (95% CI: 89.3%–96.7%), while the negative predictive value (NPV) was 47.5% (95% CI: 37.3%-57.8%). The odds ratio calculated was 13.48 (95% CI: 6.71-27.03), with likelihood ratios of 3.81 for positive results and 0.28 for negative results. Additionally, the financial risk index significantly influenced adverse outcomes, as evidenced by an odds ratio of 11.06 (95% CI: 5.90-20.75, $p<0.001$) derived from a logistic regression analysis. The results illustrate the model's effectiveness in predicting financial risks for lung cancer patients.

The decision curve analysis (DCA) presented in Figure 2A evaluates the net benefit of different treatment strategies across a range of threshold probabilities. The green curve, representing the model's net benefit in predicting adverse financial outcomes, consistently surpasses both the "Treat All" (blue line) and "Treat None" (red line) strategies within a clinically relevant threshold probability range. This model facilitates informed decision-making during this range, effectively balancing the risks of excessive caution and insufficient management.

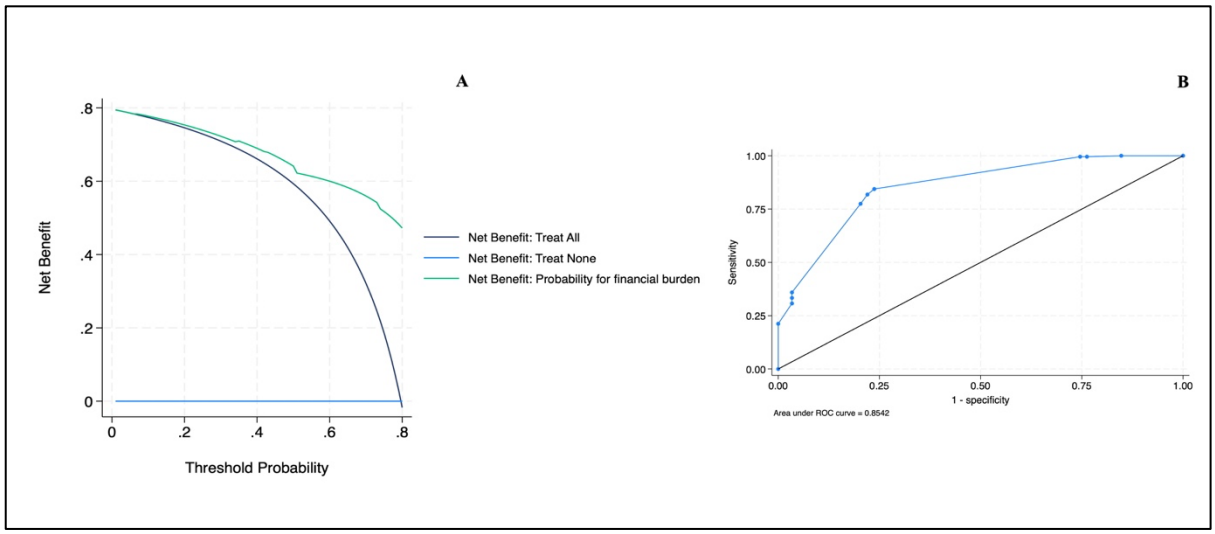

Figure 2. (A) Decision Curve Analysis and (B) AUC-ROC of the full model.

The survival analysis examined the duration of cancer treatment until discontinuation across various financial risk groups. The Kaplan-Meier survival curves (Figure 3) categorized by financial risk groups, revealed significant differences in survival durations. The log-rank test indicated that the treatment discontinuation rates among the financial risk groups differed significantly (chi^2=6.85, p=0.0326). Notably, the majority of events (31 observed compared to 24.12 expected) were reported in the highest-risk group, suggesting a significant correlation between financial risk and the likelihood of treatment discontinuation.

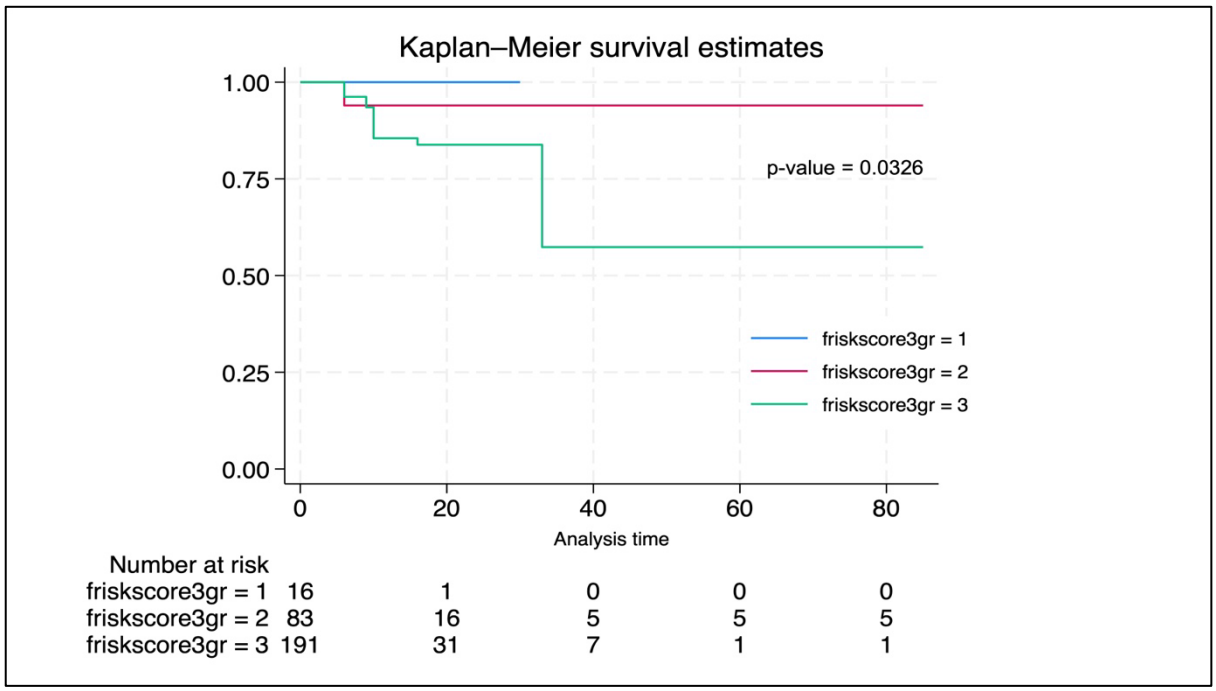

Figure 3. Survival estimation for treatment discontinuation due to financial burden

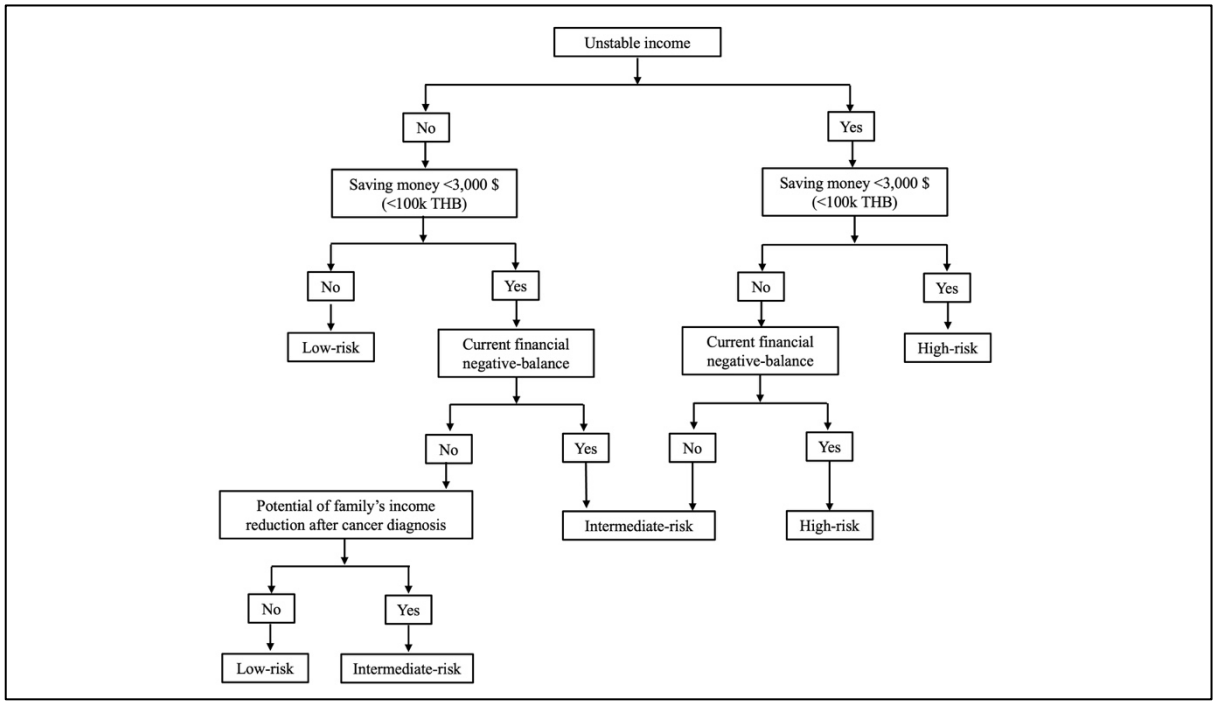

Figure 3. Decision tree for risk stratification.

DISCUSSION

This study analyzes the demographic characteristics, treatment patterns, financial burdens, and prognostic factors associated with lung cancer patients in Northern Thailand. Notably, a significant proportion (54.8%) of participants received a diagnosis at stage IV, underscoring the urgent need for improved early detection strategies and enhanced public awareness initiatives. This finding aligns with the American Cancer Society and the study of He S., et al. (2022). Late-stage diagnosis has been consistently associated with poorer outcomes.[19, 20] Our research highlights the substantial financial challenges faced by lung cancer patients, with 79.7% reporting considerable treatment-related burdens. This high prevalence of financial hardship corroborates the growing body of literature documenting the significant financial toxicity associated with cancer care.[21-23] As Abrams HR., et al. (2021) note, these burdens include both direct out-of-pocket treatment costs and indirect costs like transportation, time, and lost income, all of which can significantly strain patients and their families. Our findings further demonstrate the detrimental impact of financial problems on treatment adherence, with 34.1% of patients reporting treatment disruptions or delays due to financial constraints. This aligns with the broader understanding that financial toxicity can lead to compromised treatment journeys and poorer outcomes.[21,22] Survival analysis in our study reveals a significant link between financial risk and treatment discontinuation rates ($p=0.0326$), further emphasizing the critical role of financial stability in maintaining consistent cancer care. This observation underscores the importance of addressing the financial burden to improve patient outcomes. This study makes a significant contribution by developing a predictive model for assessing the risk of financial burden, achieving a strong performance indicator of AUC-ROC at 0.8542. While research on predictive models for financial toxicity in lung cancer is still emerging, our work builds on the

broader application of predictive analytics in financial risk management.[24] The model's ability to identify individuals at higher risk of financial struggles, incorporating factors such as unstable income, previous financial imbalances, and limited savings, offers a promising tool for informing financial risk management strategies in clinical practice.

Our study also highlights the complex interactions among insurance coverage, financial uncertainty, and work flexibility in lung cancer treatment outcomes. The high utilization of the Universal Coverage scheme (79.3%) underscores the crucial role of public health coverage in accessing essential treatments, consistent with Sun's (2021) findings on the positive impact of Medicare coverage on lung cancer screening.[25] However, the limited access to advanced therapies, such as anti-EGFR treatments (12.8%), suggests potential gaps in coverage for these vital therapies. This observation aligns with the ongoing challenges of equitable access to advanced cancer treatments, particularly in settings with resource constraints.[26,27] As Rajyaguru et al. (2015) demonstrated, insurance status can be a significant predictor of survival in metastatic NSCLC, highlighting the importance of addressing insurance-related barriers to care.[28] The limitations of this scheme render numerous patients vulnerable, particularly those experiencing additional financial pressures and inadequate coverage for advanced therapies involving anti-EGFR treatments. Only 12.8% of patients received anti-EGFR therapies, highlighting the necessity for improved policy frameworks to ensure better coverage for the changing requirements of cancer patients.

In conclusion, our study provides valuable insights into the financial burden and its impact on lung cancer patients in Northern Thailand. By examining this critical correlation, we have identified potential areas for intervention and support systems that can mitigate financial strain and improve access to equitable and effective lung cancer care in the region.

Implications for Practice and Policy

The inconsistent income levels posted significant challenges for participants in this study, with a notable percentage engaged in low-paying occupations such as farming (52.8%) and daily labor (15.9%). This financial instability limits their ability to attend treatment sessions consistently, resulting in interruptions in therapy. Implementing employment policies that improve job security and income stability, through community programs or employer incentives, could enable patients to better manage their health issues.

Community support plays a crucial role in alleviating the financial burdens associated with lung cancer treatment. Initiatives that promote resource-sharing can help address financial gaps while fostering a supportive environment, thereby reducing stigma and encouraging patients to seek assistance. Additionally, environmental factors, particularly exposure to PM2.5, significantly elevate the risk of lung cancer in Northern Thailand.

The interplay of insurance coverage, income instability, employment flexibility, community support, and environmental influences profoundly impacts the treatment experiences and outcomes of lung cancer patients. To improve medical care and overall quality of life, strategies must include financial support, improved healthcare accessibility, community involvement, and environmental protection. Addressing financial barriers is vital for improving access to lung cancer treatment. Many participants faced substantial financial hardships due to both direct and indirect costs, which hindered their adherence to treatment. Therefore, establishing comprehensive financial assistance programs and a robust healthcare system is

vital for overcoming these difficulties and improving patient outcomes.

RECOMMENDATIONS

Table 3. Treatment Strategies for Each Classified Risk Group

Low-Risk Group	Intermediate-Risk Group	High-Risk Group
1. Financial counseling and Monitoring	1. Proactive financial planning	1. Intensive financial support
2. Cost-effectiveness treatment options	2. Assistance program	2. Personalized treatment approach
3. Inquiry on healthcare coverage	3. Insurance review and optimization	3. Multidisciplinary support
	4. Early response for financial distress	4. Close monitoring for financial toxicity
		5. End-of-life financial planning

After categorizing individuals into low, middle, and high financial risk groups, personalized management strategies can be implemented (see Table 3). For the low-risk group, effective management of healthcare expenses primarily involves offering financial counseling and education. Prompt identification and resolution of any issues can be achieved through regular evaluations of financial status throughout treatment. Additionally, emphasizing cost-efficient treatment alternatives and leveraging government healthcare schemes may help reduce out-of-pocket costs.

Individuals in the intermediate-risk group require proactive financial planning. Developing a comprehensive financial strategy for these patients begins with preliminary discussions about anticipated treatment expenses and ongoing care. Accessing patient assistance programs, subsidies, and funding sources can further alleviate the financial burdens of treatment. It is crucial to review and optimize health insurance plans while exploring supplemental options, as well as monitoring for early signs of financial distress to ensure timely interventions.

The high-risk group needs intensive financial assistance. Enrolling in financial assistance programs, social security, or charitable funding is vital. Collaborating with healthcare providers to identify cost-effective treatment options is key to ensuring optimal care while minimizing expenses. Utilizing social workers and financial counselors within an interdisciplinary framework can improve healthcare and financial planning outcomes. Ongoing assessments of financial burdens will allow for immediate adjustments to treatment plans, including discussions about palliative care and end-of-life planning to alleviate unnecessary financial stress.

By integrating financial counseling with initiatives aimed at reducing environmental pollution, such as PM2.5 exposure, we can improve outcomes and tackle the complex challenges faced by this vulnerable population.

Limitations and Future Directions

This investigation presents several limitations. While the sample size is considerable, it may not fully capture the

diverse population of lung cancer patients in Northern Thailand, potentially affecting the generalizability of the findings. The reliance on self-reported data regarding financial status and treatment experiences could introduce bias, as patients may either underreport or overreport their financial burdens due to stigma or memory recall issues. Additionally, the cross-sectional design restricts the ability to assess causal relationships between financial factors and treatment outcomes.

Future research should focus on examining the long-term implications of financial toxicity on treatment adherence and outcomes. Assessing targeted interventions, including financial counseling and optimizing insurance policies, is essential to enhance access to treatment and alleviate financial burdens faced by patients.

CONCLUSION

The research highlights a significant correlation between financial barriers, treatment accessibility, and outcomes for lung cancer patients in Northern Thailand. The findings emphasize the urgent need for comprehensive financial assistance programs and policy improvements, in addition to integrating the predictive model into standard clinical practice. This model empowers healthcare providers to identify patients at risk of financial toxicity early in their treatment journey, facilitating timely and tailored solutions. By establishing a supportive framework that encompasses financial counseling, assistance programs, and community resources, healthcare providers can alleviate financial burdens and enhance the quality of care. This study lays the groundwork for future initiatives aimed at improving cancer care in resource-limited settings, ultimately leading to better survival rates and quality of life for lung cancer patients.

AUTHOR CONTRIBUTIONS

Conceptualization, N.P., and A.I.; Data curation, N.P. and A.I.; Formal analysis, N.P.; Investigation, N.P.; Methodology, N.P., Model development, N.P.; Project administration, A.I.; Software, N.P.; Supervision and Validation, A.I.; Writing – original draft, N.P.; Writing – review & editing, N.P., and A.I.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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