

Healthcare Cost Trajectories in the Last 2 Years of Life Among Patients With a Solid Metastatic Cancer: A Prospective Cohort Study

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ABSTRACT

Background: Most studies describe the “average healthcare cost trend” among patients with cancer. We aimed to delineate heterogeneous trajectories of healthcare cost during the last 2 years of life of patients with a metastatic cancer and to assess the associated sociodemographic and clinical characteristics and healthcare use.

Patients and Methods: We analyzed a sample of 353 deceased patients from a cohort of 600 with a solid metastatic cancer in Singapore, and we used group-based trajectory modeling to identify trajectories of total healthcare cost during the last 2 years of life.

Results: The average cost trend showed that mean monthly healthcare cost increased from SGD \$3,997 during the last 2 years of life to SGD \$7,516 during the last month of life (USD \$1 = SGD \$1.35). Group-based trajectory modeling identified 4 distinct trajectories: (1) low and steadily decreasing cost (13%); (2) steeply increasing cost in the last year of life (14%); (3) high and steadily increasing cost (57%); and (4) steeply increasing cost before the last year of life (16%). Compared with the low and steadily decreasing cost trajectory, patients with private health insurance (β [SE], 0.75 [0.37]; $P=.04$) and a greater preference for life extension (β [SE], -0.14 [0.07]; $P=.06$) were more likely to follow the high and steadily increasing cost trajectory. Patients in the low and steadily decreasing cost trajectory were most likely to have used palliative care (62%) and to die in a hospice (27%), whereas those in the steeply increasing cost before the last year of life trajectory were least likely to have used palliative care (14%) and most likely to die in a hospital (75%).

Conclusions: The study quantifies healthcare cost and shows the variability in healthcare cost trajectories during the last 2 years of life. Policymakers, clinicians, patients, and families can use this information to better anticipate, budget, and manage healthcare costs.

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Background

Cancer is a leading cause of death globally, accounting for nearly 10 million deaths in 2020,¹ and has a significant economic impact on patients, families, and the healthcare system.² Studies show wide variation in the end-of-life (EoL) healthcare cost among patients dying with cancer.^{3–5} Understanding this variation and drivers of high costs can offer insights for policymakers, patients, and their families to anticipate and/or manage costs while preserving the quality of life of patients dying with cancer.

Several studies have assessed variation in EoL healthcare cost among patients with cancer by describing the average cost trend during specific time periods, such as the last year of life.^{6–10} They show a steep increase in healthcare cost during the last months of life, driven primarily by an increase in inpatient costs.^{11–14} However, due to a wide variation in the pattern of healthcare cost among patients with advanced cancer over time, it is possible that many patients do not follow a trajectory of steeply increasing cost during the last months of life. Furthermore, some patients may incur higher healthcare costs than others even earlier in their disease trajectory. An analysis of average cost trend is thus insufficient to inform policy and program efforts. A more nuanced assessment of heterogeneity in the pattern of EoL healthcare cost is required.

Thus, we first aimed to delineate heterogeneous trajectories of healthcare cost during the last 2 years of life in patients with a solid metastatic cancer and to compare this with the average cost trend during the same period. Although a few studies have assessed the heterogeneity in healthcare cost trajectories in the context of other diseases,^{15–18} only one study has done so in the context of metastatic cancer, and only for the last year of life.¹⁹

Second, we aimed to assess sociodemographic and clinical characteristics that predict membership of

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delineated trajectories. Based on previous studies showing the association of age,^{20–22} patient preference for life extension,⁶ and health insurance and socioeconomic status (SES)^{23–25} with healthcare costs, we hypothesized that younger patients, those preferring life extension over cost of care, those with a private health insurance, and those with higher SES would be more likely to follow a trajectory representing higher healthcare costs. Although healthcare costs have been shown to differ with cancer site, they vary widely across samples and contexts.^{12,26,27} Hence, we also assessed whether cancer site predicts membership of cost trajectories. Policymakers, patients, and families can better anticipate and budget healthcare costs by considering all of these observable factors.

Third, to better understand healthcare use and type of spending across the delineated cost trajectories, we assessed variation across delineated trajectories in total healthcare cost; outpatient and inpatient costs; total, planned, and unplanned hospital admissions; emergency department (ED) visits (in last 2 years of life); use of a palliative/hospice care service; and place of death. There is extensive literature showing that referral to palliative/hospice care reduces healthcare costs.^{28–30} We thus hypothesized that patients who access a palliative/hospice care service or who die in a hospice program will be more likely to have a trajectory with declining healthcare costs during the last months of life.

Patients and Methods

Setting

Cancer is the leading cause of death in Singapore, accounting for 28.4% of deaths in 2019.³¹ Approximately 30% of health expenditures in Singapore are out of pocket, greater than the average for high-income countries.³² A mandatory low-cost public health insurance with high deductibles (MediShield Life) partially meets patients' hospitalization costs; day surgeries; and other, more expensive, recurring outpatient treatments, such as chemotherapy and radiotherapy.^{33–36} Individuals can top up this public health insurance coverage by purchasing private health insurance.³⁷ Further details about Singapore's healthcare system financing are provided in supplemental eAppendix 1 (available with this article at JNCCN.org).

Study Design and Participants

We used data from the COMPASS study (Cost of Medical Care of Patients with Advanced Serious Illness in Singapore), a cohort of 600 patients diagnosed with metastatic cancer. After they provided written consent, eligible patients (having a diagnosis of a solid metastatic cancer, aged ≥ 21 years, and a citizen or permanent resident of Singapore) were recruited between July 2016 and March 2018 from 2 major public hospitals.

Participants were surveyed at baseline and every 3 months until death, and their billing data (starting January 2015) were obtained from hospital records. The study was approved by the Institutional Review Board at SingHealth (2015/2781). Details of the study protocol are published elsewhere.³⁸

Study Variables

Outcome: Total Healthcare Cost

We calculated total healthcare cost (gross cost before tax and subsidy) as the sum of inpatient, outpatient, ED, and pharmacy costs during the last 2 years of life based on patient billing dates and date of death. The cost includes payments made through all sources, including MediShield Life, private health insurance, MediSave, MediFund, and out of pocket. The costs were adjusted for inflation to 2019 Singapore dollars (SGD) using the consumer price index from the Department of Statistics, Singapore.³⁹ For delineating the trajectories, we aggregated total healthcare costs for every 2 months.

Covariates

Socioeconomic Characteristics

From patients' baseline surveys, we assessed patient age, sex, and type of housing (proxy for SES, classified as 1- to 2-room public, 3- to 4-room public, and 5-room public/private). More than 80% of Singapore's population lives in public housing, and larger public and private housing signifies higher SES.⁴⁰ We also assessed whether patients had any private health insurance (to top up their MediShield Life coverage).

Preference for Life Extension

Patients were asked if they would prefer treatment that extends life as much as possible or the treatment that costs them less. Response options were on scale of 1 to 9, with 1 representing extend life as much as possible at high cost and 9 representing no life extension at less cost. We used data from patients' earliest surveys in their last 2 years of life.

Cancer Site

Cancer site was categorized as breast, gynecologic/genitourinary, gastrointestinal, respiratory, and other.

Healthcare Use

We assessed total number of hospital admissions, length of hospital stay, and number of ED visits from billing records for the last 2 years of patients' lives. In addition, we asked patients in each survey whether they had ever used palliative/hospice care since diagnosis, including an inpatient, home care, or day care palliative/hospice care facility.

Place of Death

Place of death was assessed from medical records and caregiver reports and categorized as hospital, home, or hospice/care home.

Statistical Analysis

We first described the 2-year and 1-year mean total healthcare cost and its components and presented mean monthly healthcare cost for these durations. We used group-based trajectory modeling, a model-based clustering technique, to identify groups of individuals following a similar trajectory for an outcome of interest.^{41–44} We modeled log-transformed bimonthly total healthcare cost over the last 2 years of life. To identify the optimal number of trajectories and the polynomial function defining each trajectory, we first fitted models with one trajectory and sequentially increased the number of trajectories. For each specified number of trajectories, we started with a quintic polynomial function and moved down by an order of 1 if the specified function was not statistically significant. We retained the highest-order model that was significant. We considered the Bayesian information criterion, value of trajectory membership probability ($\geq 5\%$), odds of correct classification (≥ 5), and average posterior probability (≥ 0.7) to choose the optimal number of trajectories, aiming for parsimony in the number of trajectories.⁴³ More details about group-based trajectory modeling are provided in supplemental eAppendix 2.

We then assessed variation in 2-year and 1-year total healthcare costs, outpatient and inpatient costs, total number of hospital admissions, total length of hospital stay, number of ED visits (in last 2 years), use of palliative/hospice care service, and place of death across the delineated trajectories. Last, we ran a multivariable multinomial logistic regression model to investigate the predictors (age, type of housing, private health insurance status, preference for life extension, and cancer site) of trajectory group membership.

Results

Of the 600 patients, 354 died during the study period. A total of 353 patients had completed at least 1 survey in the last 2 years of life and constituted our analytic sample. The time axis was presented in 2-month intervals as time before death (0–24 months). The mean [SD] age for patients was 60.7 [10.6] years. More than half (54%) lived in 3- to 4-room public housing, 42% had a primary education or less, and 62% had private health insurance.

During the last 2 years of life, patients experienced a mean [SD] of 4.2 [3.0] hospital admissions (including unplanned admissions, 1.42 [1.89]) and 28.5 [28] days of hospital stay. Approximately 61% of the patients reported ≥ 1 ED visit (mean [SD], 2.49 [2.29]). Most patients died

in the hospital (60%), followed by home (25%) and hospice/care home (14%) (Table 1).

Mean Healthcare Cost

Patients incurred a mean total healthcare cost of SGD \$95,931 (95% CI, \$90,002–\$101,859) in the last 2 years and SGD \$60,021 (\$55,992–\$64,051) in the last year of life (USD \$1 = SGD \$1.35). The mean monthly total healthcare cost increased remarkably during the last year and the last month of life; mean monthly inpatient cost followed the same pattern. In contrast, mean monthly outpatient cost remained mostly stable, declining in the last month of life (Table 2). Over the last 2 years, outpatient and inpatient costs constituted, on average, approximately 62% and 37% of total healthcare cost, respectively.

Table 1. Sample Characteristics

Characteristic	n (%)
Total, N	353
Age at baseline (range, 27–88), mean [SD], y	60.7 [10.6]
Type of housing	
1- to 2-room public housing	26 (7.4)
3- to 4-room public housing	192 (54.4)
5-room public housing/private housing	135 (38.2)
Have private health insurance	218 (61.8)
Cancer site	
Breast	57 (16.2)
Gastrointestinal	104 (29.5)
Gynecologic/Genitourinary	64 (18.1)
Respiratory	100 (28.3)
Others	28 (7.9)
Preference for life extension vs cost (range, 1–9), ^a mean [SD] ^b	4.5 [2.4]
Healthcare use in the last 2 years of life	
Number of hospital admissions (range, 0–19), mean [SD]	4.2 [3.0]
Number of planned hospital admissions (range, 0–14), mean [SD]	2.8 [2.5]
Number of unplanned hospital admissions (range, 0–14), mean [SD]	1.4 [1.9]
Total days of hospital stay (range, 0–237), mean [SD]	28.5 [28.0]
>1 visit to emergency department	215 (61.0)
Place of death ^c	
Hospital	180 (60.4)
Hospice/Care home	43 (14.4)
Home	75 (25.2)

^aHigher values imply lower preference for life extension.

^bThe values corresponding to the earliest survey in the 2-year period.

^cUsing a subsample of participants who had information on place of death (n=298).

Table 2. Mean Healthcare Cost (in Singapore Dollars) Incurred by Patients

	Mean Total Healthcare Cost (95% CI)	Mean Total Outpatient Cost (95% CI)	Mean Total Inpatient Cost (95% CI)	Mean Monthly Total Cost (95% CI)	Mean Monthly Outpatient Cost (95% CI)	Mean Monthly Inpatient Cost (95% CI)
Last 2 y of life	95,931 (90,002–101,859)	58,342 (54,088–62,596)	36,744 (32,811–40,678)	3,997 (3,750–4,244)	2,431 (2,254–2,608)	1,531 (1,367–1,695)
Last 1 y of life	60,021 (55,992–64,051)	31,954 (29,686–34,222)	27,436 (24,300–30,572)	5,002 (4,666–5,338)	2,663 (2,474–2,852)	2,286 (2,025–2,548)
12–24 mo before death	35,909 (32,556–39,263)	26,388 (23,739–29,037)	9,309 (7,383–11,234)	2,992 (2,713–3,272)	2,199 (1,978–2,420)	776 (615–936)
Last 6 mo of life	33,826 (30,973–36,678)	13,970 (12,714–15,227)	19,385 (16,937–21,832)	5,638 (5,162–6,113)	2,328 (2,119–2,538)	3,231 (2,823–3,639)
Last 1 mo of life	7,516 (6,461–8,571)	1,140 (914–1,365)	6,202 (5,220–7,183)	7,516 (6,461–8,571)	1,140 (914–1,365)	6,202 (5,220–7,183)

Healthcare Cost Trajectories

We selected a 4-trajectory model (Figure 1). Average posterior probability was 0.99 for each trajectory. Two of these trajectories were high cost: high and steadily increasing cost (mean total healthcare costs in last 2 years: SGD \$109,134; 95% CI, \$101,175–\$117,093) and steeply increasing cost before the last year of life (SGD \$93,275; 95% CI, \$78,763–\$107,788). The remaining 2 trajectories were low and steadily decreasing cost (SGD \$75,054; 95% CI, \$59,773–\$90,336) and steeply increasing cost in the last year of life (SGD \$64,988; 95% CI, \$52,778–\$77,197). These trajectories are described in detail in the following sections (Tables 3 and 4).

Low and Steadily Decreasing Cost (13%)

Patients in this trajectory showed a pattern of declining healthcare costs in their last year of life, incurring the lowest mean total healthcare cost (SGD \$34,410; 95% CI, \$25,946–\$42,873), inpatient cost (SGD \$14,350; 95% CI, \$9,122–\$19,578), and outpatient cost (SGD \$19,630; 95% CI, \$14,338–\$24,922) compared with other trajectories.

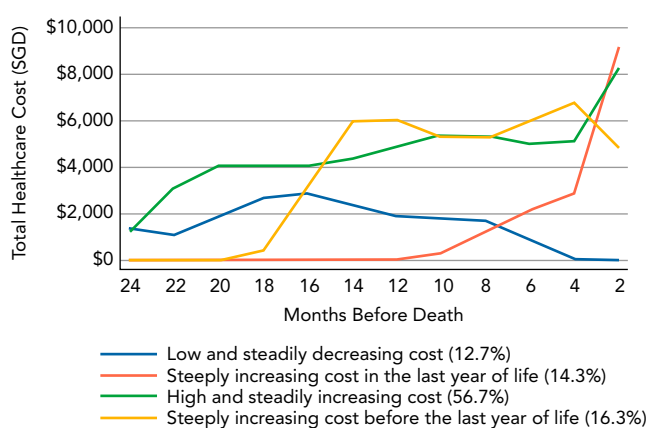


Figure 1. Trajectories of total healthcare costs during the last 2 years of life.

Abbreviation: SGD, Singapore dollars.

They experienced the lowest mean [SD] number of hospital admissions (2.78 [2.2]) and ED visits (44% with >1 ED visit) during the last 2 years of life and were most likely ever to have used a palliative/hospice care service (62%) and to die in hospice (27%). The mean [SD] age for patients in this trajectory was 64.4 [11.2] years.

Steeply Increasing Cost in the Last Year of Life (14%)

The mean [SD] age for patients in this trajectory was 60.2 [9.8] years. Compared with the low and steadily decreasing cost trajectory, younger patients (β [SE], -0.04 [0.02]; $P=.07$) and those living in larger 3- to 4-room public housing (vs 1–2-room public housing; 2.14 [1.15]; $P=.06$) were more likely to belong to this trajectory.

High and Steadily Increasing Cost (57%)

Patients in this trajectory showed a pattern of high total healthcare cost over last 2 years of life, further increasing during last months of life. These patients incurred the highest mean outpatient cost (SGD \$70,194; 95% CI, \$64,201–\$76,187) and the highest mean [SD] number of hospital admissions (4.6 [3.2]) during last 2 years of life compared with other trajectories. Compared with the low and steadily decreasing cost trajectory, patients with health insurance (0.75 [0.37]; $P=.04$), those with a greater preference for life extension (-0.14 [0.07]; $P=.06$), and those with breast or respiratory cancer (1.12 [0.63] and 0.84 [0.46], respectively; both $P=.07$ vs gastrointestinal cancer) were more likely to belong to this trajectory.

Steeply Increasing Cost Before the Last Year of Life (16%)

Patients in this trajectory incurred the highest total healthcare cost during the last year of life (mean, SGD \$68,016; 95% CI, \$54,584–\$81,448) among all trajectories. Over the last 2 years, these patients experienced the highest number of hospital admissions (mean [SD], 4.6 [2.7]), planned hospital admissions (3.4 [2.7]), and ED visits (66% with >1 ED

Table 3. Distribution of Healthcare Cost, Healthcare Use, and Place of Death, by Total Healthcare Cost Trajectories

	Low and Steadily Decreasing Cost	Steeply Increasing Cost in Last Year of Life	High and Increasing Cost	Steeply Increasing Cost Before Last Year of Life	P Value
Total, n (%)	45 (12.7)	50 (14.2)	200 (56.7)	58 (16.4)	
Healthcare cost in the last 2 years of life (Singapore dollars), mean (95% CI)					
Total healthcare cost	75,054 (9,773–90,336)	64,988 (52,778–77,197)	109,134 (101,175–117,093)	93,275 (78,763–107,788)	.00
Total outpatient cost	49,160 (38,009–60,312)	26,875 (21,118–32,633)	70,194 (64,201–76,187)	51,722 (44,015–59,428)	.00
Total inpatient cost	25,146 (17,197–33,096)	37,476 (26,126–48,826)	38,039 (32,806–43,272)	40,647 (29,601–51,693)	.16
Healthcare cost in the last year of life (Singapore dollars), mean (95% CI)					
Total healthcare cost	34,410 (259,46–42,873)	60,472 (49,599–71,345)	63,353 (58,606–68,100)	68,016 (54,584–81,448)	<.01
Total outpatient cost	19,630 (14,338–24,922)	26,041 (20,449–31,634)	34,971 (31,963–37,979)	36,211 (30,327–42,095)	<.01
Total inpatient cost	14,350 (9,122–19,578)	33,808 (24,036–43,581)	27,721 (23,938–31,504)	31,110 (20,798–41,423)	.01
Healthcare use during last 2 y of life					
Number of total hospital admissions, mean [SD]	2.8 [2.2]	3.7 [2.6]	4.6 [3.2]	4.6 [2.7]	<.01
Number of planned hospital admissions, mean [SD]	1.6 [1.8]	2.2 [1.9]	3.0 [2.7]	3.4 [2.7]	<.01
Number of unplanned hospital admissions, mean [SD]	1.2 [1.2]	1.5 [2.2]	1.6 [2.1]	1.1 [1.4]	.34
Total days of hospital stay (range, 0–237), mean [SD]	20.0 [21.2]	29.9 [37.5]	29.6 [27.0]	30.3 [25.4]	.18
>1 emergency department visit, n (%)	20 (44.4)	27 (54.0)	130 (65.0)	38 (65.5)	.05
Ever used palliative/hospice care service, n (%)	28 (62.2)	8 (16)	70 (35.0)	8 (13.8)	<.01
Place of death (n=298), n (%)					
Hospital	16 (48.5)	24 (53.3)	104 (60.5)	36 (75.0)	.10
Hospice/Care home	9 (27.3)	8 (17.8)	21 (12.2)	5 (10.4)	
Home	8 (24.2)	13 (28.9)	47 (27.3)	7 (14.6)	

visit) and the longest hospital stay (30.3 [25.4] days). They were also least likely to use palliative/hospice care service (14%) and most likely to die in a hospital (75%). The mean [SD] age of patients in this trajectory was 59.1 [10.4] years. Compared with the low and steadily decreasing cost trajectory, younger patients (-0.04 [0.02]; $P=.05$) were more likely to belong to this trajectory.

Discussion

We identified 4 distinct and heterogeneous trajectories for total healthcare cost during the last 2 years of life for patients with a solid metastatic cancer. This was in contrast to the average cost trend found in this study and previous literature^{10,12} showing that healthcare cost increases for most patients with cancer primarily during their last months of life.

Most (73%) of the patients in our sample belonged to high-cost trajectories, with 57% of them in the high and steadily increasing cost trajectory and another 16% in the steeply increasing cost before the last year of life trajectory. Patients with private health insurance, those with a high preference for life extension, and those with breast or respiratory cancer were more likely to belong to the high and steadily increasing cost trajectory. These characteristics have also previously been linked to higher healthcare costs.^{6,7,45} Longer survival rates coupled with the availability of expensive anticancer treatments have likely contributed to high healthcare costs for patients with breast or respiratory cancer.^{45,46} Younger patients were more likely to belong to the steeply increasing cost before the last year of life trajectory, similar to past studies showing higher healthcare costs among younger versus older patients.^{20–22} Consistent

Table 4. Multinomial Logistic Regression for Predictors of Total Healthcare Cost Trajectory Membership

	Total Healthcare Cost Trajectory (ref: Low and Steadily Decreasing Cost)					
	Steeply Increasing Cost in Last Year of Life		High and Steadily Increasing Cost		Steeply Increasing Cost Before Last Year of Life	
	β (SE)	P Value	β (SE)	P Value	β (SE)	P Value
Age at baseline	-0.04 (0.02)	.07	-0.02 (0.02)	.24	-0.04 (0.02)	.05
Type of housing (ref: 1- to 2-room public housing)						
3- to 4-room public housing	2.14 (1.15)	.06	0.83 (0.62)	.18	-0.55 (0.66)	.41
5-room public housing/private housing	1.07 (1.18)	.36	0.29 (0.64)	.65	-0.50 (0.67)	.45
Have private health insurance	0.60 (0.46)	.19	0.75 (0.37)	.04	0.50 (0.44)	.26
Preference for life extension vs cost	-0.14 (0.09)	.11	-0.14 (0.07)	.06	-0.10 (0.09)	.24
Cancer site (ref: gastrointestinal)						
Breast	-0.86 (0.87)	.33	1.12 (0.63)	.07	0.15 (0.74)	.84
Gynecologic/Genitourinary	-0.54 (0.60)	.37	0.01 (0.45)	.98	-0.08 (0.55)	.87
Respiratory	0.25 (0.55)	.65	0.84 (0.46)	.07	0.46 (0.54)	.40
Others	0.62 (0.93)	.51	1.12 (0.83)	.18	0.51 (0.96)	.59

with the literature,^{8,26,47} patients in both of these high-cost trajectories had more planned hospitalizations, longer hospital stays, and were more likely to die in a hospital, indicating their high use of aggressive treatments.

Approximately 13% who followed a low and steadily decreasing cost trajectory were on average older, most cost-conscious (indicated by lowest preference for life extension vs cost), and most likely to use palliative/hospice care and to die in home/hospice, indicating their preference for less aggressive treatments, explaining their declining costs in the last 6 months before death. Patients in the steeply increasing cost before the last year of life trajectory did not incur any costs between 24 and 12 months before death, possibly because of a shorter interval between their diagnosis and death. They incurred the highest inpatient cost among all trajectories during the last year of life, however, and were least likely to use palliative/hospice care. A previous study showed a similar phenomenon among patients with cancer who died soon after their diagnosis.⁴⁸

Our results have clinical and policy implications. First, we quantified patients' total healthcare costs and the components during the last 2 years of life, and we showed their association with use of palliative/hospice care services. Policymakers, clinicians, patients, and families can use this information to anticipate, budget, and manage healthcare costs and to promote an early and systematic referral to palliative care services in efforts to reduce cost while improving patient quality of life.⁴⁹⁻⁵¹ Notably, in our study, only 35% and 14% of patients in the 2 high-cost trajectories ever received care from a palliative/hospice service. Second, because >70% of patients incurred high healthcare costs through the last 2 years of life, measures to reduce healthcare costs should focus not just on the last

months of life. The association of the high and steadily increasing cost trajectory with certain observable factors, such as having private health insurance, greater preference for life extension, and having breast cancer, provides an indication of which patient subgroups may benefit most from better budgeting and managing of healthcare costs. Potential strategies for alternative payment models, such as partial capitated payments⁵² or case-based reimbursements implemented with appropriate care quality measures, can be explored to reduce healthcare costs.

The main strength of our study is that, unlike other studies using solely administrative data to assess healthcare cost trajectories, we merged administrative data with patient survey data, allowing us to investigate how patient-reported factors, such as preference for life extension and SES, influence membership of healthcare cost trajectories.

Our study also has limitations. First, because we used survey data, our sample size is smaller than in other studies relying solely on administrative data to assess healthcare costs. Second, we did not have information on date of diagnosis of metastatic cancer, cost of palliative/hospice services, and indirect costs of cancer care, such as those related to caregiving and loss of patient/caregiver productivity. Third, although the generalizability of our study results outside of Singapore needs to be explored in future studies, we expect that patients in most developed countries would also follow heterogeneous patterns of healthcare costs.

Conclusions

The present study showed that, on average, monthly healthcare cost increases in the last months of life among patients with a solid metastatic cancer. However, there is heterogeneity in the pattern of healthcare costs during the

last 2 years of life. Notably, >70% of the patients incurred high healthcare costs throughout their last 2 years of life, with those with private health insurance, greater preference for life extension, breast or respiratory cancer, and younger age being at a higher risk. Policymakers, clinicians, patients, and families can use this information to better anticipate, budget, and manage healthcare costs.

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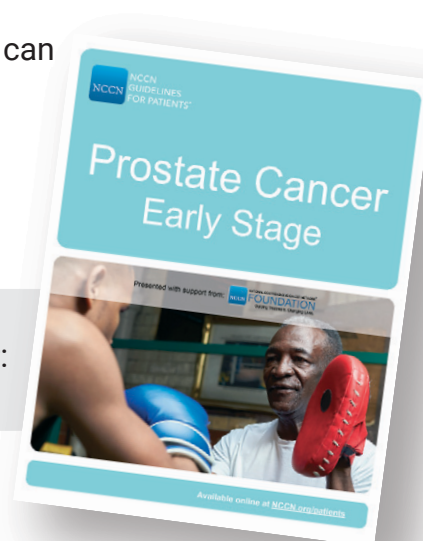
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eAppendix 1: Singapore's Healthcare Financing

eAppendix 2: Group-Based Trajectory Modelling

eAppendix 1. Singapore's Healthcare Financing

Singapore's healthcare financing is based on "3 M's": MediSave, MediShield Life, and MediFund.^{1–4}

MediSave is national medical health savings account to help cover out-of-pocket payments for medical bills for self and family members. MediSave can be used to pay for a broad range of outpatient treatments, hospitalization, and day surgery expenses as well as premiums for MediShield Life.⁵ Personal and employer salary contributions (8%–10.5%, depending on age) to MediSave accounts are compulsory for all working citizens and permanent residents. There are limits on withdrawals from MediSave.

MediShield Life is a universal basic public health insurance with high deductibles. It is mandatory for citizens and permanent residents and covers some part of large hospital bills and select costly outpatient treatments, such as chemotherapy and radiotherapy.⁵ It is structured such that patients pay less using MediSave/cash for large hospital bills for receiving subsidized treatments (B2/C-type hospital wards) in public hospitals. In Singapore, approximately two-thirds of patients opt for such subsidized treatments.⁶ The maximum amount that can be claimed from MediShield Life varies by treatment type and length of hospital stay. The maximum claim limit per policy year is set at SGD \$100,000 (USD \$71,837).⁵ There is no lifetime limit.

MediFund is the government's safety net for needy Singaporeans who cannot cover their out-of-pocket health expenses after using MediShield Life and MediSave.

Private Health Insurance

Individuals who wish to obtain additional healthcare coverage for private hospitals or want to be cared for in private wards in public hospitals can opt for an Integrated Shield Plan, which combines MediShield Life with additional private health insurance.⁶ Integrated Shield Plans ride on MediShield Life and are available only to citizens and permanent residents who can pay the premium using their MediSave account. There are also other private health insurance options offered by for-profit insurers that are not integrated with MediShield Life. Premiums for these other insurance options cannot be paid from MediSave. In our sample, approximately 62% of patients had some form of private health insurance.

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eAppendix 2. Group-Based Trajectory Modeling

Why Group-Based Trajectory Modeling?

In medical sciences and in clinical and developmental psychology, researchers are interested in modeling developmental trajectories or patterns of change in an outcome across multiple time points. For example, medical researchers may be interested in studying the progression of a disease over time. A common approach to study such developmental trajectories is to use standard growth analysis (growth curve modeling) that estimates a single trajectory that averages the individual trajectories of all members of a given sample.¹ In statistical terms, a standard growth analysis estimates 1 average intercept and 1 average slope for the outcome variable with time as the independent variable. Individual variation is captured by estimating a random coefficient. This approach may be useful if we assume that the pattern of change in the outcome for all members of the sample is similar.

However, in the real world, the pattern of change for most outcomes varies between individuals. Many researchers thus divide the sample using observable criteria (eg, men and women) or subjective criteria (eg, by using different thresholds for cost) and construct separate trajectories for each subgroup. One limitation of this approach is that these subgroups need to be identified *ex ante*. In contrast, group-based trajectory modeling (GBTM) is a statistical methodology for analyzing developmental trajectories that are not identifiable *ex ante* based on some observable individual criteria.

Technique and Assumptions

GBTM is a semiparametric technique based on finite mixture modeling that identifies distinct subgroups of individuals following a similar pattern of change over time for a given outcome.¹⁻⁴ Unlike growth models in which individual differences are captured by random coefficients, individual differences in GBTM are captured by a finite set of unique polynomial functions, each corresponding to a discrete trajectory. In other words, instead of 1 slope and 1 intercept, GBTM estimates j intercepts and j slopes, assuming there are j trajectories. However, within a trajectory, the slope and intercept are not assumed to vary across individuals. This assumption can be justified because the individual differences are mostly captured by the multiple trajectories. The way the outcome of interest has been measured or defined dictates the specific probability distribution used to estimate the parameters. Currently, GBTM analysis in SAS/STATA allows censored normal, binary logit, Poisson, and β -distributions for the outcome.

For a censored normal model, each trajectory is described as a latent variable (y_{it}^*) for a given trajectory (j) at a specific time (t) as follows⁵:

$$y_{it}^* = \beta_0^j + \beta_1^j X_{it} + \beta_2^j X_{it}^2 + \beta_3^j X_{it}^3 + \varepsilon_{it}$$

In the equation, X represents the independent variable (time/age). The trajectories can be modeled as a polynomial of any order. In the above equation, for example, each trajectory is modeled as a cubic function. The coefficients of the polynomial terms dictate the shape of the trajectories.

Estimation

To estimate the model, the researcher has to specify the number of trajectories to be extracted from the data. Next, for the number of trajectories specified, the researcher should specify the polynomial function for each trajectory. Preferably, this should come from theory. In the absence of theory, to identify the optimal number of trajectories and the polynomial function defining each trajectory, we first fitted models with one trajectory and sequentially increased the number of trajectories. For each specified number of trajectories, we started with a quintic polynomial function and moved down by an order of 1 if the specified function was not statistically significant. We retained the highest-order model that was significant. We considered the Bayesian information criterion, the value of trajectory membership probability ($\geq 5\%$), the odds of correct classification (≥ 5), and the average posterior probability (≥ 0.7) to choose the optimal number of trajectories, aiming for parsimony in the number of trajectories.¹

(continued on next page)

eAppendix 2. Group-Based Trajectory Modeling (cont.)

The model is estimated in STATA, version 16.0 (StataCorp LLC) using the following command⁶:

```
traj, var (dependent variable*) indep(independent variable*) model(cnorm)
order (5 5 5 4) max(13) min(0) risk(other independent variables) refgroup (3)
```

In our analysis, log-transformed bimonthly total healthcare cost is the dependent variable and months before death is the independent variable. “cnorm” specifies that a censored normal distribution is used to estimate the parameters. The order specifies the polynomial function for each trajectory. After the iteration technique detailed above, we used a quintic function for the first 3 trajectories and a quartic function for the last trajectory. The maximum and minimum values are observed maximum and minimum values of the dependent variable in the sample. After the optimal model is obtained using only time as the independent variable, we introduce more independent variables in the option “risk” to estimate how these variables impact the membership in each trajectory. “refgroup” specifies which of the trajectory groups should be used as a reference group while presenting the results.

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