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Potential profile analysis of financial toxicity and its related factors among lung cancer patients

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Abstract

Background Financial Toxicity (FT) is prevalent among lung cancer patients. Identifying high-risk groups and implementing comprehensive, targeted interventions can alleviate FT and improve patients' quality of life. Hence, the objective of this study was to analyze the status and potential profiles of FT in lung cancer patients and explore the related factors of FT levels in different categories of lung cancer patients.

Methods A cross-sectional design was used in this study. A total of 421 patients with lung cancer hospitalized in the oncology department of a Grade A general hospital and a provincial oncology hospital in Shandong Province from October to December 2023 were selected by convenience sampling. General data questionnaires, FT scale for reported outcomes of cancer patients, Chinese version of the Quality of Life Scale for lung cancer patients, Social Support Rating Scale and simplified version of the Mental Resilience Scale were used. Potential profile analysis of FT levels in lung cancer patients was performed, and multiple logistic regression was used to analyze the related factors of FT levels in different categories.

Results Among 421 lung cancer patients, the median FT (FT) score was 16 (IQR: 9–24). Latent profile analysis identified four distinct FT patterns: mild (19.5%), moderate resource-deficient (7.8%), moderate balanced (35.6%), and severe (37.1%). Multivariate analysis revealed significant associations between FT severity and hospitalization frequency, lifestyle modifications, employment status, insurance coverage, education level, social support, emotional distress, family resilience, problem-solving capacity, and social resource utilization.

Conclusion FT demonstrates high prevalence and substantial heterogeneity in lung cancer patients, with over 70% experiencing moderate-to-severe levels. Clinical interventions should prioritize early screening and stratified management through psychological support, financial navigation programs, cost-containment strategies, and enhanced health literacy to alleviate economic burdens and optimize treatment outcomes.

Keywords Lung cancer, Financial toxicity, Latent profile analysis

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Introduction

Cancer is one of the leading causes of death globally [1], posing significant barriers to the extension of human life expectancy and contributing substantially to the global burden of disease [2]. According to the World Health Organization (WHO), cancer was the first or second leading cause of death in 112 countries and the third or fourth leading cause of death in 23 countries in 2019 [1]. Among these, lung cancer ranks high in morbidity and mortality in China and worldwide. In January 2021, the latest global cancer statistics report published by the International Agency for Research on Cancer indicated 2.207 million new cases of lung cancer globally, second only to breast cancer, with 1.796 million deaths, making it the leading cause of cancer death worldwide [1].

Recent advances in science and technology, including cancer screening, biomarker detection, and the development of targeted and immunotherapy drugs [3–5], as well as advancements in neoadjuvant therapy [6], surgical, radiation, and chemotherapy treatments [7, 8], have significantly improved treatment regimens and patient outcomes. However, targeted immunotherapy drugs are expensive, and some are not covered by public health insurance (average OOP expenditure ratio is about 60%) [9], imposing a substantial financial burden on patients. Studies indicate that the average indirect cost of patients with advanced non-small cell carcinoma, including economic losses from missed work by patients and their caregivers, is 7,842.24 yuan, with the average caregiver indirect cost accounting for 93.6% of this total [10]. Additionally, 77.6% of cancer patients find the economic burden unbearable, with many considering it catastrophic [11].

FT refers to the negative effects of high economic costs on patients and their families during cancer treatment, encompassing both objective economic burdens and subjective economic distress. The concept was first mentioned by American scholar Bullock [12] and further elaborated by Zafar [13] to describe the impact of out-of-pocket expenses on patients' cancer experiences. FT focuses on the multifaceted short- and long-term harm caused by economic pressure on patients, families, and society [14].

In recent years, the issue of FT has garnered attention in health-related fields, with relevant research spanning cancer [15–17], cardiovascular and cerebrovascular diseases [18, 19], among others. Multiple studies [17, 20, 21] have shown high FT incidence, ranging from 16 to 73% in cancer patients, negatively affecting their quality of life and mental health, increasing the risk of anxiety and depression, reducing health-related quality of life [22], and subjective well-being [23]. Higher FT levels can lead to reduced treatment compliance, delayed or abandoned treatment, and ultimately poorer patient outcomes and increased mortality [24].

FT has been recognized as an important policy issue in high-income countries but remains a significant barrier to cancer treatment in low- and middle-income countries, where there is a high but unmet need for FT support among cancer patients in China [25]. Compared to developed countries, there is less research on FT in China, and it has not been widely recognized [26]. A national survey on lung cancer patients in China in 2023 showed that 77% of patients experienced FT, with those living in less developed areas, males, less educated, lower annual household income, and poorer health status significantly associated with higher FT [20]. Patients with higher FT tend to have lower medical adherence, higher risk of debt, and reduced living expenses compared to patients with lower FT [20].

Previous studies have identified various factors affecting patients' FT, including sociodemographic factors such as age [27], race [22], gender [20], education level [20], marital status [28], place of residence [29], employment status [30], health insurance [31], and commercial insurance [27]. Disease-related factors include cancer stage and type treatment decisions [28], length of stay, number of hospitalizations [32], out-of-pocket costs [27], comorbidities [22, 32], physical health status [20], and symptom burden, as well as psychological factors such as mental resilience [33]. Studies have also shown that FT is related to socioeconomic status and social support level, with lower socioeconomic status associated with higher FT levels [34]. Family income and savings are also risk factors for FT in advanced lung cancer patients, with higher family income closely correlated with lower FT [35].

Latent profile analysis (LPA) can identify groups with different characteristics based on response patterns on explicit variables, helping to classify individuals with similar response patterns into the same potential subgroup [36]. Existing studies have shown that the FT of elderly cancer survivors in China is divided into three groups: low FT level, medium FT level, and high FT level [37, 38]. Similarly, stroke patients' FT levels in China are divided into three groups: low, medium, and high FT [35]. However, differences in treatment measures, disease progression, and economic expenditure among different groups and types of diseases result in varying FT levels [28].

Methods

Study design

A cross-sectional design was adopted in this study.

Study setting and sampling

Patients with lung cancer hospitalized in the oncology department of a general Grade A hospital and a specialized tumor hospital in Shandong Province from October 2019 to January 2019 were selected by convenience sampling. Inclusion criteria for participants were: (1) Patients diagnosed with primary lung cancer by pathological diagnosis; (2) Stable vital signs; (3) Patients aged ≥18 years; (4) Clear consciousness after assessment, no intellectual, cognitive, or language impairment; (5) Informed consent and voluntary participation. Exclusion criteria for participants were: (1) Patients or their family members withdrew from the study in advance; (2) Incomplete clinical data; (3) Combined with mental illness or other evil tumor patients.

Sample size

Based on the multi-factor analysis method, the sample size should be 5–10 times the number of study variables. The study variables included 14 general data variables, 8 clinical relevant data variables, 3 dimensions of the FT comprehensive rating scale, 3 dimensions of the Social Support Rating Scale, 1 dimension of the simplified Mental Resilience Scale and 5 dimensions of the Chinese version of the Lung Cancer Patients' Quality of Life Scale, totaling 33 variables. The sample size was expanded to 413 cases, considering a 20% inefficiency rate. A total of 430 questionnaires were distributed, with 421 valid responses (97.91% effective recovery rate).

Data collection

Paper-based questionnaires were distributed to cancer patients who met the inclusion criteria. Members of the research team received thematic training to familiarize themselves with each patient's medical history. Before collecting the questionnaires, the investigators explained the purpose of the research, the procedures involved, the required time commitment, potential risks, confidentiality measures, questionnaire requirements, and participants'right to withdraw at any time, using clear and accessible language. All patient inquiries were thoroughly addressed before participants voluntarily decided whether to sign the informed consent form.

The questionnaires were self-administered by patients, with assistance provided as needed. Upon completion, researchers reviewed each questionnaire to promptly address any missing items and exclude invalid responses. Data accuracy was ensured through double-checking procedures.

Research tools

General and clinical data questionnaires

Designed by the researchers, this study included patients'general demographic data (age, race, gender, education level, marital status, residence, employment status, occupation, current working status, type of medical insurance, reimbursement ratio, commercial insurance, family income, and savings) as well as clinical data (diagnosis time, cancer type and stage, distant metastasis, treatment plan, hospitalization frequency, length of stay, out-of-pocket costs, and indirect costs). For further details, please refer to the supplementary file.

Comprehensive Scores for FT based on Patient-Reported Outcome Measures (COST-PROM)

Compiled by De Souza [39] and translated into Chinese by Yu [40], the reliability and validity of the scale were tested in a sample of 440 patients with gastric cancer, colorectal cancer, and breast cancer. The scale demonstrated high reliability and validity, with a Cronbach's α coefficient of 0.889 [40] and a cumulative contribution rate of 68.04%. The scale consists of 11 items and is scored using a 5-point Likert scale (0–4 points), where lower scores indicate more severe fatigue (FT). A pilot study was conducted among 50 lung cancer patients in November 2023, which revealed a Cronbach's alpha coefficient of 0.920 for the scale.

Chinese Functional Assessment of Cancer Therapy-Lung (FACT-L)

The questionnaire was developed between 1987 and 1993 and was first published in 1995 to assess patients'quality of life [41]. It was translated into Chinese by scholars Wan Chonghua et al., and the reliability and validity of the scale were tested in a sample of 181 lung cancer patients. The Cronbach's α coefficient was found to be 0.898 [41], indicating that the scale possesses good reliability, validity, and responsiveness, making it suitable for measuring the quality of life of Chinese lung cancer patients. This scale comprises 36 items across five dimensions: physiological status, social/family status, emotional status, functional status, and lung cancer-related symptoms. Responses are scored using a 5-point Likert scale (0–4 points), with higher scores reflecting a better quality of life. A pilot study was conducted among 50 lung cancer patients in November 2023, which revealed a Cronbach's alpha coefficient of 0.894 for the scale.

Social Support Rating Scale (SSRS)

Developed by Xiao [42], this self-rating scale evaluates sources of social support and subjective psychological feelings through 10 items that encompass three

dimensions: objective support, subjective support, and the utilization of social support. Higher scores reflect greater levels of social support. Initially designed to assess the social support of college students, the scale has been widely adopted in numerous studies, with a Cronbach's α coefficient of 0.896 [43]. A pilot study was conducted in November 2023 among 50 lung cancer patients, during which the Cronbach's alpha coefficient of the scale was found to be 0.716.

Simplified version of the 10-item Connor-Davidson Resilience Scale (CD-RISC- 10)

The simplified version of the 10-item CD-RISC- 10 was derived from the original 25-item CD-RISC, which was adapted and revised by Wang Li et al. [44]. The reliability and validity of the scale were assessed in a sample of 303 parents of children with tumors, demonstrating that the scale possesses good reliability and validity and is widely utilized in China [44]. This unidimensional scale comprises 10 items, each scored using a 5-point Likert scale ranging from 0 to 4, with higher scores indicating greater levels of psychological resilience. The scale exhibits high reliability and validity, with a Cronbach's α coefficient of 0.91 [44]. Additionally, a pilot study conducted in November 2023 among 50 lung cancer patients revealed a Cronbach's alpha coefficient of 0.881 for the scale.

Statistical methods

LPA

LPA was established using Mplus8.3 software, with the mean of the 11 COST-PROM entries as the explicit variable. Multiple indicators evaluated model quality: AIC, BIC, aBIC, entropy, LMR, and BLRT. The best model had the smallest AIC, BIC, and aBIC values, entropy >0.8, and significant LMR and BLRT values ($P < 0.05$).

Common method bias assessment

Since the data in for this were collected through self-reported measures, potential common method bias was assessed evaluated Harman's single-factor test. The results revealed indicated that first unrotated principal component accounted for 18.702% of the total variance, variance, which is below 50% threshold, indicating suggesting a lack of significant bias.

Statistical analysis

Analyses were performed conducted SPSS. The Shapiro–Wilk test was applied employed assess the normality of sociodemographic data, clinical variables, and continuous scale scores. Normally distributed data were presented as mean ± standard deviation, while non-normally distributed data were expressed as median (interquartile range). Categorical variables were summarized using frequencies and percentages. The results demonstrated indicated that the total FACT-L scores of lung cancer patients met met the assumptions of normality, scores from other scales/subscales and all healthcare cost variables violated normality these assumptions. The of FT latent classes were was using Mann–Whitney U tests, Kruskal–Wallis tests, or one-way ANOVA, as appropriate. Logistic regression analysis was conducted performed statistically significant variables as independent variables, using the mild FT group as the reference category. Missing values were addressed through multiple imputation (MI) procedures.

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Qilu Hospital, Shandong University (Approval No. KYLL- 202310–042). The following ethical principles were strictly observed:Voluntary Participation: Written informed consent was obtained from all participants prior to data collection. Before interviews, researchers thoroughly explained the study purpose, procedures, time commitment, potential risks, confidentiality measures, and participants'right to withdraw at any time using lay-person-friendly language. All questions raised by participants were addressed conscientiously. Signed informed consent forms were collected as documentation of voluntary participation;Confidentiality Protection: All research data and findings will be used exclusively for scientific purposes. Participants'personal privacy and identifiable information will remain strictly confidential;Equity Principle: All eligible candidates meeting the inclusion criteria were provided equal opportunities to participate in this investigation.

Results

Participant characteristics

A total of 430 paper questionnaires were distributed, with 421 valid responses (97.91% response rate).The median (IQR) FT was 16 (9,24). The median (IOR) age was 62 (52,69) with 3.6% aged ≤45 years, 39.4% aged 46–60 years, 50.8% aged 61–75 years, and 6.2% aged >75 years. Males constituted 69.4% of the sample. Most patients (75.8%) lived in rural areas, 61.8% were covered by the new rural cooperative medical service, 58% were unemployed, and 12.1% were employed. Educational levels varied, with 41.3% having primary education or below and 7.1% having college education or above. 42.0% had a per capita family income of less than 1000 yuan, and 15.4% had an income of more than 5000 yuan. Disease characteristics included 73.4% diagnosed within one year, 61.8% in stage IV, and 50.4% with adenocarcinoma. 90.97% chose to change their lifestyle. For details see Table 1.

Table 1 Patient characteristics and COST values ($N = 421$)

Characteristic	N (%)	COST M (Q1,Q3)	Z/H Value	P
Age (Years)			13.412**	0.004
≤ 45	15 (3.6)	15 (9,32)		
46 ~ 60	166 (39.4)	13 (7,22)		
61 ~ 75	214 (50.8)	17 (10,24.25)		
> 75	26 (6.2)	20 (13.5,29.5)		
Sex			− 0.482*	0.630
Male	292 (69.4)	16 (9,24)		
Female	129 (30.6)	16 (9,23)		
Residence			27.035**	< 0.001
Urban	102 (24.2)	22 (13,32)		
Rural	319 (75.8)	14 (8,22)		
Medical Expense Insurance			64.780**	< 0.001
New Rural Cooperative Medical Insurance	260 (61.8)	13 (7,19)		
Medical Insurance for Urban Residents	26 (6.2)	20 (8.75,27.25)		
Medical Insurance for Urban Workers	133 (31.6)	23 (15,31)		
Employment Status			63.431**	< 0.001
On the job	58 (13.8)	17 (11.75,22.5)		
Retired	119 (28.3)	23 (15,31)		
Unemployed	244 (58.0)	12 (7,19)		
Education Level			33.747**	< 0.001
Primary School or Below	174 (41.3)	14 (8,20)		
Junior High School/Technical Secondary School	150 (35.6)	15 (8,24)		
Minimum of Senior High School	67 (15.9)	20 (13,28)		
Junior College or Above	30 (7.1)	24 (18,34.5)		
Reimbursement Ratio				
≤ 50%	164 (39.0)	12 (7.25,17)	66.923**	< 0.001
50% ~ 75%	150 (35.6)	14.5 (8,23)		
> 75%	107 (25.4)	24 (18,32)		
Household Monthly Income/Person (Yuan)			53.013**	< 0.001
≤ 1000	177 (42.0)	12 (7,19)		
1000 ~ 2999	105 (24.9)	16 (10,24)		
3000 ~ 4999	70 (16.6)	18.5 (10.75,26.25)		
5000 ~ 9999	49 (11.6)	24 (15,30)		
> 10,000	20 (4.8)	27.5 (15.25,36.75)		
Length of Cancer Diagnosis			4.563**	0.207
≤ 1 Year	309 (73.4)	17 (10,25)		
1 ~ 5 Years	97 (23.0)	15 (7,22)		
5 ~ 10 Years	11 (2.6)	13 (4,25)		
> 10 Years	4 (1.0)	11.5 (2.5,20.5)		
Number of Hospitalizations			8.621**	0.035
≤ 3	117 (27.8)	17 (11,29)		
3 ~ 10	162 (38.5)	15 (8,24)		
10 ~ 20	59 (14.0)	19 (7,26)		
> 20	79 (18.8)	15 (10,21)		
Pathological Pattern			4.392**	0.356
Squamous Cell Carcinoma	84 (20.0)	17 (11.25,24)		
Adenocarcinoma	212 (50.4)	15 (8,23)		
Adenosquamous Carcinoma	5 (1.2)	13 (6,23)		
Other Neuroendocrine Tumors	12 (2.9)	14 (2.5,27.75)		

Table 1 (continued)

Characteristic	N (%)	COST M (Q1,Q3)	Z/H Value	P
Small Cell Cancer	105 (24.9)	17 (9.5,25)		
Other	3 (0.7)	12		
Cancer Stage			3.112**	0.375
I	13 (3.1)	20 (8,33)		
II	32 (7.6)	16.5 (11,26.5)		
III	116 (27.6)	17 (12,24)		
IV	260 (61.8)	15 (8,23)		
Change Life Style			− 5.783*	< 0.001
Yes	383 (90.97)	15 (9,23)		
No	38 (9.03)	29 (19.75,36.25)		
Change of Medical Plan			− 6.680*	< 0.001
Yes	37 (9.64)	6 (4,10)		
No	384 (90.36)	17 (10,24)		
Ask Others for Help			− 8.225*	< 0.001
Yes	154 (36.58)	11 (5,17)		
No	267 (63.42)	19 (12,29)		
Access to Medical Assistance			− 1.873*	0.061
Yes	9 (2.14)	7 (1.5,19.5)		
No	412 (97.86)	16 (9,24)		
Commercial Insurance			− 1.742*	0.082
Yes	79 (18.76)	18 (10,30)		
No	342 (81.24)	15.5 (9,23)		

* Stands for Mann–Whitney test and ** Stands for Kruskal-Wallish test

The data of COST-PROM, SSRS, FACT-L, CD-RISC-10 and FHI of lung cancer patients and their scores in each dimension and various medical expenses (total hospital expenses, out-of-pocket hospital expenses, out-of-pocket drug expenses, room and board expenses, transportation expenses and nutrition expenses) are shown in Table 2.

Table 2 Scores of SSRS, FACT-L, CD-RISC- 10, FHI, and medical expenses for lung cancer patients ($N = 421$)

Variables	(Mean ± SD)/M (Q1,Q3)
COST-PROM	16 (9,24)
FACT-L	79.08 ± 19.185
PWB	17 (13,21)
SWB	15 (12,18)
EWB	14 (7,19)
FWB	10 (7,15)
ACL	24 (19,28)
SSRS	31 (28,35)
Subjective Support	10 (8,11)
Objective Support	16 (14,19)
Utilization of Social support	5 (4,7)
CD-RISC- 10	19 (11,26)
Total Hospital Expenses (yuan)	68000 (30000160000)
Out-of-Pocket Expenses (yuan)	15000 (330030000)
Cost of Outsourcing Drugs (yuan)	2000 (022500)
Board and Lodging Expenses (yuan)	4000 (1500,8100)
Total Transportation Cost (yuan)	2000 (800,5600)
Total Nutrition Cost (yuan)	30 (0,4250)

Identification of financial toxicity subgroups

Using the 11 entries of COST-PROM as explicit variables, the optimal number of potential categories was explored, fitting 1 to 5 models. The fitting indices of each explored potential category are shown in Table 3. The 4-category model was determined as the optimal model for FT type of lung cancer patients based on AIC, BIC, aBIC values, entropy, LMR, and BLRT values.

The average attribution probability of the 4-class samples in each class was calculated, showing high classification accuracy, indicating the reliability of the potential profile analysis results. For details see Table 4.

The median (IQR) of COST-PROM scores for the four profiles were 32 (29, 37.25), 19 (16.5, 21), 18 (15, 22), and 7 (4, 10). Each profile was designated as follows: C1:

Table 3 Fitting indicators of different categories of models

Models	AIC	BIC	aBIC	Entropy	LMR (P)	BLRT (P)	Class quilt probability (%)
1	15546.504	15635.442	15565.629	/	/	/	/
2	13916.49	14053.939	13946.046	0.928	< 0.001	< 0.001	70.546/29.454
3	13431.01	13616.971	13470.999	0.888	0.0878	< 0.001	45.606/34.679/19.715
4	13282.149	13516.622	13332.569	0.912	0.0187	< 0.001	19.477/7.838/35.629/37.055
5	13127.221	13410.206	13188.074	0.923	0.004	< 0.001	33.729/27.078/16.152/15.439/7.601

Table 4 Average attribution probability (Column) of samples of each potential category (Row)

Potential category	Category 1 (%)	Category 2 (%)	Category 3 (%)	Category 4 (%)
Category 1 (%)	96.9	0.1	3.0	0.0
Category 2 (%)	0.1	89.4	7.5	3.0
Category 3 (%)	0.9	1.2	94.6	3.4
Category 4 (%)	0	0.6	2.6	96.8

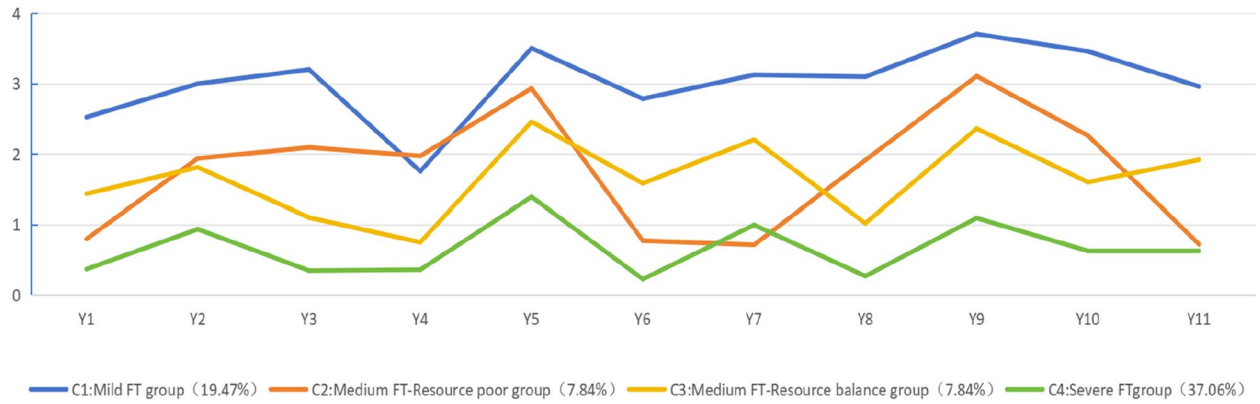

Fig. 1 Potential profile characteristics of FT in lung cancer patients

mild FT group (19.47%), C2: moderate FT-resource deficient group (7.84%), C3: moderate FT-balanced group (35.63%), and C4: severe FT group (37.06%). For further details, see Fig. 1.

Differences in financial toxicity among the four latent profiles

Individual characteristic differences among the four latent profiles are shown in Table 5. Variables such as residence, type of health insurance, employment status, education level, reimbursement ratio, household income, commercial insurance, clinical variables, lifestyle changes, medical plan changes, and seeking help from others showed significant differences among the four subgroups.

Table 6 shows a comparison of SSRS, FACT-L, CD-RISC- 10 and FHI scores and a comparison of various medical costs (total hospital costs, hospital out-of-pocket costs, out-of-pocket drug costs, room and board costs, transportation costs, and nutrition costs) for lung cancer in 4 potential FT categories. Lung cancer patient FACT-L score and its PWB score, SWB score, EWB score, FWB score, ACL score, SSRS score and objective support dimension score, CD-RISC- 10 score, FHI score and family communication and problem solving dimension score, utilization of social resources dimension score and maintaining a positive outlook dimension score, There were statistically significant differences in total hospital cost, out-of-pocket hospital cost, out-of-pocket drug cost, room and board cost and transportation cost ($P < 0.05$). The total quality of life of lung cancer patients decreased with the increase of FT severity, and the scores of PWB, SWB, EWB, FWB and ACL in the mild FT group were always higher than those in the severe FT group. There was no significant difference between the four groups

Table 5 Individual characteristics and FT scores of the four profiles ($N = 421$)

Variables	Latent profile (N [%])				H	P
	C1	C2	C3	C4		
Age, Y					4.016	0.260
≤ 45	4 (26.7)	0 (0.0)	6 (40.0)	5 (33.3)		
46 ~ 60	27 (16.3)	12 (7.2)	56 (33.7)	71 (42.8)		
61 ~ 75	43 (20.1)	18 (8.4)	81 (37.9)	72 (33.6)		
> 75	8 (30.8)	3 (11.5)	7 (26.9)	8 (30.8)		
Sex					1.279	0.734
Male	60 (20.6)	22 (7.5)	100 (34.2)	110 (37.7)		
Female	22 (17.0)	11 (8.5)	50 (38.8)	46 (35.7)		
Residence					30.719	< 0.001
Urban	35 (19.9)	3 (8.0)	43 (36.3)	21 (37.8)		
Rural	47 (14.8)	30 (9.4)	107 (33.5)	135 (42.3)		
Medical expense insurance					54.114	< 0.001
New Rural Cooperative Medical Insurance	29 (11.07)	27 (10.31)	84 (32.06)	122 (46.56)		
Medical Insurance for Urban Residents	6 (23.0)	2 (7.7)	8 (30.8)	10 (38.5)		
Medical Insurance for Urban Workers	47 (35.4)	4 (3.0)	58 (43.6)	24 (18.0)		
Employment Status					33.716	< 0.001
On the job	11 (19.0)	7 (12.0)	23 (39.7)	17 (29.3)		
Retired	45 (37.8)	5 (4.2)	48 (40.4)	21 (17.6)		
Unemployed	26 (10.7)	21 (8.6)	79 (32.4)	118 (48.3)		
Education level					27.902	< 0.001
Primary School or Below	19 (10.9)	17 (9.8)	63 (36.2)	75 (43.1)		
Junior High School/Technical Secondary School	29 (19.4)	11 (7.3)	48 (32.0)	62 (41.3)		
Minimum of Senior High School	21 (31.3)	4 (6.0)	25 (37.3)	17 (25.4)		
Junior College or Above	13 (43.3)	1 (3.3)	14 (46.7)	2 (6.7)		
Reimbursement Ratio					60.656	< 0.001
≤ 50%	16 (9.8)	20 (12.2)	47 (28.7)	81 (49.3)		
50% ~ 75%	27 (18.0)	9 (6.0)	53 (35.3)	61 (40.7)		
> 75%	39 (36.4)	4 (3.7)	50 (46.7)	14 (13.2)		
Household Monthly Income/Person (Yuan)					57.614	< 0.001
≤ 1000	16 (9.0)	20 (11.3)	49 (27.7)	92 (52.0)		
1000 ~ 2999	21 (20.0)	4 (3.8)	42 (40.0)	38 (36.2)		
3000 ~ 4999	19 (27.1)	5 (7.1)	27 (38.7)	19 (27.1)		
5000 ~ 9999	16 (32.6)	4 (8.2)	24 (49.0)	5 (10.2)		
> 10,000	10 (50.0)	0 (0.0)	8 (40.0)	2 (10.0)		
Length of Cancer Diagnosis					19.952	< 0.001
≤ 1 year	68 (22.0)	15 (4.9)	119 (38.5)	107 (34.6)		
1 ~ 5 years	12 (12.5)	17 (17.5)	25 (25.8)	43 (44.2)		
5 ~ 10 years	2 (18.2)	0 (0.0)	5 (45.5)	4 (36.3)		
> 10 years	0 (0.0)	1 (25.0)	1 (25.0)	2 (50.0)		
Number of Hospitalizations					32.168	< 0.001
≤ 3	32 (27.4)	2 (1.7)	48 (41.0)	35 (29.9)		
3 ~ 10	32 (19.7)	7 (4.3)	56 (34.6)	67 (41.4)		
10 ~ 20	14 (23.7)	9 (15.3)	17 (28.8)	19 (32.2)		
> 20	4 (4.82)	15 (18.07)	29 (34.94)	35 (42.17)		
Pathological pattern					1.182	0.757
Squamous Cell Carcinoma	16 (19.0)	6 (7.1)	34 (40.5)	28 (33.4)		
Adenocarcinoma	38 (17.9)	15 (7.1)	74 (34.9)	85 (40.1)		
Adenosquamous Carcinoma	0 (0.0)	1 (20.0)	1 (20.0)	3 (60.0)		

Table 5 (continued)

Variables	Latent profile (N [%])				H	P
	C1	C2	C3	C4		
Other Neuroendocrine Tumors	4 (33.3)	1 (8.3)	2 (16.7)	5 (41.7)		
Small Cell Cancer	24 (22.9)	10 (9.5)	37 (35.2)	34 (32.4)		
Other	0 (0.0.)	0 (0.0)	2 (66.7)	1 (33.3)		
Cancer Stage					12.765	0.005
I	4 (30.8)	0 (0.0)	4 (30.8)	5 (38.4)		
II	8 (25.0)	1 (3.1)	16 (50.0)	7 (21.9)		
III	24 (20.7)	6 (5.2)	49 (42.2)	37 (31.9)		
IV	46 (17.6)	26 (10.0)	81 (31.2)	107 (41.2)		
Distant Metastasis					21.277	< 0.001
Yes	47 (17.0)	32 (11.6)	88 (31.9)	109 (39.5)		
No	35 (24.1)	1 (0.7)	62 (42.8)	47 (32.4)		
Chemotherapy					0.804	0.849
Yes	74 (19.6)	30 (8.0)	136 (36.1)	137 (36.3)		
No	8 (18.2)	3 (6.8)	14 (31.8)	19 (43.2)		
Radiotherapy					0.563	0.905
Yes	26 (20.0)	11 (8.5)	43 (33.0)	50 (38.5)		
No	56 (19.2)	22 (7.6)	107 (36.8)	106 (36.4)		
Immunotherapy					0.900	0.825
Yes	31 (19.7)	13 (8.2)	52 (32.9)	62 (39.2)		
No	51 (19.4)	20 (7.6)	98 (37.3)	94 (35.7)		
Targeted Therapy					7.164	0.067
Yes	27 (17.9)	16 (10.6)	44 (29.1)	64 (42.4)		
No	55 (20.4)	17 (6.3)	106 (39.3)	92 (34.0)		
Operative Treatment					0.440	0.932
Yes	14 (20.0)	5 (7.1)	223 (32.9)	28 (40.0)		
No	68 (19.4)	28 (8.0)	127 (36.1)	128 (36.5)		
Change Life Style					31.572	< 0.001
Yes	62 (16.2)	32 (8.4)	138 (36.0)	151 (39.4)		
No	20 (52.6)	1 (2.6)	12 (31.6)	5 (13.2)		
Change of Medical Plan					52.499	< 0.001
Yes	0 (0.0)	0 (0.0)	3 (8.1)	34 (91.9)		
No	82 (21.3)	33 (8.6)	147 (38.3)	122 (31.8)		
Ask Others for Help					71.446	< 0.001
Yes	6 (3.9)	17 (11.0)	40 (26.0)	91 (59.1)		
No	76 (28.5)	16 (6.0)	110 (41.2)	65 (24.3)		
Access to Medical Assistance					3.683	0.298
Yes	1 (11.1)	0 (0.0)	2 (22.2)	6 (66.7)		
No	82 (19.7)	33 (8.0)	150 (35.9)	156 (36.4)		
Commercial Insurance					9.125	0.028
Yes	24 (30.4)	4 (5.1)	29 (36.7)	22 (27.8)		
No	58 (17.0)	29 (8.5)	121 (35.4)	134 (39.1)		

in the subjective support dimension and the utilization dimension of support in SSRS, and the score of the objective support dimension was the lowest in the severe FT group.

Psychological resilience was lowest in the moderate FT-resource deficient group. The total hospital expenditure, out-of-pocket hospital expenses, out-of-pocket drug expenses, room and board expenses and transportation expenses were the highest in the moderate

Table 6 Comparison of SSRS, FACT-L, CD-RISC- 10, FHI, and medical costs among patients with 4 FT potential categories of cancer ($N = 421$)

Variables	C1 $N = 82$ Mean (SD)/M (Q1,Q3)	C2 $N = 33$ Mean (SD)M (Q1,Q3)	C3 $N = 150$ Mean (SD)M (Q1,Q3)	C4 $N = 156$ Mean (SD)M (Q1,Q3)	F/H	P
FACT-L	91.12 (18.04)	79.21 (8.75)	80.73 (17.52)	71.13 (19.33)	23.243**	< 0.001
PWB	19.5 (16.75,23)	21 (18.5,23)	17 (13,21)	14.5 (11,18)	63.633*	< 0.001
SWB	17 (14.75,20)	9 (8,12.5)	15 (12,17.25)	15 (13,17)	57.493*	< 0.001
EWB	19.5 (10,20)	19 (17.5,19)	14 (7,19)	9 (4,15)	63.742*	< 0.001
FWB	14 (9,19)	6 (3,9)	11 (7,15)	9 (6,12.75)	56.205*	< 0.001
ACL	26 (20.75,29.25)	24 (21.5,28)	23 (19,28)	23 (17,27)	11.393*	0.010
SSRS	31.5 (28,35.25)	35 (30,38)	30 (28,35)	30 (27,34)	14.193*	0.003
Subjective Support	10 (8,10.25)	9 (8,10)	10 (8,10)	10 (8,11)	6.258*	0.200
Objective Support	17 (14,20)	19 (16.5,21)	16 (14,19)	15 (12,18)	25.00*	< 0.001
Utilization of Social Support	6 (4,7)	7 (4.5,9)	5 (4,7.25)	5 (4,7)	6.731*	0.081
CD-RISC- 10	26.5 (18.75,31)	7 (3,13)	20 (12,25)	18 (11,23.75)	74.872*	< 0.001
Total Hospital Expenses	40000 (20000,86250)	150000 (8000,200000)	53000 (22000,15000)	90000 (40000, 200000)	31.531*	< 0.001
Out-of-Pocket Expenses	120000 (0,23000)	60000 (25000,105000)	15000 (1125,26000)	15000 (7250,27500)	32.239*	< 0.001
Cost of Outsourcing Drugs	0 (0,10000)	8000 (320,52000)	1000 (0,16000)	6750 (0,34000)	20.679*	< 0.001
Board and Lodging Expenses	2700 (1387.5,6000)	6300 (4800,11400)	3550 (1100,9000)	4450 (1800,8362.5)	16.156*	0.001
Total Transportation Cost	1275 (415,3000)	6000 (3000,16500)	2280 (600,4400)	2000 (1090,6000)	37.479*	< 0.001
Total Nutrition Cost	400 (0,4250)	0 (0,5000)	215 (0,5000)	0 (0,3000)	0.628*	0.653

* stands for H test

** stands for F test

FT-scarce group, and the expenditure in the mild FT-poor group was lower than that in the severe FT-poor group.

Related factors associated with cancer patients' financial toxicity

The four subgroups of financial toxicity trajectories in lung cancer patients were defined as dependent variables. Independent variables included factors that demonstrated statistical significance in prior univariate analyses: residence, health insurance type, employment status, education level, reimbursement rate, household income, commercial insurance, clinical variables, lifestyle modifications, treatment plan adjustments, help-seeking behaviors, the FACT-L total score and its subscale scores (PWB, SWB, EWB, FWB, ACL), the SSRS total score along with its objective support subscale, the CD-RISC- 10 total score, the FHI total score with the family communication/problem-solving subscale, the social resource utilization subscale, the positive outlook subscale, and financial variables such as total hospitalization costs, out-of-pocket medical expenses, out-of-pocket medication costs, accommodation expenses, and transportation costs. A multinomial logistic regression model was employed for analysis. All independent variables underwent collinearity diagnostics, with tolerance values greater than 0.1 and variance inflation factors (VIF) less than 10 across all variables, confirming the absence of multicollinearity.

Multiple logistic regression analysis identified related factors for FT characteristics classification, including social support rating scale scores, emotional status dimension scores, employment status, number of hospitalizations, lifestyle changes, seeking help from others, commercial insurance, and education level. For details see Table 7.

Discussion

This study analyzed the financial toxicity (FT) among patients with lung cancer using the latent profile analysis (LPA) method, revealing the FT subgroups and associated related factors. The findings provide evidence-based data for identifying high FT risk groups and developing targeted intervention programs.

This study employed LPA to categorize FT heterogeneity in lung cancer patients. Based on FT severity and multidimensional evaluations from 11 COST-PROM items, four distinct subgroups were identified: mild FT (19.47%), moderate FT-resource deficient (7.84%), moderate FT-balanced (35.63%), and severe FT (37.06%). While prior studies stratified FT into three broad levels (mild, moderate, severe) using aggregate scores [37, 38], our analysis

Table 7 Multinomial logistic regression analysis of factors influencing FT characteristics of lung cancer patients ($N = 421$)

Group comparison	Variable	β	P	OR	OR 95% CL
C3 VS C1	**FACT-L**				
	EWB	− 0.122	0.025	0.885	(0.796,0.984)
	Employment Status (reference: Unemployed)				
	Retired	− 1.681	0.006	0.186	(0.056,0.623)
	Change Life Style (reference: No)				
	Yes	1.580	0.005	4.856	(1.601,14.730)
	Ask Others for Help (reference: No)				
	Yes	1.713	0.006	5.546	(1.558,21.289)
C4 vs C1	**SSRS**				
	SSRS	− 0.221	0.005	0.802	(0.687,0.937)
	FACT-L				
	EWB	− 0.145	0.024	0.865	(0.763,0.981)
	Employment Status (reference: Unemployed)				
	Retired	− 2.485	0.001	0.083	(0.018,0.376)
	Education Level (reference: Junior College or Above)				
	Primary School or Below	2.543	0.046	12.712	(1.046,154.520)
	Junior High School/Technical Secondary School	2.700	0.030	14.876	(1.296,170.732)
	Number of Hospitalizations (reference: > 50)				
	10 ~ 20	− 2.228	0.024	0.108	(0.016,0.741)
	Change Life Style (reference: No)				
	Yes	2.454	0.003	11.635	(2.280,59.381)
	Ask Others for Help (reference: No)				
	Yes	3.251	< 0.001	25.818	(7.103,93.842)
	Commercial Insurance (reference: No)				
	yes	− 1.430	0.015	0.239	(0.076,0.756)

a:C1: mild FT group, C2: moderate FT-deficient group; C3: moderate FT-balance group; C4: severe FT group

revealed critical heterogeneity within the moderate category. The resource-deficient subgroup demonstrated disproportionately low economic resource scores (e.g., healthcare affordability items) compared to other dimensions, falling below corresponding scores in the severe FT group. This finding necessitated multidimensional subgroup refinement, highlighting the unique contribution of economic resource indicators to FT stratification.

This study revealed a median FT score of 16 (IQR: 9–24) among lung cancer patients, with 72.53% (moderate FT-balanced/resource-deficient and severe FT groups) reporting moderate-to-severe FT, compared to 19.47% in the mild FT group. This aligns with findings in elderly Chinese cancer survivors [38] but contrasts with two prior studies: one Chinese lung cancer cohort [20] reported a higher proportion of mild FT (54.5% vs 19.47%), likely due to regional sampling limitations in our single-province cohort, while another postoperative lung cancer study [30] reported lower moderate/severe FT prevalence (13.4% vs 72.53%). This discrepancy may stem from socioeconomic differences—the surgical cohort excluded patients with financial constraints precluding surgery, whereas our study included broader socioeconomic strata. Additionally, our use of LPA for multidimensional subgrouping, rather than simple COST-PROM score thresholds, may have enhanced sensitivity in identifying economic resource-specific deficits, contributing to higher severe FT classification rates.

This study identified key factors associated with FT severity in lung cancer patients. The severe FT group exhibited significantly higher total medical expenditures, out-of-pocket payments, and medication costs compared to the mild FT group. Patients hospitalized < 20 times were more prevalent in the mild FT group (vs. moderate FT-balanced and severe FT groups). Concurrent lifestyle modifications and external support-seeking behaviors characterized moderate-to-severe FT subgroups, aligning with prior evidence linking high treatment costs to diminished quality of life, employment disruption, and household income reduction [20]. Economic adaptations included reduced discretionary spending, reliance on loans, and charitable aid [45]. Despite financial constraints, most patients remained adherent to their treatment, with only 9.6% modifying

their treatment plans in our study. less patients implemented preemptive financial planning—setting cost thresholds for treatment continuation based on prognostic and economic projections [16, 20, 46]. These findings underscore the need for clinicians to provide transparent cost–benefit discussions tailored to patients' FT profiles, facilitating informed decisions to mitigate treatment-related financial crises.

This study identified employment status as a significant predictor of FT severity in lung cancer patients. Retired patients showed higher prevalence in the mild FT group (vs. moderate/severe FT groups), likely attributable to stable pension-based income, reduced familial financial obligations (e.g., had financially independent adult children), and greater healthcare resource accessibility [47–49]. In contrast, employed patients on sick leave demonstrated elevated severe FT risk [35], while unemployed patients faced compounded financial strain from treatment cost escalation and income loss [50]. This financial-pressure cascade correlated with heightened psychological distress and increased severe FT likelihood [51], underscoring the socioeconomic dimensions of treatment-related financial burden.

Patients with a junior high school education or lower demonstrated significantly higher prevalence in severe FT versus mild FT groups, consistent with educational disparities observed in cancer-related FT studies [20]. This association may reflect limited health literacy and medical information processing capacity among less-educated patients. These findings underscore the need for culturally sensitive communication strategies, including simplified treatment explanations using visual aids and systematic family involvement to mitigate information-related distress and improve financial decision-making.

This study found that lung cancer patients with commercial insurance were more likely to belong to the mild FT group than the severe FT group. Depending on coverage specifics, commercial insurance can partially offset medical expenses through reimbursement mechanisms, thereby reducing out-of-pocket costs and mitigating financial strain [52]. Notably, only 18.76% of participants held commercial insurance, reflecting limited societal acceptance of supplemental insurance in China [53, 54]. While China's universal basic medical insurance system achieves >95% enrollment and covers most inpatient expenses [55, 56], two key barriers persist: perceived redundancy of commercial policies among economically stable patients and unaffordability for low-income households. Limited access to comprehensive treatment resources and elevated FT levels highlight the need for financial safeguards. Targeted public education addressing insurance literacy gaps could enhance awareness of commercial insurance's role in bridging coverage limitations, particularly for high-cost therapies.

China's medical insurance system is a multi-layered and diversified safeguard framework [57, 58], primarily comprising the following components: 1. Basic medical insurance, which includes urban employee basic medical insurance and basic medical insurance for both urban and rural residents; 2. Supplementary medical insurance, which mainly encompasses enterprise supplementary medical insurance, medical subsidies for civil servants, and commercial health insurance; 3. Medical assistance; and 4. Other safeguard measures, including large medical expense mutual assistance systems and social medical assistance systems. The various types of insurance differ in terms of individual contributions and reimbursement rates. In this study, the research subjects primarily relied on basic medical insurance, which aligns with the fundamental characteristics of China's social basic medical insurance and has significant clinical implications.This study revealed that the type of medical insurance among patients showed significant differences across various FT groups. The new rural cooperative medical insurance, which has a lower reimbursement ratio, constituted the highest proportion in the severe FT group, whereas the medical insurance for urban workers, which offers a higher reimbursement ratio, represented the lowest proportion in the severe FT group.

China's hybrid system of"social medical insurance + individual self-payment"has achieved universal health coverage; however, it still grapples with a relatively high proportion of individual out-of-pocket expenses. This situation arises from a combination of factors, including restrictions in the medical insurance directory, the establishment of deductibles and caps, and variations in reimbursement rates [58]. This system is fundamentally distinct from the National Health Service (NHS) in the United Kingdom, which provides free healthcare to all citizens, or the U.S. model, which is primarily driven by commercial insurance [59, 60]. Additionally, China's socio-economic conditions and healthcare system exhibit significant differences compared to those in other countries or regions, which may affect the applicability of cross-national research.

In this study, patients categorized in the mild FT group demonstrated significantly higher quality of life scores measured by the Chinese version of the Lung Cancer Patients Quality of Life Scale compared to moderate FT-resource poor, moderate FT-balance, and severe FT groups, consistent with prior findings [22]. This disparity may stem from dual factors: disease-related physical impairments and the economic constraints influencing treatment prioritization. Patients with elevated FT levels reported greater financial strain, potentially

compromising non-essential aspects of quality of life to allocate limited resources toward essential medical care [45].Notably, multivariate analysis revealed a negative correlation between emotional state scores and FT severity. Lower emotional dimension scores correlated with heightened concerns regarding disease progression and increased psychological burden, suggesting emotional distress mediates the relationship between economic strain and subjective FT perception [61]. These findings align with evidence that financial stressors exacerbate cancer-related emotional distress, potentially hindering adaptive coping mechanisms [61]. Clinical implications emphasize targeted psychosocial interventions, including cognitive-behavioral strategies and financial navigation support, to enhance emotional resilience and mitigate FT-associated psychological burdens. Healthcare providers should prioritize routine emotional assessments and implement evidence-based coping interventions for high-FT patients.

Patients with higher levels of social support were more likely to be in the mild FT group than those in the severe FT group. Previous research has shown that supportive social support can mitigate the adverse effects of financial or emotional stress on mental health [62].Compared with patients with low level of social support, less available social support and only relying on their own ability for treatment, patients with higher level of social support have more resources to obtain support from the outside world, which can relieve the economic pressure brought by paying medical expenses and reduce the pressure of patients' objective economic expenditure [63, 64]. At the same time, under the comfort and care of outside world such as friends and colleagues, it is beneficial for patients to maintain a positive psychological state, relieve the psychological pressure of patients' anxiety, further reduce the psychological distress of patients [62, 65], make patients more confident in the face of the disease, and reduce patients' FT from both subjective psychological distress and objective economic expenditure. Social support should be provided to poverty-stricken groups such as subsistence allowances or groups with family difficulties, such as free medical treatment and public welfare donations. Mobilize powerful social support at multiple levels, and provide material, information and emotional assistance through multiple resources, so that patients can feel the care from the society, with a view to reducing patients' FT.

Although monthly family income was different among the four FT characteristic groups, half (52%) of the patients with monthly family income ≤1000 yuan were in the severe FT group, while 50% of the patients with monthly family income >10,000 yuan were in the mild FT group. However, through multiple logistic regression analysis, age and family monthly income were not factors influencing the classification of FT characteristics. The reason may be that the stratification range of sample age and family monthly income in this study was different from that in previous studies, and there were differences in the study samples, resulting in a bias in the results.

Patients exhibited conflicting age-related FT risk patterns across prior studies, with some identifying advanced age and low income as predictors [38], while others linked younger age (50–59 years) and limited savings to higher FT [35]. In this study, age distribution did not differ significantly across FT severity groups. While 52% of patients with monthly household incomes ≤¥1,000 were classified into the severe FT group versus 50% of those earning >¥10,000 in the mild FT group multivariate analysis revealed no significant associations between FT severity and age or income. These inconsistencies may stem from methodological variations, including divergent age stratification and income categorization thresholds compared to prior studies [20, 35, 38], potentially introducing sampling bias. Further research using standardized socioeconomic metrics is warranted to clarify these relationships.

To address the issue of FT, especially in the context of cancer patients such as those with lung cancer, it is recommended to employ a scientific research approach combining quantitative and qualitative methods to comprehensively understand, measure, and mitigate FT [66]. Based on quantitative measurements of patients'FT levels, potential profile analysis of FT, and analysis of influencing factors, regression models or machine learning can be used to identify key predictors of FT. Additionally, focus groups or in-depth interviews with patients and their families should be conducted to gather their experiences with FT [67]. Collaborating with patients, caregivers, healthcare providers, policymakers, and insurance companies, solutions can be co-designed. Subsequently, targeted interventions tailored to different FT levels should be designed and tested, with randomized controlled trials or quasi-experimental designs used to evaluate the effectiveness of these interventions [68, 69]. Longitudinal studies should be conducted to track patients over the long term, understanding the long-term impacts of FT and interventions. Assessments should also be made on how FT evolves with treatment progress and changes in healthcare policies [70]. Currently, our research group has conducted studies on potential profile analysis of FT in lung cancer patients, analysis of influencing factors, and qualitative research on the FT experiences of patients and their caregivers. We are in the process of conducting longitudinal studies on the trajectories of FT changes in lung cancer patients. Future research is needed on FT predictors, intervention

development, and effectiveness evaluations, to gain a comprehensive understanding of FT in cancer patients and provide references for addressing or mitigating FT in this population.

LPA identified four distinct FT severity profiles among lung cancer patients, warranting tiered intervention strategies [68, 69]: Mild FT: Characterized by manageable out-of-pocket costs primarily covered by insurance/savings, with minimal income loss. Recommended interventions: (1) cost-anticipation education (e.g., treatment cost calculators, insurance navigation resources) [71]; (2) biannual financial distress screening to preempt escalation [35]. Moderate FT: Higher direct costs requiring borrowing/savings depletion, with moderate income disruption. Subgroup analysis revealed: Resource-depleted subgroup: Prioritize immediate cost-sharing solutions: insurance maximization, charity fund applications, and evidence-based treatment streamlining (e.g., eliminating redundant imaging) [69]. Balanced subgroup: Implement dual financial counseling (e.g., debt management) and cognitive-behavioral interventions to mitigate anxiety linked to financial strain [72]. Severe FT: Catastrophic costs exceeding 40% household income, correlating with treatment discontinuation risk [71]. Require urgent multimodal support: (1) emergency subsidies or government relief programs; (2) integrated mental health services (e.g., crisis counseling for depression screening-positive patients); (3) community-based resource mobilization (e.g., peer-led financial advocacy groups) [68, 69]. This stratification highlights the necessity of protocolized FT screening tools and resource-tiered intervention algorithms in oncology care pathways.

Previous studies have identified several interventions to mitigate FT in patients, including financial navigation [73–75], financial counseling [73, 76], insurance education [73, 77], multidisciplinary psychosocial support [78], and app-based economic assistance resource guides [79]. Among these, financial navigation (FN) has been proposed as a potential intervention to alleviate financial toxicity among cancer survivors. FN requires systematic identification of high-risk patients for FT throughout the cancer survivorship continuum, initiation of cost-related discussions, provision of personalized out-of-pocket (OOP) cost information and guidance tailored to individual financial circumstances, and facilitation of assistance to overcome financial hardships. Effective FN programs typically incorporate four core components: 1) assessment of financial needs, 2) enhancement of cost-related health literacy, 3) support for shared decision-making, and 4) referrals to financial assistance resources [73].

Existing research on FT interventions and their feasibility has predominantly been conducted in high-income countries, particularly the United States. However, China's healthcare system and socioeconomic environment differ substantially from Western counterparts, resulting in unique FT challenges for cancer patients that necessitate tailored interventions [73, 80]. To date, only one intervention study addressing financial toxicity has been conducted in China, which implemented and preliminarily evaluated a FN program for breast cancer patients [80]. The FN program comprised four key components:①Needs assessment module: Conducted through a self-designed cost-related health literacy questionnaire, including a brief FT introduction and evaluation of patients'informational needs. ②Cost-related health education module: Provided training in patient-physician cost communication strategies, skills for tracking treatment expenses, basic health insurance knowledge, guidance on accessing financial assistance, recommendations for reintegrating into daily life and work, and strategies for conducting family financial meetings. ③Resource/service referral module: Facilitated timely referrals to economic assistance programs and clinical professionals for unresolved issues. ④Personalized counseling module: Delivered one-on-one consultations addressing cost-related concerns and coping strategies.Participants in the intervention group received both FN and standard care, while the control group received standard care alone [80]. The results demonstrated the program's feasibility and acceptability, with significant improvements in cost-related health literacy observed in the intervention group. However, no statistically significant between-group differences in FT reduction were detected [80]. For developing FT interventions in China, this breast cancer FN program provides a foundational framework. Future studies should consider expanding to multiple research centers, diversifying sample sources, increasing sample sizes, and extending follow-up durations to enhance intervention efficacy evaluation [80].

Clinicians should utilize latent profile-derived FT risk stratification (mild, moderate, severe) to tailor risk communication strategies. For example, high-risk patients (severe FT profile) may benefit from visual aids illustrating cost-saving resources, while moderate-risk groups might require structured financial counseling to address anxiety about treatment affordability [68, 69]. This evidence-based framework informs targeted communication protocols for lung cancer patients at elevated FT risk.

Future priorities include:Longitudinal intervention studies to quantify survival and quality-of-life outcomes associated with FT mitigation strategies [68]. Precision support toolkits integrating patient-specific socioeconomic data (e.g., insurance type, caregiver availability) to automate intervention triaging. Multidisciplinary care models involving oncology social workers, financial

navigators, and mental health specialists to address intersecting economic and psychological burdens [69]. Implementing risk-stratified communication and protocolized support systems may enhance treatment adherence and reduce disparities in financial hardship among socioeconomically diverse cohorts [68, 69].

Limitations

This study has several limitations: Firstly, the issue of sample representativeness: This study selected two highly representative hospitals in Shandong Province, both of which have good representativeness in terms of hospital influence and patient sources. The general hospital has 3,246,323 outpatient and emergency visits annually, 230,546 discharges, and approximately 5,000 beds, including six departments related to lung cancer treatment. The cancer specialty hospital has 721,483 outpatient and emergency visits, 245,230 discharges, and 10 wards related to lung cancer, all covering treatment methods such as surgery, radiotherapy, chemotherapy, and targeted immunotherapy. However, the sample is still relatively limited. China's geographical and social environments are relatively complex, and there may be certain differences in results among hospitals of different sizes and levels, which may limit the universality of the conclusions. Therefore, the applicability and generalization of the conclusions of this study need further validation. Future research should consider expanding the sample sources and sample sizes across different regions, covering more areas and types of medical institutions, to improve the external validity of the conclusions. Secondly, this study adopted a convenience sampling method, selecting inpatients from the oncology departments of the two representative hospitals in Shandong Province. Since the sample selection depends on convenience, there may be selection bias, resulting in differences between the sample and the general population in terms of age, gender, education level, etc. Therefore, the universality of the research results is limited and may only be applicable to specific groups or situations. Future research can adopt random sampling or multi-site sampling to improve the representativeness of the sample and the generalization of the results.

Secondly, the issue of scale reliability and validity: Some of the scales used in this study were originally developed based on Western culture and have not been fully validated in the target culture or specific patient groups. Cultural differences and the specificity of patient groups may affect the reliability and validity of the scales. Future research should consider culturally adapting and validating the scales or developing measurement tools that are more suitable for this group.

Thirdly, the issue of confounding factors: In this study, although the authors considered multiple aspects such as sociodemographic characteristics, clinical characteristics, psychological resilience, social support, and family resilience, there may still be other unmeasured confounding factors, such as disease progression speed and comorbidities of patients. These factors may have a significant impact on FT levels, but due to research resource limitations, they could not be comprehensively collected and analyzed. Future research should further expand the scope of data collection, include more potential influencing factors, and adopt a longitudinal design to more comprehensively explore the dynamic changes and mechanisms of FT.

Fourthly, the issue of latent profile analysis: The latent profile analysis in this study was mainly based on the scores of 11 items from the COST-PROM scale and did not include other important variables that may affect FT, such as patients'economic status and utilization of medical resources. These factors may have a significant impact on FT levels, but due to research design limitations, they could not be included as classification criteria. Future research can consider incorporating multidimensional data (e.g., economic, medical, psychological, social support) into latent profile analysis to more comprehensively reflect the FT status of lung cancer patients and improve the explanatory power and practicality of the classification results.

Moreover, while this study provided detailed statistical data and charts describing the characteristics of patients in different latent classes, it lacked in-depth exploration of the underlying causes of these characteristics. Future research should conduct qualitative methods such as in-depth interviews or focus group discussions on patients in different FT groups based on latent profiles to gain a deeper understanding of FT experiences and related factors, further revealing the deep-seated reasons for FT experiences among patients with different FT levels, and providing a scientific basis for formulating targeted interventions.

Although this study collected data on patients'family per capita monthly income, total hospitalization costs, out-of-pocket expenses, and other indirect expenses (accommodation, transportation, and nutrition fees), it did not use these data to assess the latent profile analysis of patients'FT. Future research can consider incorporating multidimensional data (e.g., economic, medical, psychological, social support) into latent profile analysis to more comprehensively reflect the FT status of lung cancer patients and improve the explanatory power and practicality of the classification results.

In addition, although multiple logistic regression analysis in this study identified multiple factors affecting

FT levels, it did not explore the interactions and potential mediation among these factors. Future research will adopt structural equation modeling or path analysis models to further explore the interactions and potential mediation among factors to more comprehensively reveal the complex relationships among various influencing factors.

Then, this study mainly focused on the impact of FT on quality of life and mental health, without fully exploring the potential impact of FT on treatment adherence and prognosis. The impact of FT on lung cancer patients extends beyond the scope of quality of life and may affect treatment adherence and long-term prognosis through complex mechanisms. Future research needs to break through single-dimensional analysis, combine clinical data, policy effects, and social support networks to construct a multi-level intervention system, ultimately achieving a balance between"survival benefits"and"economic accessibility."

Finally, this study is a cross-sectional study that can only represent the current status of FT at a single point in time. FT is dynamic and persists throughout the patient's treatment process. Future research is necessary to investigate the longitudinal trends of patients'FT. Our research team is conducting longitudinal research on the FT of lung cancer patients to assess the changes in FT over time and the dynamic changes in its influencing factors, aiming to provide a scientific basis for formulating effective interventions and policies.

Conclusion

FT is prevalent among lung cancer patients, with significant heterogeneity in its characteristics and related factors. Identifying high-risk groups and implementing comprehensive, targeted interventions can alleviate FT and improve patients' quality of life. Healthcare providers and policymakers should collaborate to develop and implement effective strategies to address FT in lung cancer patients.

Implications for practice and policy

Government policymakers should:

- Policy Advocacy: Advocate for governments to formulate and implement equitable economic policies aimed at reducing income inequality and promoting social equity. This includes establishing regulatory frameworks to address systemic financial disparities that exacerbate FT among vulnerable populations.
- Insurance Coverage Expansion: Promote policies to reduce OOP healthcare expenditures, such as capping OOP cost ratios and providing targeted subsidies for unemployed individuals and low-income patients. These measures would alleviate treatment-related financial burdens and improve access to appropriate therapeutic regimens.
- Strengthening Multi-tiered Medical Security Systems: Consolidate the foundational medical security framework through a multi-tiered approach comprising basic medical insurance, critical illness insurance, and medical assistance programs, which collectively alleviate healthcare burdens across socioeconomic strata. Concurrently, enhance public awareness of insurance policies via targeted outreach campaigns to promote universal enrollment and equity. Develop supplementary commercial health insurance with innovative, tailored products, fostering differentiated growth between private and public insurance sectors. Refine medical assistance and social mutual aid mechanisms to deliver precise support for vulnerable populations, while incentivizing philanthropic and community-based initiatives. Future efforts should prioritize dismantling data silos, optimizing public–private insurance coordination, and addressing emerging challenges such as aging populations and rare diseases.
- Implementing Price Transparency and Value-Based Treatment Protocols: Enact policies mandating healthcare providers to disclose treatment costs prospectively, enabling patients to make informed decisions aligned with their financial capacity. This transparency empowers patients to prioritize clinically appropriate, cost-effective therapeutic options, thereby enhancing value-based care delivery.
- Enhancing Medical Insurance Administration and Service Quality: Infrastructure Development: Strengthen medical insurance information systems to enable real-time data interoperability. Process Optimization: Streamline reimbursement procedures and simplify administrative workflows. Governance Improvement: Intensify oversight of healthcare institutions to ensure regulatory compliance and operational efficiency. Capacity Building: Conduct specialized training for insurance personnel and establish service quality evaluation mechanisms. Patient-Centric Feedback: Implement systematic patient feedback channels to drive continuous service improvements. Strengthening Primary Healthcare Support: Allocate increased funding to primary medical institutions through elevated insurance reimbursement rates, coupled with public awareness campaigns to incentivize utilization of community-based care. This strategy alleviates pressure on tertiary hospitals while improving healthcare accessibility at the grassroots level.

Community and societal should:

- Comprehensive Policy Education Initiatives: Launch nationwide public education campaigns to enhance public understanding of multi-tier medical insurance systems through diversified outreach strategies. Concurrently, implement cancer prevention literacy programs aligned with tertiary prevention principles (primary, secondary, and tertiary) to improve population-level oncology knowledge. Systematic awareness-raising about FT should be integrated into health communication frameworks to foster societal support for vulnerable groups.
- Social Security System Optimization: Establish an integrated social safety net incorporating unemployment benefits, low-income subsidies, and elderly care provisions to ensure basic living standards during treatment. Develop strategic partnerships with accredited nonprofit organizations to deliver targeted financial assistance, effectively preventing treatment discontinuation due to economic constraints among disadvantaged populations.
- Education and Skills Development Programs: Flexible Workforce Training: Reform unemployment benefits to permit concurrent job-seeking and skill-building activities, enhancing re-employment capabilities. Industry-Aligned Curriculum: Partner with enterprises to design market-driven vocational training programs tailored for unemployed/low-income patients, focusing on emerging sector competencies. Labor Market Adaptation: Implement career counseling services to facilitate workforce reintegration amidst evolving economic demands.
- Workplace Accommodation Policies: Advocate for corporate social responsibility frameworks requiring employers to:Guarantee paid medical leave for cancer patients. Implement flexible work arrangements (e.g., remote options, adjusted schedules). Provide transitional employment support during treatment/recovery phases.
- Community Empowerment Strategies: Economic Cooperatives: Establish community-owned cooperatives to boost collective income through shared enterprise models. Social Capital Development: Strengthen volunteer networks and mutual aid systems to enhance community cohesion and crisis resilience. Quality-of-Life Enhancement: Coordinate cultural/recreational initiatives to improve psychosocial well-being across socioeconomic strata.
- Psychosocial Support Mechanisms: Structured Mental Health Services: Deliver subsidized counseling programs addressing financial stress-related anxiety/depression. Peer Support Networks: Create moderated platforms for resource/information exchange among economically vulnerable groups. Community Anchoring Programs: Facilitate social integration through mentorship partnerships and neighborhood support teams.

Healthcare provider system should:

- Systematic FT Assessment Integration: Implement routine financial toxicity screening (e.g., COST) within standard lung cancer care protocols. Nursing staff should conduct FT evaluations at admission to stratify risk levels, followed by tiered interventions:High-risk patients: Immediate referral to FN and psychological support services. Moderate-risk patients: Biweekly financial counseling sessions. All patients: Quarterly FT monitoring via validated tools to dynamically adjust intervention intensity.
- Comprehensive Cost Counseling and Treatment Optimization: Personalized Financial Navigation:Deliver comparative cost-efficacy analyses of treatment options using decision aids. Conduct insurance literacy training (public/private coverage distinctions, reimbursement mechanisms). Develop individualized budgeting plans incorporating:Household income/assets Government subsidies (e.g., critical illness support). Charity/grant eligibility. Multidisciplinary Cost-Team Collaboration:Establish clinician-financial counselor partnerships to:Co-design treatment pathways balancing clinical efficacy and affordability. Negotiate payment plans with healthcare providers. Expedite prior authorization processes.
- Patient Assistance Programs: Establishing or expanding programs that provide free or discounted medications and treatments, enabling some patients to obtain effective treatments at lower costs.
- Psychosocial Support: Promptly attending to patients'psychological conditions, identifying their psychological pressures in a timely manner, providing psychological counseling to help patients cope with the pressures brought about by economic burdens.
- Peer Support Groups: Creating platforms for experience sharing, allowing patients with the same conditions to share their disease experiences and management strategies. For example, establishing different patient groups such as newly diagnosed, stable, and recovery role model groups, setting up family-involved workshops (including medication supervision skills training), and emergency response drills (e.g., acute pain management).

- Promoting Scientific Research and Innovation: Advancing research on FT, such as developing predictive models using artificial intelligence and machine learning to predict which patients are at highest risk; testing new interventions: piloting and evaluating innovative solutions, such as digital tools for cost tracking or crowdfunding platforms.

Patient and caregiver should:

- Enhancing Disease Awareness for Patients and Caregivers: Organizing health education lectures to provide detailed information and help patients and caregivers fully understand their conditions.
- Developing Family-Based Financial Navigation Interventions and Educating Patients and Caregivers: Providing detailed information and resources to help patients understand the available treatment options and related costs for their conditions. Enabling patients and their families to have a clearer understanding of medical expenses and make more informed decisions.
- Improving Insurance Awareness for Patients and Caregivers: Offering insurance knowledge training courses for patients and caregivers, introducing insurance types, coverage, claims processes, etc.; establishing insurance advisory services in medical institutions to provide professional consultations and answer questions about insurance from patients and caregivers; providing personalized insurance consulting services and formulating suitable insurance recommendations based on patients'specific circumstances.

Abbreviations

FT	Financial toxicity
LPA	Latent profile analysis
COST-PROM	Comprehensive Scores for Financial Toxicity Based on Patient-Reported Outcome Measures
FHI	Chinese Version of the Family Hardiness Index
FACT-L	Chinese Functional Assessment of Cancer Therapy-Lung
SSRS	Social Support Rating Scale
CD-RISC- 10	Simplified Version of the 10-item Connor-Davidson Resilience Scale
FN	Financial Navigation
OOP	Out-Of-Pocket
VIF	Variance Inflation Factors

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Authors' contributions
H.Y. and Y.C. designed this study; X.Z., L.Z., Z.G, M.S., A.W., X.Z., C.L.and T.Z. collected the data; X.Z. analyed the data; X.Z. writed the Manuscript; X.Z. and H.Y. i nterpretated this data. All authors reviewed the manuscript.

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Data availability
The data sets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee on Science Research of Qilu Hospital of Shandong University, approved document number KYLL-202310–042.All study participants provided informed consent and that their anonymity was preserved, the research conforms to the provisions of the Declaration of Helsinki (as revised in Brazil 2013).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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