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Economic burden of patients with leading cancers in China: a cost-of-illness study

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Abstract

Background China accounts for 24% of newly diagnosed cancer cases and 30% of cancer-related deaths worldwide. Comprehensive analyses of the economic burden on patients across different cancer treatment phases, based on empirical data, are lacking. This study aims to estimate the financial burden borne by patients and analyze the cost compositions of the leading cancers with the highest number of new cases in China.

Methods This cross-sectional cost-of-illness study analyzed patients diagnosed with lung, breast, colorectal, esophageal, liver, or gastric cancer, identified through electronic health records (EHRs) from 84 hospitals across 17 provinces in China. Patients completed any one of the initial treatment phase, follow-up phase, and relapse/metastasis phase were recruited by trained attending physicians through a stratified sampling procedure to ensure enough cases for each cancer progression stage and cancer treatment phase. Direct and indirect costs by treatment phase were collected from the EHRs and self-reported surveys. We estimated per case cost for each type of cancer, and employed subgroup analyses and multiple linear regression models to explore cost drivers.

Results We recruited a total of 13,745 cancer patients across three treatment phases. The relapse/metastasis phase incurred the highest per case costs, varying from $8,890 to $14,572, while the follow-up phase was the least costly, ranging from $1,840 to $4,431. Being in the relapse/metastasis phase and having an advanced clinical stage of cancer at diagnosis were associated with significantly higher cost, while patients with low socioeconomic status borne lower costs.

Conclusions There were substantial financial burden on patients with six leading cancers in China. Health policymakers should emphasize comprehensive healthcare coverage for marginalized populations such as the uninsured, less educated, and those living in underdeveloped regions.

Keywords Cost-of-illness, Cancer costs, China, Treatment phases

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Background

Cancer is the second leading cause of death globally, responsible for nearly 10 million deaths in 2020, accounting for nearly one in every six deaths [1]. Also, China accounted for 24% of newly diagnosed cases and 30% of cancer-related deaths worldwide [2]. The burden of cancer has been increasing in recent decades in China [3]. At the individual level, patients pay substantially high out-of-pocket expenses on cancer treatments which may lead to catastrophic impact on the entire family [4]. Cancer also imposes a substantial economic burden at the societal level. A previous modeling study found that China accounted for 24.1% of the global economic burden of cancer from 2020 to 2050, but the direct impact on patients and their families is less frequently highlighted [5].

Numerous studies have examined the economic burden borne by patients. For example, in the US, the out-of-pocket costs of thyroid cancer diagnosis and treatment ranged from $1,425 to $17,000 [6]. Globally, studies reported the average costs of metastatic colorectal cancer ranged from $12,346 to $293,461 [7], and the direct medical costs of lung cancer ranged from $4,484 to $45,364, reflecting significant financial demands on patients [8]. In China, nationwide studies have found that the overall average expenditure per case for esophageal cancer, liver cancer, colorectal cancer, lung cancer ranged from $3,000~$10,000 [9–13]. Another study reported the average costs for lung cancer, liver cancer, esophageal cancer, and stomach cancer between 1996 and 2006 as $1,418, $1,333, $1,307, and $1,411, respectively, again emphasizing the financial challenges faced by patients [14].

Despite these findings, significant variations in cost estimates among current studies likely arise due to differences in cancer types, clinical stages, and time frames considered. Moreover, these studies were mainly focused on direct medical cost [6, 7], without accounting for the full spectrum of costs incurred by patients across different treatment phases [6–8, 15–17]. Additionally, much of the cost data in China has been collected through patient self-reports, which raises concerns about the validity and reliability of these figures. Comprehensive data on patient-incurred costs, considering various cancer types, treatment phases, and clinical stages are currently unavailable. This lack of robust data limits our understanding of the true economic burden borne by patients and hinders efforts to develop effective financial support strategies [18].

To address these gaps, we conducted a cross-sectional study in 2021 ~ 2022 to estimate the comprehensive costs of cancer borne by patients in China. We focused on costs across different treatment phases for the six leading cancers, providing a clearer picture of the financial impact on patients and their families.

Methods

Study design and data collection

We adopted a societal perspective to evaluate the economic burden borne by individuals diagnosed with the six cancers with the highest number of new cases in China in 2020: lung (815,563 cases), colorectal (555,477 cases), gastric (478,508 cases), breast (416,371 cases), liver (410,038 cases), and esophageal (324,422 cases) cancer [19]. Our study aimed to capture financial strain on patients through a national survey conducted across hospitals in 17 provinces (North: Beijing, Shanxi, Inner Mongolia, Hebei; East: Shandong, Jiangxi, Jiangsu, Zhejiang, Anhui; Middle: Henan, Hubei, Hunan; West: Sichuan, Chongqing; South: Guangdong, Hainan, Guangxi). Please refer to Supplementary Table 1 for more details of the survey sites and the hospitals. Trained attending physicians recruited patients through a stratified sampling procedure to ensure enough cases for each cancer progression stage and cancer treatment phase. The cancer treatment phases were illustrated in Fig. 1 and the details of the sample sizes were in Supplementary Table 2 [20].

Eligible patients must have completed one of the following phases between November 1, 2021, and December

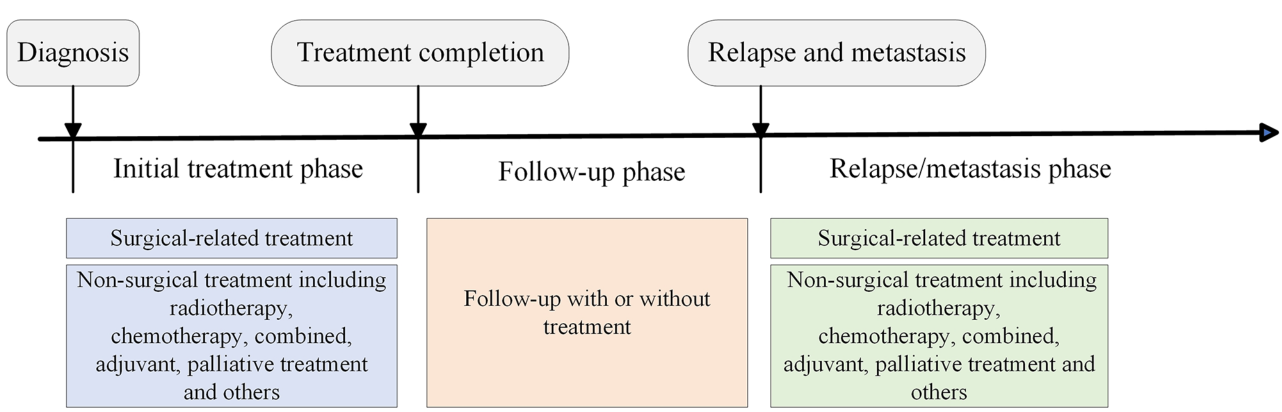

Fig. 1 Diagram of Cancer Treatment Phases Division

31, 2022: (I) the initial treatment phase, which includes surgical interventions (Ia) or non-surgical treatment interventions (Ib). Phase Ib encompasses more conservative strategies, such as radiotherapy, chemotherapy, palliative care, and traditional Chinese medicine, used when surgery is not applicable; (II) the follow-up phase, defined as the 5-year period following initial treatment, where patients who experienced no cancer relapse or metastasis for more than 5 years are considered cancer-free; and (III) the relapse/metastasis phase, during which patients experience cancer progression, relapse, or metastasis. Given the varying and often lengthy treatment durations, this approach allowed us to capture the full spectrum of patient-incurred cancer-related costs through a cross-sectional survey.

In addition to completing one of these phases, patients had to meet the following inclusion criteria: 1) they were diagnosed with one of the six cancers as the primary tumor; 2) they received treatment in the participating hospitals, with complete diagnostic and treatment information available; and 3) their medical expenses were fully documented. Patients were excluded if they had more than one primary cancer.

The socio-demographic characteristics and clinical information—including hospital location, hospital type (general or specialized), age at diagnosis, gender, education level, marital status, health insurance status, diagnostic methods, diagnosis records, treatment phases, and clinical stages—were collected through Electronic Health Records (EHRs) from the participating hospitals and supplemented by a self-reported questionnaire survey (refer to Supplementary Methods for the self-reported questionnaires). The EHRs comprise both outpatient (OPD) and inpatient (IPD) data. In the OPD, we validated diagnoses using three key factors: diagnosis codes, primary diagnosis code, and primary diagnosis name. The codes used in both OPD and IPD are based on the International Classification of Diseases, Tenth Revision (ICD-10) (Supplementary Table 3). The validation process involves the following steps: first, we verified the primary diagnosis corresponds to the cancer of interest by checking the primary diagnosis code within the diagnosis codes. Next, we selected cases where the diagnosis codes corresponded accurately with the diagnosis name. The validation method for IPD closely followed that of the OPD data. The key factors are the discharge diagnosis codes, primary discharge diagnosis code, and primary discharge diagnosis name. The process ensured that the primary discharge diagnosis code was included within the discharge diagnosis codes and matched the cancer of interest, while also aligning with the discharge diagnosis name.

We employed a bottom-up micro-costing approach [21] to quantify service and resource utilization from a societal perspective. Total costs were categorized into direct medical costs, direct non-medical costs, and indirect costs. Direct medical costs encompassed the total consumption of healthcare services, such as diagnosis costs, inpatient hospitalization stays, outpatient visits, prescription medications, emergency department visits, and nursing services, during the treatment phases. These costs were extracted from the EHRs. Costs incurred outside the participating hospitals, along with direct non-medical costs and indirect costs, were collected through a self-reported questionnaire survey administered by trained attending physicians or project field workers. Direct non-medical costs included expenses for transportation, relocation, and nutrition during the treatment process that patients usually need to pay out of pocket. Indirect costs in this study were defined as the loss of income for both patients and their informal caregivers due to absenteeism measured using the product of daily wages and days of absenteeism. The human capital approach was chosen over the friction cost approach, given the focus on the economic burden borne by patients from a societal perspective [22, 23]. Additionally, we differentiated cancer-related costs data from non-cancer visits by two ways. First, we included cases where the primary diagnosis in OPD or the primary discharge diagnosis in IPD was the cancer of interest. Second, to appropriately allocate a portion of the direct medical costs for comorbid conditions or complications, we measured the excess costs associated with comorbidities or complications using multiple regression analyses. Specifically, the logarithmic value of direct medical costs were regressed on binary indicators identifying the diagnosis of any comorbidities or complications, while controlling for factors such as age at diagnosis, sex, regional residence, education level, marital status, health insurance status, diagnosis method, treatment phases, and clinical stages.

A three-tiered quality control process was implemented to ensure the validity and reliability of cost data collected outside designated hospitals. The first level involved data collectors validated the data from the self-report form by cross-referencing it with the EHRs. The second- and third-levels involved the research supervisors from the hospitals and the National Cancer Center, who conducted further rounds of quality control and data verification.

All costs have been adjusted to 2022 currency values using the Consumer Price Index (CPI) in China and then converted to US dollars using the 2022 annual average exchange rate of 6.73 [24, 25].

Statistical analysis

We reported descriptive statistics on the per-case economic burden of cancer across three main treatment phases, including the mean, standard deviation, median, and interquartile ranges for all cost types: direct medical costs, direct non-medical costs, indirect costs, and total costs. We also calculated the proportion of direct medical costs in total costs.

Given that the economic burden may vary by age, treatment type, and health insurance coverage [6, 15], we also investigated potential cost drivers. Subgroup analyses and multiple linear models with log transformation were used to analyze the cost drivers of medical expenditure for cancer. We presented the coefficient estimates for factors such as age at diagnosis, sex, regional residence, education level, marital status, health insurance status (considering five major insurance categories per the latest national policies) [26], diagnosis method, comorbidities, complications, cancer types, treatment phases, and clinical stages [27]. These coefficients indicate how the costs for each subgroup change in relation to the reference group.

All analyses were performed using R version 4.0.1 (R Foundation for Statistical Computing, Vienna, Austria). Two-sided P value < 0.05 was considered statistically significant.

Results

The self-report survey achieved a 85.0% response rate. We recruited a total of 13,745 cancer patients across the three treatment phases (Table 1). Among them, 2,866 (20.9%) were diagnosed with lung cancer, 2,808 (20.4%) with breast cancer, 2,420 (17.6%) with colorectal cancer, 2,039 (14.8%) with gastric cancer, 1,906 (13.9%) with liver cancer, and 1,706 (12.4%) with esophageal cancer. Patients were recruited from hospitals across the north, east, middle, west, and south regions of China, with roughly half of the patients treated in general hospitals and the other half in specialized hospitals. The mean ages at diagnosis ranged from 60 to 65 years, except for breast cancer patients, who had a younger mean age of 53 years. Across most cancer types, except for breast cancer, the proportion of male patients was higher than that of female patients (28.7%~45.7%). More than half of the patients in the surgical-related treatment phase were diagnosed at early clinical stages (Stage I/II), while over 50% of patients in the systemic treatment and relapse/metastasis phases were at advanced clinical stages (Stage III/IV), with the exception of breast cancer patients. Additional demographic details are provided in Supplementary Table 4.

Table 2 and Fig. 2 show the per-case costs borne by patients at different treatment phases for each cancer type, along with a detailed breakdowns (with cancer staging information provided in Supplementary Fig. 1). The relapse/metastasis phase incurred the highest median costs for patients, ranging from $8,890 (Interquartile range: 4,939 to 15,428) to $14,572 (6,953 to 26,914), followed by the initial treatment phase, with costs ranging from $6,359 (4,187 to 10,533) to $13,704 (9,294 to 19,784). The follow-up phase had the lowest median costs, ranging from $1,840 (911 to 4,390) to $4,431 (2,235 to 11,230). Among surgical-related treatments, gastric cancer patients faced the highest median total costs ($13,398; 8,885 to 17,763), while breast cancer patients incurred the highest total costs during the non-surgical treatment phase ($9,531; 4,488 to 18,577) and the relapse/metastasis phase ($14,572; 6,953 to 26,914). Liver cancer patients faced the highest total costs during the follow-up phase ($4,431; 2,235 to 11,230). Notably, the mean direct medical expenses accounted for the largest share of the total costs, ranging from 52.6 to 87.7% across all cancer types (Table 2).

Subgroup analysis (Table 3) reveals significant variations in the economic burden on patients across different geographic regions, hospital types, diagnostic methods, treatment phases, and clinical stages. Generally, patients hospitalized in specialized hospitals (predominantly oncology hospitals in this study), those diagnosed through physical examinations, and those in the relapse/metastasis phase incurred higher treatment costs.

The associations between cost drivers and direct medical expenses are shown in Supplementary Fig. 2. Geographically, patients hospitalized in eastern and southern China incurred 13% (95% CI: 7–19%) and 14% (95% CI: 7–22%) higher medical costs, respectively, compared to those in northern regions, while patients in western regions had 24% (95% CI: 18–30%) lower costs. Patients treated in specialized hospitals faced 30% (95% CI: 26–35%) higher costs than those in general hospitals. Among demographic characteristics, patients younger than 45 years, those with higher levels of education, those who were divorced, and those with Urban Employee Basic Medical Insurance (UEBMI) coverage incurred significantly higher direct medical costs. For example, across all cancer types, direct medical costs for patients under the age of 45 were 10% higher (95% CI: 3–17%) than for individuals aged 55 to 64. Similarly, direct medical costs were 9% higher (95% CI: 1–16%) for patients with primary education, 15% higher (95% CI: 7–22%) for those with secondary education, and 14% higher (95% CI: 4–23%) for those with post-secondary education compared to those with no schooling. Divorced patients incurred 20% greater direct medical costs (95% CI: 5–35%) than married patients. Individuals with UEBMI coverage had medical expenses that were 55% (95% CI: 47–63%) higher than those who were uninsured and 19% (95% CI: 15–24%) higher than those with Urban and Rural Residents' Basic Medical Insurance (URRBMI). In terms of disease characteristics, cancer complications were associated with a 17% increase in costs (95% CI: 10–24%) across all cancer types. Patients identified

Table 1 Characteristics of included cancer cases across different treatment phases

	Lung cancer	Breast cancer	Colorectal cancer	Esophageal cancer	Liver cancer	Gastric cancer
Phase Ia (Surgical-related treatment), *N* *=3738						
	N=717	*N*=824	*N*=778	*N*=376	*N*=389	*N*=654
Region, ***N*(%)**						
North	202 (28.2)	236 (28.6)	139 (17.9)	51 (13.6)	81 (20.8)	199 (30.4)
East	182 (25.4)	193 (23.4)	213 (27.4)	140 (37.2)	92 (23.7)	148 (22.6)
Middle	128 (17.9)	176 (21.4)	154 (19.8)	79 (21.0)	68 (17.5)	111 (17.0)
South	88 (12.3)	80 (9.7)	91 (11.7)	35 (9.3)	64 (16.5)	67 (10.2)
West	117 (16.3)	139 (16.9)	181 (23.3)	71 (18.9)	84 (21.6)	129 (19.7)
Hospital type, ***N*(%)**						
General hospital	323 (45.0)	387 (47.0)	432 (55.5)	170 (45.2)	161 (41.4)	253 (38.7)
Specialized hospital	394 (55.0)	437 (53.0)	346 (44.5)	206 (54.8)	228 (58.6)	401 (61.3)
Age at diagnosis						
Years, mean (SD)	60 (11)	53 (11)	63 (11)	65 (9)	60 (10)	62 (11)
Gender, ***N*(%)**						
Male	388 (54.1)	7 (0.8)	478 (61.4)	306 (81.4)	302 (77.6)	468 (71.6)
Female	329 (45.9)	817 (99.2)	300 (38.6)	70 (18.6)	87 (22.4)	186 (28.4)
Clinical stage**, ***N*(%)**						
I	384 (53.6)	338 (41.0)	230 (29.6)	114 (30.3)	137 (35.2)	201 (30.7)
II	151 (21.1)	281 (34.1)	210 (27.0)	114 (30.3)	111 (28.5)	159 (24.3)
III	126 (17.6)	164 (19.9)	234 (30.1)	117 (31.1)	97 (24.9)	202 (30.9)
IV	56 (7.8)	41 (5.0)	104 (13.4)	31 (8.2)	44 (11.3)	92 (14.1)
Phase Ib (Non-surgical treatment), ***N*=5,940**						
	N=1,256	*N*=1,282	*N*=1,006	*N*=719	*N*=914	*N*=763
Region, ***N*(%)**						
North	200 (15.9)	327 (25.5)	262 (26.0)	57 (7.9)	147 (16.1)	200 (26.2)
East	307 (24.4)	224 (17.5)	194 (19.3)	251 (34.9)	221 (24.2)	213 (27.9)
Middle	320 (25.5)	335 (26.1)	244 (24.3)	156 (21.7)	236 (25.8)	158 (20.7)
South	126 (10.0)	191 (14.9)	141 (14.0)	91 (12.7)	158 (17.3)	79 (10.4)
West	303 (24.1)	205 (16.0)	165 (16.4)	164 (22.8)	152 (16.6)	113 (14.8)
Hospital type, ***N*(%)**						
General hospital	739 (58.8)	579 (45.2)	601 (59.7)	342 (47.6)	464 (50.8)	356 (46.7)
Specialized hospital	517 (41.2)	703 (54.8)	405 (40.3)	377 (52.4)	450 (49.2)	407 (53.3)
Age at diagnosis						
Years, mean (SD)	63 (9)	52 (10)	60 (11)	65 (10)	59 (12)	61 (11)
Gender, ***N*(%)**						
Male	896 (71.3)	10 (0.8)	636 (63.2)	592 (82.3)	741 (81.1)	529 (69.3)
Female	360 (28.7)	1,272 (99.2)	370 (36.8)	127 (17.7)	173 (18.9)	234 (30.7)
Clinical stage**, ***N*(%)**						
I	229 (18.2)	317 (24.7)	185 (18.4)	77 (10.7)	166 (18.2)	93 (12.2)
II	205 (16.3)	429 (33.5)	271 (26.9)	178 (24.8)	228 (24.9)	194 (25.4)
III	377 (30.0)	306 (23.9)	312 (31.0)	270 (37.6)	288 (31.5)	234 (30.7)
IV	445 (35.4)	230 (17.9)	238 (23.7)	194 (27.0)	232 (25.4)	242 (31.7)
Phase II (Follow-up treatment), ***N*=1,554**						
	N=283	*N*=256	*N*=262	*N*=282	*N*=201	*N*=270
Region, ***N*(%)**						
North	26 (9.2)	43 (16.8)	12 (4.6)	15 (5.3)	6 (3.0)	32 (11.9)
East	73 (25.8)	80 (31.2)	103 (39.3)	83 (29.4)	49 (24.4)	79 (29.3)
Middle	67 (23.7)	37 (14.5)	69 (26.3)	49 (17.4)	30 (14.9)	32 (11.9)
South	57 (20.1)	36 (14.1)	25 (9.5)	71 (25.2)	65 (32.3)	65 (24.1)
West	60 (21.2)	60 (23.4)	53 (20.2)	64 (22.7)	51 (25.4)	62 (23.0)
Hospital type, ***N*(%)**						
General hospital	124 (43.8)	109 (42.6)	159 (60.7)	124 (44.0)	56 (27.9)	107 (39.6)
Specialized hospital	159 (56.2)	147 (57.4)	103 (39.3)	158 (56.0)	145 (72.1)	163 (60.4)

Table 1 (continued)

	Lung cancer	Breast cancer	Colorectal cancer	Esophageal cancer	Liver cancer	Gastric cancer
Age at diagnosis						
Years, mean (SD)	61 (11)	53 (11)	62 (11)	64 (9)	60 (12)	61 (11)
Gender, ***N*(%)**						
Male	173 (61.1)	3 (1.2)	161 (61.5)	233 (82.6)	169 (84.1)	173 (64.1)
Female	110 (38.9)	253 (98.8)	101 (38.5)	49 (17.4)	32 (15.9)	97 (35.9)
Clinical stage**, ***N*(%)**						
I	100 (35.3)	67 (26.2)	52 (19.8)	66 (23.4)	62 (30.8)	65 (24.1)
II	66 (23.3)	70 (27.3)	80 (30.5)	77 (27.3)	44 (21.9)	64 (23.7)
III	62 (21.9)	55 (21.5)	96 (36.6)	81 (28.7)	55 (27.4)	63 (23.3)
IV	55 (19.4)	64 (25.0)	34 (13.0)	58 (20.6)	40 (19.9)	78 (28.9)
Phase III (Treatment after relapse/metastasis), ***N*=2,513**						
	N=610	*N*=446	*N*=374	*N*=329	*N*=402	*N*=352
Region, ***N*(%)**						
North	84 (13.8)	47 (10.5)	56 (15.0)	33 (10.0)	35 (8.7)	58 (16.5)
East	148 (24.3)	111 (24.9)	102 (27.3)	78 (23.7)	102 (25.4)	129 (36.6)
Middle	138 (22.6)	87 (19.5)	83 (22.2)	75 (22.8)	108 (26.9)	68 (19.3)
South	67 (11.0)	103 (23.1)	53 (14.2)	54 (16.4)	72 (17.9)	49 (13.9)
West	173 (28.4)	98 (22.0)	80 (21.4)	89 (27.1)	85 (21.1)	48 (13.6)
Hospital type, ***N*(%)**						
General hospital	326 (53.4)	179 (40.1)	205 (54.8)	142 (43.2)	203 (50.5)	156 (44.3)
Specialized hospital	284 (46.6)	267 (59.9)	169 (45.2)	187 (56.8)	199 (49.5)	196 (55.7)
Age at diagnosis						
Years, mean (SD)	63 (9)	53 (11)	60 (12)	64 (10)	58 (12)	63 (11)
Gender, ***N*(%)**						
Male	421 (69.0)	2 (0.4)	226 (60.4)	269 (81.8)	323 (80.3)	250 (71.0)
Female	189 (31.0)	444 (99.6)	148 (39.6)	60 (18.2)	79 (19.7)	102 (29.0)
Clinical stage**, ***N*(%)**						
I	83 (13.6)	68 (15.2)	30 (8.0)	36 (10.9)	63 (15.7)	34 (9.7)
II	62 (10.2)	98 (22.0)	53 (14.2)	54 (16.4)	66 (16.4)	51 (14.5)
III	130 (21.3)	108 (24.2)	90 (24.1)	87 (26.4)	113 (28.1)	84 (23.9)
IV	335 (54.9)	172 (38.6)	201 (53.7)	152 (46.2)	160 (39.8)	183 (52.0)

Note * *N* stands for the number of cases counted

** Clinical stage at diagnosis

through screenings incurred 22% more costs (95% CI: 9–35%) than those diagnosed from symptoms. Costs increased with clinical stage: Stage II, III, and IV diagnoses led to 9% (95% CI: 4–14%), 26% (95% CI: 21–31%), and 32% (95% CI: 26–38%) higher direct medical costs, respectively, compared to Stage I.

Table 4 indicates the population attributable fraction of costs of complications and the cancer-related per case direct medical costs for the six cancer types. We found the existence of complications was associated with 30% (95% CI: 14– 46%), 22% (95% CI: 3– 41%), and 38% (95% CI: 21 – 54%) increase of direct medical costs for lung cancer, breast cancer, and esophageal cancer, respectively. The population attributable fraction percentage of costs associated with complication is no higher than 5.9% for all cancer types. We did not find statistically significant differences for the estimates of comorbidities on direct medical costs.

Discussion

This study is the first to present a comprehensive analysis that estimated the economic burden on patients with leading cancers in China. We assessed the per-case financial burden on patients across three main treatment phases. Notably, patients in the relapse/metastasis phase faced the highest costs, ranging from $8,890 to $14,572. Additionally, our findings highlight that hospital location, hospital type, clinical stage at diagnosis, and patient demographics significantly influence the financial burden on individuals undergoing cancer treatment.

Previous studies on the cost of illness in China [9–13] have documented direct medical costs ranging from $3,000 to $10,000. In contrast, studies from other regions globally [7, 8, 28, 29] report medical expenses ranging from $1,000 to $45,000. In our study, the medical expenditures by cancer patients for initial treatment had a median range of $4,685 to $12,024 and a

Table 2 Per case direct and indirect costs (US$) of six cancers by treatment phases and cancer types

Treatment phases	Cancer sites	Direct medical costs			Direct non-medical costs			Indirect costs			Total costs	
		Mean (SD)	Median (Q1 - Q3)	%	Mean (SD)	Median (Q1 - Q3)	%	Mean (SD)	Median (Q1 - Q3)	%	Mean (SD)	Median (Q1 - Q3)
Surgical-related treatment	Lung, N = 717	11,911 (52,251)	8,361(5,920 – 11,139)	87.7	402 (704)	164 (61–446)	3.0	1,273 (2,288)	606 (249–1,445)	9.4	13,586 (52,346)	9,684 (6,788 – 13,033)
	Breast N = 824	8,622 (18,276)	4,685(3,157–7,673)	71.8	701 (1,742)	223 (74–606)	5.8	2,693 (11,100)	611 (170–1,869)	22.4	12,016 (22,602)	6,359 (4,187 – 10,533)
	Colorectal, N = 778	11,351 (11,081)	9,135(6,910 – 12,119)	82.9	773 (3,255)	267(105–594)	5.6	1,567 (3,866)	557 (166–1,466)	11.4	13,690 (13,714)	10,583 (7,968 – 14,299)
	Esophageal, N = 376	13,386 (17,056)	11,422(7,970 – 15,157)	83.5	463 (584)	297(117–570)	2.9	2,178 (9,431)	623 (163–1,828)	13.6	16,026 (20,119)	13,398 (8,885 – 17,763)
	Liver, N = 389	10,420 (7,468)	8,950(5,944 – 12,482)	85.4	510 (924)	232 (89–530)	4.2	1,275 (2,689)	489 (133–1,320)	10.4	12,205 (8,604)	10,249 (7,156 – 14,100)
	Gastric, N = 654	14,366 (14,470)	12,024(7,951 – 17,280)	84.8	861 (1,657)	303(134–903)	5.1	1,721 (7,087)	608 (146–1,554)	10.2	16,949 (17,582)	13,704 (9,294 – 19,784)
Non-surgical treatment	Lung, N = 1,256	9,070 (12,623)	5,406(2,288 – 10,884)	76.8	696 (3,091)	236 (91–609)	5.9	2,050 (4,866)	801 (265–1,954)	17.3	11,816 (15,020)	7,270 (3,427 – 14,314)
	Breast, N = 1,282	11,118 (15,114)	7,082(2,972 – 14,578)	75	864 (2,034)	297 (91–789)	5.8	2,846 (6,881)	733 (174–2,552)	19.2	14,829 (18,677)	9,531 (4,488 – 18,577)
	Colorectal, N = 1,006	10,285 (18,918)	5,975(2,204 – 13,206)	76.3	829 (2,240)	297(121–758)	6.2	2,362 (6,861)	725 (186–2,030)	17.5	13,476 (21,188)	7,964 (3,581 – 17,928)
	Esophageal, N = 719	10,171 (13,041)	6,704(2,593 – 12,867)	78.1	669 (954)	321(125–743)	5.1	2,175 (4,617)	814 (208–2,443)	16.7	13,015 (14,498)	8,642 (4,217 – 16,779)
	Liver, N = 914	9,308 (15,772)	5,063(2,567 – 10,077)	77.1	579 (1,266)	217 (74–594)	4.8	2,194 (7,398)	565 (187–1,583)	18.2	12,080 (19,400)	6,757 (3,528 – 12,855)
	Gastric, N = 763	9,690 (31,379)	4,976(1,934 – 10,401)	75.4	1,040 (2,646)	357(104–970)	8.1	2,124 (8,568)	570 (113–1,790)	16.5	12,853 (33,778)	6,925 (2,882 – 13,890)
Follow-up	Lung, N = 283	4,726 (8,794)	1,448 (611–4,458)	63.2	493 (969)	157 (64–465)	6.6	2,262 (8,987)	326 (60 – 1,241)	30.2	7,481 (13,511)	2,766 (1,222–8,384)
	Breast, N = 256	6,057 (9,803)	1,697 (813–7,521)	75.2	739 (1,560)	178 (75–606)	9.2	1,259 (3,362)	244 (11–659)	15.6	8,056 (12,086)	2,453 (1,290 – 10,737)

Table 2 (continued)

Treatment phases	Cancer sites	Direct medical costs			Direct non-medical costs			Indirect costs			Total costs	
		Mean (SD)	Median (Q1 - Q3)	%	Mean (SD)	Median (Q1 - Q3)	%	Mean (SD)	Median (Q1 - Q3)	%	Mean (SD)	Median (Q1 - Q3)
	Colorectal, *N* = 262	8,276 (18,342)	2,011 (708–9,012)	82.1	694 (1,411)	210 (76–594)	6.9	1,113 (2,687)	259 (34–957)	11	10,083 (20,140)	3,047 (1,079 – 10,238)
	Esophageal, *N* = 282	4,170 (6,827)	1,272 (523–4,477)	52.6	760 (1,308)	338(149–833)	9.6	3,002 (7,574)	497 (50 – 2,932)	37.8	7,932 (11,331)	3,379 (1,226 – 10,777)
	Liver, *N* = 201	6,487 (8,585)	3,031(1,226–7,429)	75.4	590 (1,476)	152 (91–446)	6.9	1,530 (2,319)	526 (61 – 1,767)	17.8	8,607 (10,281)	4,431 (2,235 – 11,230)
	Gastric, *N* = 270	5,587 (15,974)	1,038 (540–2,716)	78.9	378 (809)	154 (83–340)	5.3	1,116 (2,841)	202 (30–826)	15.8	7,082 (16,717)	1,840 (911–4,390)
Treatment after relapse/metastasis -	Lung, *N* = 610	13,461 (25,198)	7,671(3,043 – 15,423)	78.7	892 (1,914)	318(138–892)	5.2	2,747 (5,380)	748 (177–2,655)	16.1	17,100 (27,259)	10,180 (4,686 – 20,701)
	Breast, *N* = 446	16,452 (18,221)	10,975(5,201 – 21,428)	77.8	889 (1,996)	300(143–743)	4.2	3,810 (13,304)	872 (244–3,053)	18	21,151 (24,360)	14,572 (6,953 – 26,914)
	Colorectal, *N* = 374	13,368 (16,694)	8,507(3,813 – 17,139)	74.5	974 (2,047)	344(136–888)	5.4	3,599 (14,526)	997 (249–3,257)	20.1	17,942 (24,457)	11,761 (5,247 – 22,718)
	Esophageal, *N* = 329	11,975 (15,593)	8,033(3,180 – 14,724)	72.1	1,002 (1,525)	461(152–1,048)	6	3,628 (9,110)	1,163(261–3,083)	21.8	16,605 (20,035)	10,947 (5,208 – 20,654)
	Liver, *N* = 402	11,328 (18,846)	7,025(3,053 – 14,496)	80	523 (875)	178 (92–594)	3.7	2,315 (5,468)	803 (244–2,280)	16.3	14,166 (20,647)	9,029 (4,147 – 17,584)
	Gastric, *N* = 352	10,382 (14,406)	7,123(3,484 – 12,428)	77.9	720 (1,376)	251 (91–743)	5.4	2,229 (3,829)	884 (299–2,443)	16.7	13,332 (16,623)	8,890 (4,939 – 15,428)

Note N stands for the number of cases counted. Q1: 25% quantile, Q3: 75% quantile. "%" means the proportions of direct medical costs, direct non-medical costs, and indirect costs in the total costs

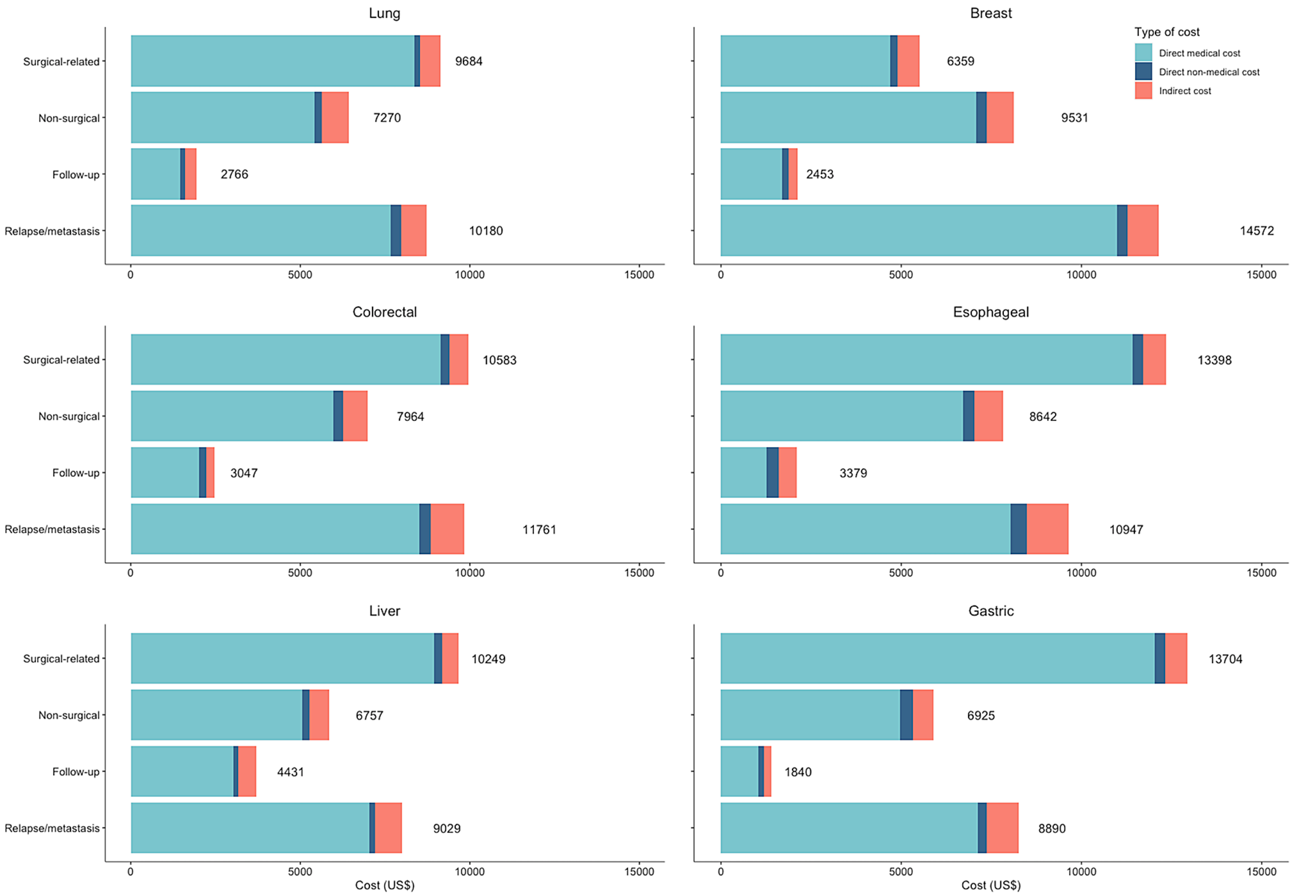

Fig. 2 The median of per case costs of six cancers by treatment phases in China (in US dollars at constant 2022 prices)

mean of $8,622 to $14,366. These findings are close to those of the cost-of-illness studies in China. Some discrepancies in cost estimates compared to studies from other countries [30] are largely due to variations that likely arise from differences in economic contexts, healthcare systems, and market disparities across regions [31].

Furthermore, Sorensen et al. [32] found that treatment-related costs, including both active treatment and supportive care, accounted for 75% of total expenditures, a finding that aligns closely with our results. In our study, the surgical-related and relapse/metastasis phases consistently emerged as the most expensive for patients [31]. This insight helps identify the most financially demanding phases in the cancer treatment course and suggests a need to rethink medical reimbursement strategies for different treatment stages. It also underscores the importance of preventing cancer relapse/metastasis to substantially lower medical costs. Moreover, we found that individuals detected through screening incurred higher initial costs than those diagnosed based on symptoms. This is because participants detected by screening tend to undergo more examinations to reach a definitive diagnosis, leading to increased expenses. However, screening programs are intended to lead to earlier detection of disease and better prognoses, which can be cost-effective in the long term by potentially reducing the costs of advanced disease treatment. Additionally, the increase in health expenditures may result from the intended effects of screening, as patients with better health awareness—who participate in screenings—are more likely to invest more in their medical care [33].

Our study also identified several factors associated with higher costs for patients. Generally, we found that in different treatment phases, the highest-cost cancer varies, reflecting the differences in disease or therapy characteristics. Thus, tailored medical or social

Table 3 Subgroup analysis of per case medical expenditure (US$) of six cancers

	Lung cancer		Breast cancer		Colorectal cancer		Esophageal cancer		Liver cancer		Gastric cancer	
	Mean (95% CI)	**P-Value***	**Mean (95% CI)**	***P*-Value***	**Mean (95% CI)**	**P-Value***	**Mean (95% CI)**	***P*-Value***	**Mean (95% CI)**	***P*-Value***	**Mean (95% CI)**	***P*-Value***
Overall	10,286 (9,187, 11,386)		10,772 (10,161, 11,382)		10,886 (10,232, 11,541)		10,236 (9,566, 10,905)		9,663 (9,005, 10,322)		10,766 (9,782, 11,749)	
Region		< 0.001		< 0.001		< 0.001		< 0.001		< 0.001		< 0.001
North	10,530 (5,201, 15,859)		9,453 (8,609, 10,297)		12,553 (10,709, 14,397)		7,570 (6,353, 8,786)		8,476 (6,915, 10,038)		14,221 (12,771, 15,672)	
East	11,852 (10,722, 12,983)		12,462 (11,053, 13,872)		11,407 (10,319, 12,495)		11,040 (9,663, 12,417)		9,935 (8,433, 11,437)		11,342 (8,271, 14,413)	
Middle	11,410 (9,600, 13,221)		10,827 (9,259, 12,395)		9,121 (8,312, 9,930)		10,555 (9,378, 11,733)		9,815 (8,635, 10,994)		10,498 (9,289, 11,706)	
South	11,015 (9,621, 12,410)		14,851 (12,811, 16,891)		16,262 (13,393, 19,131)		13,633 (11,469, 15,797)		12,115 (10,150, 14,080)		7,020 (6,223, 7,817)	
West	6,891 (6,150, 7,632)		7,038 (6,244, 7,832)		7,138 (6,055, 8,222)		7,670 (6,515, 8,824)		7,638 (6,636, 8,639)		8,083 (6,827, 9,338)	
Hospital type		< 0.001		< 0.001		< 0.001		< 0.001		< 0.001		< 0.001
General hospital	9,098 (7,130, 11,066)		7,579 (6,969, 8,190)		9,939 (9,122, 10,755)		9,029 (7,965, 10,093)		8,101 (7,344, 8,859)		9,848 (8,705, 10,991)	
Specialized hospital	11,613 (10,849, 12,377)		13,348 (12,379, 14,316)		12,181 (11,111, 13,250)		11,247 (10,402, 12,092)		11,014 (9,982, 12,047)		11,452 (9,960, 12,943)	
Diagnostic method		< 0.001		< 0.001		0.083		0.4		< 0.001		< 0.001
Free screening by government	7,610 (5,815, 9,405)		16,058 (11,686, 20,431)		10,528 (7,825, 13,230)		7,300 (5,797, 8,804)		17,881 (9,337, 26,426)		16,861 (1,357, 35,080)	
Physical examination	12,655 (8,344, 16,966)		12,337 (10,690, 13,983)		14,077 (10,495, 17,658)		11,930 (9,522, 14,338)		10,253 (9,096, 11,411)		13,982 (11,975, 15,989)	
Incidentally detected	10,487 (8,880, 12,094)		8,454 (5,421, 11,488)		10,241 (8,081, 12,400)		10,760 (6,817, 14,704)		11,352 (8,563, 14,142)		10,422 (7,683, 13,160)	
With symptoms	9,566 (8,805, 10,327)		10,336 (9,665, 11,008)		10,528 (9,882, 11,173)		10,075 (9,357, 10,793)		9,083 (8,290, 9,877)		10,264 (9,165, 11,362)	
Comorbidity		0.2		0.4		0.5		0.2		< 0.001		0.2
Yes	10,332 (9,419, 11,245)		10,286 (9,272, 11,300)		10,771 (9,337, 12,206)		11,194 (9,798, 12,591)		10,581 (9,600, 11,562)		10,199 (9,103, 11,295)	
No	10,263 (8,666, 11,859)		10,949 (10,202, 11,696)		10,944 (10,273, 11,615)		9,838 (9,088, 10,588)		8,787 (7,906, 9,669)		11,078 (9,677, 12,479)	
Complication		< 0.001		0.091		0.4		< 0.001		0.051		0.9
Yes	15,832 (10,152, 21,512)		10,743 (8,464, 13,021)		11,200 (9,289, 13,112)		13,816 (11,412, 16,221)		13,935 (9,924, 17,946)		13,214 (5,107, 21,321)	
No	9,888 (8,783, 10,993)		10,773 (10,143, 11,403)		10,854 (10,159, 11,549)		9,641 (8,973, 10,309)		9,185 (8,608, 9,762)		10,516 (9,809, 11,222)	
Treatment phases		< 0.001		< 0.001		< 0.001		< 0.001		< 0.001		< 0.001

Table 3 (continued)

	Lung cancer		Breast cancer		Colorectal cancer		Esophageal cancer		Liver cancer		Gastric cancer	
	Mean (95% CI)	**P-Value***	**Mean (95% CI)**	***P*-Value***	**Mean (95% CI)**	**P-Value***	**Mean (95% CI)**	***P*-Value***	**Mean (95% CI)**	***P*-Value***	**Mean (95% CI)**	***P*-Value***
Initial	10,102 (8,641, 11,563)		10,142 (9,438, 10,845)		10,750 (10,007, 11,492)		11,275 (10,408, 12,142)		9,640 (8,888, 10,392)		11,848 (10,538, 13,158)	
Follow-up	4,726 (3,697, 5,755)		6,057 (4,851, 7,264)		8,276 (6,044, 10,507)		4,170 (3,370, 4,970)		6,487 (5,293, 7,681)		5,587 (3,673, 7,501)	
Relapse/metastasis	13,461 (11,458, 15,465)		16,452 (14,756, 18,148)		13,368 (11,671, 15,066)		11,975 (10,284, 13,666)		11,328 (9,480, 13,176)		10,382 (8,872, 11,892)	
Clinical stages		0.045		< 0.001		< 0.001		0.077		0.4		0.3
I	10,141 (6,686, 13,597)		7,859 (7,053, 8,666)		9,658 (7,856, 11,459)		9,681 (7,904, 11,458)		9,120 (7,822, 10,418)		9,945 (8,449, 11,442)	
II	8,718 (7,735, 9,701)		9,415 (8,510, 10,319)		8,951 (8,245, 9,657)		9,304 (8,223, 10,386)		8,745 (7,797, 9,694)		9,726 (8,305, 11,146)	
III	10,453 (9,465, 11,441)		12,599 (10,959, 14,238)		10,086 (9,309, 10,862)		11,053 (9,785, 12,321)		10,883 (9,250, 12,515)		9,833 (8,940, 10,727)	
IV	11,137 (9,678, 12,597)		15,378 (13,665, 17,090)		15,021 (13,159, 16,882)		10,471 (9,142, 11,801)		9,602 (8,503, 10,700)		13,040 (10,146, 15,933)	

policies are needed for various cancer types taking the treatment phases into consideration. Patients treated in specialized hospitals incurred higher costs, which may be attributed to more advanced treatments, specialized staff, and state-of-the-art equipment available in these institutions, offering more comprehensive and personalized care. A more advanced clinical stage at diagnosis was also a significant driver of higher costs. This finding underscores the importance of early diagnosis and treatment to not only improve patient outcomes but also reduce the financial burden on patients [34].

Our findings also revealed lower medical costs among marginalized populations, which likely reflect financial hardship and underutilization of healthcare services. A study in China reported disparities in cancer diagnosis rates between rural and urban areas, suggesting that residents in rural areas may not receive timely or adequate cancer prevention and treatment services [35]. These findings emphasize the existence of inequalities in healthcare access, financing, and outcomes across different population groups [36]. This highlights the need for targeted policies to ensure equitable access to healthcare, particularly for underserved populations.

There are a few limitations in this study. Firstly, the non-randomized sampling method may affect the representativeness of the study sample. To address this, we implemented a stratified sampling procedure to mitigate this issue, ensuring the sample retains a degree of representativeness. Secondly, the cross-sectional nature of this study means that we observed the treatment course within a specific time frame, potentially underestimating the lifelong economic burden on patients. While longitudinal studies would provide more comprehensive data, they are currently difficult to conduct. Thirdly, we only covered 17 out of the 34 provincial administrations in China. Data in some remote areas like Xinjiang and Tibet were missing in this study and should be taken into consideration in further studies. Fourthly, our primary analysis did not specifically differentiate between cancer-related and non-cancer-related costs. However, the relatively low population attributable fraction of costs (no higher than 5.9%) further supports the notion that our results primarily reflected the economic burden caused by cancer-related medical services. This suggests that the main results of this study were indeed indicative of the financial impact related to cancer, as well as the burden faced by cancer patients. Finally, the generalizability of this study to other countries is closely related to whether the local cancer treatment methods and technological levels are similar to those in China.

Table 4 Impact of complications on direct medical cots across different cancer types

		Lung cancer	Breast cancer	Colorectal cancer	Esophageal cancer	Liver cancer	Gastric cancer
Complication rate		192/2866 (7.2%)	121/2808 (4.5%)	227/2420 (10.4%)	243/1706 (16.6%)	192/1906 (11.2%)	189/2039 (10.2%)
CIC (Cost increment associated with complication)		30% (14– 46%)	22% (3– 41%)	4% (-11 – 19%)	38% (21 – 54%)	8% (-8 – 24%)	2% (-15 – 19%)
Per case direct medical costs	Surgical-related treatment	11,911	8622	11,351	13,386	10,420	14,366
	Non-surgical treatment	9070	11,118	10,285	10,171	9308	9690
	Follow-up treatment	4726	6057	8276	4170	6487	5587
	Treatment after relapse/metastasis	13,461	16,452	13,368	11,975	11,328	10,382
PAF%*		2.1%	1%	0.4%	5.9%	2.4%	2.2%
Cancer-related direct medical costs per case**	Surgical-related treatment	11,660	8537	11,304	12,591	10,169	14,050
	Non-surgical treatment	8879	11,009	10,243	9567	9084	9477
	Follow-up treatment	4626	5998	8242	3922	6331	5464
	Treatment after relapse/metastasis	13,177	16,291	13,313	11,264	11,056	10,154

Note *PAF%, Population Attributable Fraction %, calculated by: complication rate* CIC/(complication rate* CIC + 1)

** Cancer-related direct medical costs per case = Per case direct medical costs * PAF%

Conclusions

The six leading cancers in China impose a substantial financial burden on patients. Key factors influencing these costs include patient demographics, disease stage at diagnosis, and geographic location. The relapse/metastasis treatment phase and advanced clinical staging at diagnosis are associated with significantly higher costs, underscoring the critical importance of early diagnosis and consistent follow-up care to mitigate financial strain on patients. Additionally, patients with lower levels of education, those without UEBMI, and those residing in less developed regions face greater financial challenges due to insufficient healthcare provision. These findings highlight the need for targeted policy interventions to reduce the economic burden on vulnerable patient populations and ensure equitable access to cancer care across different regions and socioeconomic groups.

Abbreviations

EHR Electronic health records
CPI Consumer Price Index
UEBMI Urban Employee Basic Medical Insurance
URRBMI Urban and Rural Residents' Basic Medical Insurance

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions

Concept and design: Y.Y., F.X, G.G.L.Acquisition of data: Y.Y.Analysis and interpretation of data: Z.W., Y.Y.Drafting of the manuscript: Z.W., Y.Y.Critical revision of the paper for important intellectual content: Z.W., Y.Y., F. X., Q. C., C.Z., S. C., G.G.L.Obtaining funding: Y.Y., G.G.L.Administrative, technical, or logistic support: Z.W., Y.Y., G.G.L.Supervision: F.X, G.G.L. All authors reviewed the manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the ethics committees of the China National Cancer Center/Cancer Hospital, the Chinese Academy of Medical Sciences, Peking Union Medical College, and all hospitals involved (NO. 15-071/998), and was conducted in accordance with the Declaration of Helsinki. All patients provided written informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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