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ORIGINAL RESEARCH ARTICLE

Healthcare Expenditure Trajectories in the Last 5 Years of Life: A Retrospective Cohort Study of Decedents with Advanced Cancer and End-Stage Organ Diseases

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Abstract

Background Patients with nonmalignant end-stage organ diseases often incur healthcare costs in the last year of life that are disproportionately higher than in the period prior. Studies on healthcare expenditure (HCE) trends in these patients have largely focused on the final year of life, and examining a longer-term trajectory could better support healthcare professionals to target the timing and methods of care management. In this study, we aim to describe the HCE trajectories of end-stage organ disease (ESOD) over the last 5 years of life, compared against advanced cancer (AC).

Methods We conducted a retrospective cohort study to profile decedents who had either a primary or secondary diagnosis of AC, advanced dementia, severe liver disease, as well as heart failure (HF), end-stage renal failure (ESRF), or respiratory failure (RF) in the last 5 years of their lives using a regional health system database in Singapore. Hospital-based HCE and utilization for each diagnosis group was reported cumulatively for 5 years, by year and by month. The proportion of the 5-year HCE incurred in each year was also reported.

Results Across all conditions, monthly HCE started to increase rapidly around 3 years prior to death, with 80% of the 5-year expenditure incurred in the same period. Expenditure among patients with ESODs other than dementia was £12,787 to £21,019 higher in comparison with patients with AC. Patients with RF incurred the highest 5-year HCE, driven by inpatient admissions.

Conclusions Our findings highlight the importance of examining HCE trends in ESOD and their cost drivers over multiple years prior to the last year of life to inform healthcare policy and to review care processes to ensure appropriate and efficient end-of-life (EOL) care.

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Key Points for Decision Makers

Healthcare expenditure for patients with advanced cancer and end-stage organ disease begins to increase at 3 years before death, even prior to the end-stage, emphasizing the importance of managing chronic disease among older adults to moderate subsequent end-of-life healthcare costs.

Patients with end-stage respiratory failure incurred the highest costs over 5 years prior to death, highlighting the need for dedicated care pathways for these patients to moderate their resource use over time.

1 Introduction

Patients at the end-of-life (EOL) often incur healthcare expenditure (HCE) distinctly higher than in the period immediately prior [1–4], which may signal that a disproportionate share of healthcare resources are concentrated amongst individuals with limited life expectancy [5]. Several studies have opted to define EOL as the 1-year prior to death and to characterize the magnitude, trends, and drivers of HCE incurred across different patient groups in this period [6–11]. Sizing this cost burden attributable to various groups and identifying their respective drivers can motivate their prioritization for review of current care processes, and apprise intervention development and modification, thereby ensuring care provided at the EOL is appropriate and efficient [2].

Within the last year of life, the trajectory of a steady increase in HCE before a spike in the last few months is well-documented in older decedent populations [6, 7, 12–14] and in patients dying of cancer [15]. In recent years, evidence has demonstrated that patients with end-stage organ diseases (ESODs) incur substantial costs at the EOL, similar or higher in comparison to patients with cancer [8, 9, 11, 16]. In contrast to the relatively predictable decline in patients with cancer, the deterioration of patients with ESOD is one interspersed with unplanned hospital admissions for potentially intensive and burdensome treatment, leading to accumulation of high healthcare costs over a prolonged period before death [17].

While studies on EOL cost of decedents with ESODs have provided invaluable information on cost and care patterns in the final year of life, examining longer-term trajectories could additionally facilitate the identification of junctures for earlier intervention. Cohen-Mansfield et al. noted in a comparison of EOL trajectories that while HCE for patients with terminal illness remained low until the final 6 months, HCE in patients with organ failure was elevated up to 2 years prior to death [4]. French et al. reported that 16.7–24.5% of EOL spending across nine health systems was incurred in the last 3 years of life, highlighting the potential for cost reduction through management of patients with chronic conditions to prevent high persistent spending at the EOL [18]. By studying HCE trajectories over multiple years before death, conditions that are costlier over a longer term, or subgroups likely to incur persistently high costs over several years can be identified for targeted intervention earlier, resulting in a more substantial impact on the system in terms of cost, quality of care, and life for patients [12, 19, 20].

Hence, we aimed to describe the HCE trajectories of patients with ESODs in their last 5 years of life, comparing them against patients who lived with advanced cancer. Describing the healthcare resource use and expenditure of various ESOD patient populations allowed for the identification of similarities in trends across conditions, as well as points of divergence specific to each disease. Studying trajectories over 5 years prior to death, including the period prior to the end-stage of disease, would provide a comprehensive view of the long-term cost burden of ESODs. The insights gained will inform policy decisions by highlighting high-cost subgroups for further study, and the potential junctures for intervention, with the eventual aim of reducing the burden of high healthcare costs at the EOL.

2 Methods

2.1 Setting

Singapore's public health system is organised into three regional health systems (RHS), each consisting of acute and community hospitals, national specialty centers, and primary care clinics [21]. The National Healthcare Group (NHG) RHS, consists of two acute hospitals, Tan Tock Seng Hospital (TTSH) and Khoo Teck Puat Hospital (KTPH), as well as six polyclinics providing primary care. The NHG RHS also serves as the healthcare manager of residents who live in the central and northern regions of Singapore, providing care to more than 1.5 million, or a quarter of the national population [22, 23].

2.2 Study Design and Population

A retrospective cohort study was conducted. Patients were included in the study if they were Singapore residents aged 21 years and above who died between January 2017 and

December 2019 and were diagnosed with ESOD or advanced cancer (AC) in TTSH or KTPH in the last 5 years of their lives. We chose to study decedents from 2017 to 2019, as the occurrence of coronavirus disease-2019 (COVID-19) in 2020 onwards could have impacted healthcare resource use subsequently. We opted to include patients on the basis of their diagnosis prior to death, instead of their cause of death, to identify a cohort of patients with advanced illness who were likely to satisfy referral criteria for palliative care. Patients with AC were included as a comparator in this study, as the cost trajectory of cancer at the EOL has been well established [15] and would inform relative comparisons of cost burden in ESOD.

Patients were allocated to diagnosis groups on the basis of the International Classification of Diseases, tenth revision, clinical modification (ICD-10-CM) diagnoses, including both primary and secondary diagnoses. Groupings from Kaur et al. (Online Resource 1) were adopted [8], with ESOD spanning heart failure (HF), respiratory failure (RF), end-stage renal failure (ESRF), severe liver disease (SLD), and advanced dementia (AD). To accurately identify patients at the EOL, patients diagnosed with HF and RF were included only if they had two or more all-cause admissions within their final year of life, while patients diagnosed with AD were included only if they also were on enteral tube feeding or had pneumonia in the last year of life. For this study, we omitted Parkinson's disease from the list of diagnoses, as it was challenging to identify patients with advanced disease on the basis of administrative claims data. Diagnosis codes for SLD, RF, and sepsis (as part of AD criteria) were also expanded to include a wider range of patients (Online Resource 2). Patients who had AC and concurrent ESODs remained classified as patients with AC. This was done because the illness trajectory of AC is often a short predictable decline toward the EOL, while that of ESOD may be a protracted "entry–reentry" trajectory. If a patient had both conditions, their trajectory would likely be of the condition progressing more rapidly [17] and would hence resemble that of a patient with AC. Patients with ESODs were included in multiple groups if they had more than one condition.

2.3 Data Source and Variables

We extracted data from the NHG RHS database, a data warehouse containing episodic data on demographics, diagnoses, billing information, and healthcare utilization across institutions within the RHS [24]. We extracted information on patients' visits to the inpatient, specialist outpatient, emergency department (ED), or day procedure (DP) settings of TTSH and KTPH up to 5 years before death. Healthcare expenditure associated with each visit was measured using the gross charge, which encompasses manpower, facility, and procedural charges and reflects the cost to the healthcare system to deliver these services. To compute the total monthly and annual HCE, we aggregated the expenditure incurred across the abovementioned settings for each specific timeframe. The HCE incurred from 2012 to 2019 reported in this study was deflated by the consumer price index to the base year 2019 [25] and converted to British pounds (1 Singapore dollar (SGD) = 0.59 Great British Pound (GBP)), on the basis of the average exchange rate in 2024.

Each group was profiled with regards to their sociodemographic characteristics, duration of ESOD diagnosis, and multi-morbidity of ESOD. We grouped patients as ethnically Chinese or non-Chinese for profiling, as approximately 75% of the resident population in Singapore is of Chinese descent [26], and the remaining minority is constituted by Malays, Indians, and other ethnicities. In addition, as more than 75% of residents live in public housing [27], and average household income increases with apartment size [28], housing type was reported as a proxy of patients' socioeconomic status. Multi-morbidity was reflected by the number of ESOD diagnoses a patient was recorded to have within the last 5 years of life.

2.4 Statistical Methodology

Patient characteristics were compared between patients with AC and each ESOD group, using Wilcoxon rank sum for non-normally distributed continuous variables and Fisher's tests for categorical variables. Bonferroni's correction was used to correct the threshold for statistical significance to account for multiple testing between patients with AC and individual ESOD groups [29].

To illustrate HCE trajectories over the 5-year period prior to death, we reported the mean HCE incurred per month for each group and highlighted points where the monthly HCE had doubled since the start of the trajectory. The mean yearly HCE, cumulative 5-year HCE, and proportion of the 5-year HCE incurred within each year was reported. The mean HCE incurred within the last year and 5 years of life was compared between groups using a generalized linear model (GLM) incorporating a Gamma family and log link. We opted for a Gamma GLM with log link as it provides accurate estimates of mean HCE despite the inherent skewness of the data [30]. For diagnostic checks, we generated plots of residuals and Cook's statistic and additionally tested the assumptions of the log link and Gamma distribution for the GLM. Sensitivity analyses adjusting for age distribution were conducted to ensure differences in HCE estimates between the ESODs were not due to differences in age structure. The average number of inpatient admissions, specialist outpatient

clinic (SOC) visits, ED attendances, and DPs per year were also reported for each diagnosis group. All analyses were conducted using RStudio (version 2023.3.0.386) [31].

3 Results

A total of 11,549 decedents with AC or ESODs were studied. Patients with AC constituted the largest group, followed by AD, HF, RF, ESRF, and SLD (Table 1).

The median time from diagnosis to death was the shortest in AC at 0.3 years (interquartile range (IQR): 0.1–1.1 years) and the longest in HF at a median of 1.2 years (IQR 0.3–3.0 years). Of the 7154 patients with ESODs, 35% had more than one ESOD diagnosis before death, with more than half of the patients with HF, SLD, and RF having multiple ESOD diagnoses.

Comparing the AC and individual ESOD groups, we noted demographic differences (Table 1). Patients with ESOD were generally older than patients with AC (all $p < 0.01$). Most patients with AD were aged 85 years and above, compared with only a third in the other ESOD groups. The gender distribution of AC differed from all the ESOD groups other than SLD, where six in ten patients were male ($p = 0.05$). The proportion of non-Chinese patients was similar between patients with AC and AD at around 18%, while this proportion was around one third in patients with HF, SLD, RF, and ESRF. Compared with AC, the proportion of decedents with HF, SLD, and ESRF who were residing in 1–2 roomed public housing was similar, ranging from 8 to 11%.

Trajectories of HCE incurred over the last 5 years of life are shown in Fig. 1. Across all groups, HCE accelerated rapidly only in the last 2–3 years before death, evident from the reduction in time between doubling of monthly HCE. Comparing between ESOD and AC, in the final year, patients with non-AD ESODs incurred £4,038 to £10,317 more HCE than patients with AC ($p < 0.001$, Table 2, Online Resource 3), and patients with RF incurred the highest HCE (mean: £31,041). Similarly, over the 5 years, patients with non-AD ESODs incurred higher HCE than patients with AC, except for patients with AD (£12,787–21,019, $p = 0.23$), and patients with RF remained the highest in HCE incurred (mean: £56,395). While patients with HF incurred the second highest HCE in the last year of life, patients with ESRF instead incurred the second highest cost over the 5-year period (1-year: HF, £27,108; ESRF, £24,762; 5-year: HF, £50,729; ESRF, £51,840). Sensitivity analyses adjusting for age similarly identified patients with RF to incur the highest HCE in the last year and 5 years of life, and patients with ESODs incurred higher HCE than patients with AC (Online Resources 4 and 5).

Examining the distribution of HCE incurred across the 5 years, more than 80% of the 5-year HCE was incurred in the last 3 years of life, with more than 50% incurred in the final year alone. (Fig. 2, Online Resource 6). The highest proportion incurred in the final year was observed for patients with AC, while a higher proportion of expenditure in patients with ESRF was spread over in the years prior to the final year (Fig. 2).

Corresponding trends in healthcare utilization across various settings are presented in Online Resource 7 and Fig. 3. The average number of visits generally increased with proximity to death across all groups. Patients with ESODs recorded more admissions than patients with AC across all years, while their increase in outpatient utilization was notably slower in comparison. Patients with HF and RF were admitted most frequently, with an average of more than eight times over the 5-year period (mean, HF: 8.8; RF: 8.7), half of which were recorded in the final year (mean, HF: 4.1; RF: 4.0). Patients with RF also recorded the longest inpatient length of stay (mean: 96.7 days). In contrast, patients with ESRF recorded the highest mean SOC utilization with 54 outpatient visits over the 5-year period, while patients with AC averaged 15 visits in the last year of life (mean: 15.8 visits).

4 Discussion

We characterized a cohort of decedents who were diagnosed with AC and ESOD up to 5 years before death and monitored their trajectory of hospital-based HCE and utilization over time. Across all conditions, HCE started to increase rapidly around 3 years prior to death, with 80% of the 5-year HCE incurred in the same period. Patients with ESODs in general incurred higher HCE in comparison to patients with AC, and patients with RF incurred the highest costs overall, driven by frequent inpatient admissions.

The sizeable accumulation of HCE in the 3 years leading up to death underscores the importance of reviewing and addressing potential high resource use prior to the end-stage of disease, when patients are still receiving treatment. This is because half of the patients met the criteria for end-stage disease only in the last year of life, and palliative intervention or other efforts introduced after would have a limited impact on the long-term cost burden. Moreover, the increase in HCE at 3 years prior to death is consistent with trends seen in older decedents where a substantial proportion of patients incur high expenditure multiple years before death [19, 20]. The acceleration in HCE growth in the last 3 years also corroborates with the description of the organ failure

Table 1 Sociodemographic and clinical characteristics of study population, *n* (%)

		AC (*n* = 4395)	AD (*n* = 2970)	ESRF (*n* = 2074)	HF (*n* = 2435)	RF (*n* = 2075)	SLD (*n* = 828)
Years from diagnosis to death	Median (Q1–Q3)	0.3 (0.1–1.1)	1.2 (0.3–2.8)	1.0 (0.2–3.0)	1.2 (0.3–3.0)	1.0 (0.2–3.0)	0.8 (0.2–2.5)
Number of diagnoses	1	4395 (100%)	1887 (63.5%)	1016 (49.0%)	732 (30.1%)	649 (31.3%)	384 (46.4%)
	2	0 (0%)	748 (25.2%)	639 (30.8%)	1103 (45.3%)	909 (43.8%)	255 (30.8%)
	3	0 (0%)	283 (9.5%)	346 (16.7%)	517 (21.2%)	445 (21.4%)	137 (16.5%)
	4	0 (0%)	52 (1.8%)	73 (3.5%)	83 (3.4%)	72 (3.5%)	52 (6.3%)
Age at death (years)	Median (Q1–Q3)	72 (63–80)	87 (82–92)	76 (66–84)	80 (71–87)	79 (70–86)	76 (66–84)
Age category	64 years and below	1252 (28.5%)	30 (1%)	460 (22.2%)	335 (13.8%)	286 (13.8%)	189 (22.8%)
	65–74 years	1245 (28.3%)	208 (7%)	532 (25.7%)	481 (19.8%)	450 (21.7%)	211 (25.5%)
	75–84 years	1261 (28.7%)	846 (28.5%)	599 (28.9%)	808 (33.2%)	717 (34.6%)	233 (28.1%)
	85 years and above	637 (14.5%)	1886 (63.5%)	483 (23.3%)	811 (33.3%)	622 (30.0%)	195 (23.6%)
Gender	Female	1853 (42.2%)	1666 (56.1%)	1040 (50.1%)	1213 (49.8%)	791 (38.1%)	318 (38.4%)
	Male	2542 (57.8%)	1304 (43.9%)	1034 (49.9%)	1222 (50.2%)	1284 (61.9%)	510 (61.6%)#
Ethnicity	Chinese	3,610 (82.1%)	2421 (81.5%)	1421 (68.5%)	1,657 (68.0%)	1,511 (72.8%)	601 (72.6%)
	Non-Chinese	785 (17.9%)	549 (18.5%)#	653 (31.5%)	778 (32.0%)	564 (27.2%)	227 (27.4%)
Housing type	Public housing, 1–2 rooms	364 (8.3%)	228 (7.7%)	165 (8.0%)	239 (9.8%)	230 (11.1%)	89 (10.7%)
	Public housing, 3–4 rooms	2537 (57.7%)	1602 (53.9%)	1165 (56.2%)	1359 (55.8%)	1180 (56.9%)	456 (55.1%)
	Public housing, 5 rooms and larger	854 (19.4%)	588 (19.8%)	437 (21.1%)	493 (20.2%)	392 (18.9%)	158 (19.1%)
	Others	640 (14.6%)	552 (18.6%)	307 (14.8%)#	344 (14.1%)#	273 (13.2%)	125 (15.1%)#

Difference in characteristics between AC and ESOD groups was not statistically significant ($p > 0.01$)

AC, advanced cancer; AD, advanced dementia; ESRF, end-stage renal failure; HF, heart failure; RF, respiratory failure; SLD, severe liver disease

trajectory by Cohen-Mansfield et al. [4]. Taken together, these observations echo the calls from other studies to intervene earlier in the disease trajectory and address the needs of older adults with chronic conditions to have an impact on EOL HCE [12, 20].

Of the ESOD groups, patients with RF incurred the highest HCE both in the last year of life and cumulatively over the last 5 years. While Kaur et al. similarly reported that patients with non-cancer advanced illnesses accumulated more HCE in the last year of life compared with patients with AC, they instead found patients with RF to be second to those with HF in the quantum incurred [8]. Nonetheless, patients with RF in this study were hospitalized multiple times in the last year of life, consistent with observations elsewhere that inpatient utilization constitutes the bulk of EOL HCE for these patients [11, 32]. Existing care pathways for management of severe respiratory diseases should be reviewed to ensure that these admissions are appropriate and whether adaptations are needed.

In contrast, patients with AD had the lowest HCE among the ESODs in this study. This could be attributable to initiatives targeted at shifting dementia care out from acute care into the community [33, 34], reducing the burden of care within the hospital [35]. Health systems with stronger long-term care support have been noted to lower hospital-based spending at the end of life [18], and community palliative interventions have been associated with judicious healthcare allocation and cost-effectiveness [35, 36]. Funding for these care models to support patients living with life-threatening disease in the community could potentially reduce the exponential increase in costs in the last few years of life, and engagement of patients in their goals and values can better align treatment and care plans to avoid unnecessary hospital admissions and reduce inappropriately burdensome interventions.

Most decedents with HF and RF, who had the highest EOL HCE among the groups, had more than one ESOD diagnosis, alluding to the salience of multi-morbidity as a driver of EOL HCE. Multi-component and

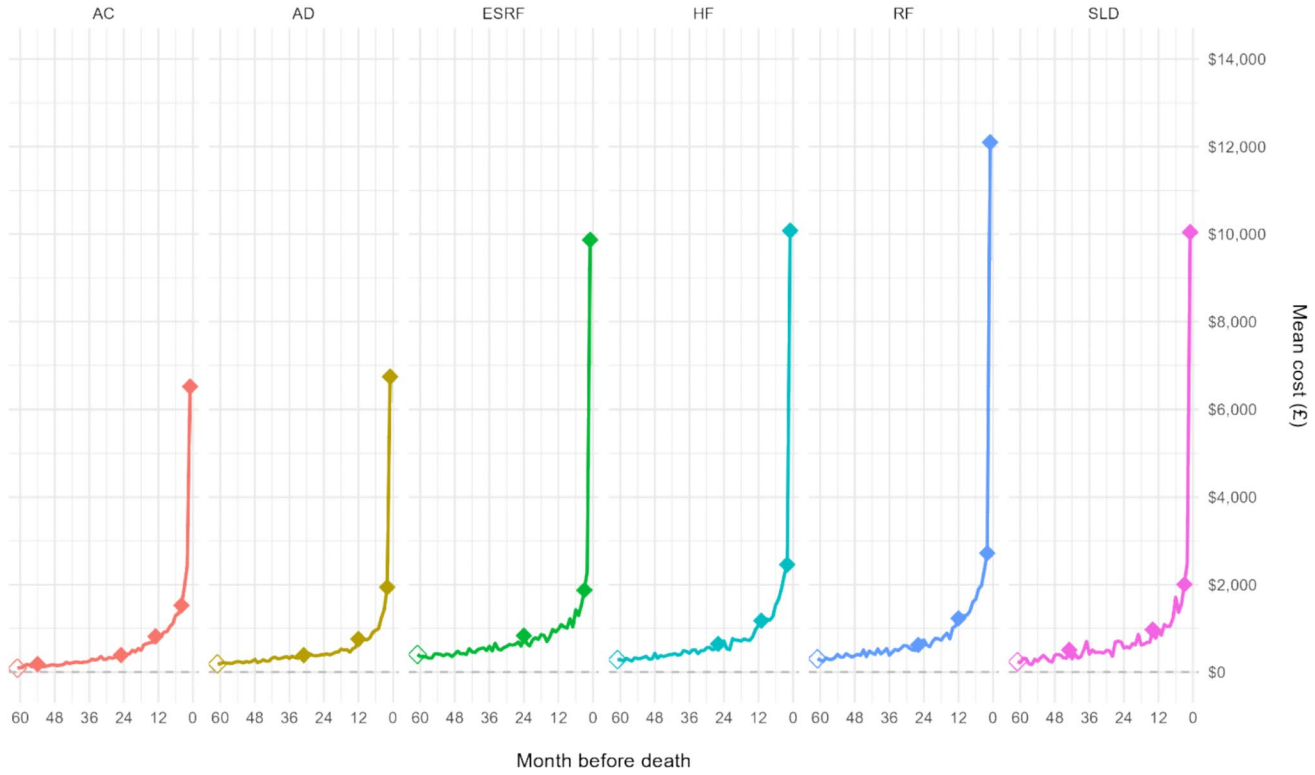

Fig. 1 Monthly healthcare expenditure over the last 5 years of life, by diagnosis group. AC, advanced cancer; AD, advanced dementia; ESRF, end-stage renal failure; HF, heart failure; RF, respiratory failure; SLD, severe liver disease. Points plotted indicate each time the average monthly healthcare expenditure doubled in comparison with the amount at month 61 before death

Table 2 Comparison of healthcare expenditure in the last 5 years

Group	HCE by year before death, mean (standard deviation)					Mean ratio (95% CI)	Cumulative HCE, mean (standard deviation)	Mean ratio (95% CI)
	5	4	3	2	1		5-year	
AC	£1726 (£5898)	£2411 (£6749)	£3821 (£8911)	£6694 (£12,283)	£20,724 (£19,782)	1.00	£35,376 (£33,127)	1.00
AD	£2704 (£5488)	£3507 (£6609)	£4512 (£8157)	£5662 (£9172)	£18,124 (£15,683)	0.87 (0.84–0.91)	£34,510 (£27,637)	0.98 (0.94–1.02)*
ESRF	£4690 (£9267)	£5726 (£10,847)	£7153 (£12,238)	£9508 (£14,531)	£24,762 (£28,035)	1.19 (1.14–1.26)	£51,840 (£49,140)	1.47 (1.40–1.53)
HF	£3783 (£7991)	£4794 (£8896)	£6318 (£10,568)	£8726 (£13,072)	£27,108 (£23,854)	1.31 (1.25–1.37)	£50,729 (£40,526)	1.43 (1.37–1.50)
RF	£4103 (£9257)	£5272 (£12,554)	£6573 (£11,154)	£9406 (£15,269)	£31,041 (£30,689)	1.50 (1.42–1.57)	£56,395 (£48,822)	1.59 (1.52–1.67)
SLD	£3393 (£7,133)	£4753 (£10,787)	£6254 (£12,045)	£8215 (£12,018)	£25,548 (£24,928)	1.23 (1.15–1.32)	£48,163 (£41,734)	1.36 (1.28–1.45)

AC, advanced cancer; AD, advanced dementia; CI, confidence interval; ESRF, end-stage renal failure; HCE, healthcare expenditure; HF, heart failure; RF, respiratory failure; SLD, severe liver disease

*$p < 0.001$

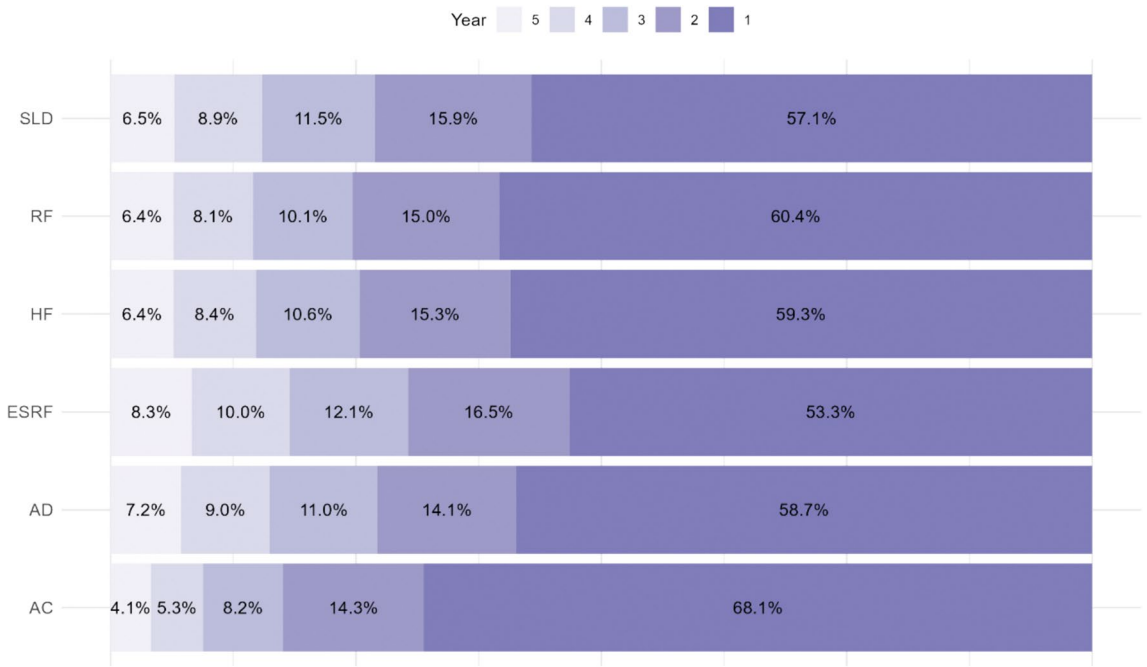

Fig. 2 Proportion of a patient's healthcare expenditure incurred in each year before death, mean. AC, advanced cancer; AD, advanced dementia; ESRF, end-stage renal failure; HF, heart failure; RF, respiratory failure; SLD, severe liver disease

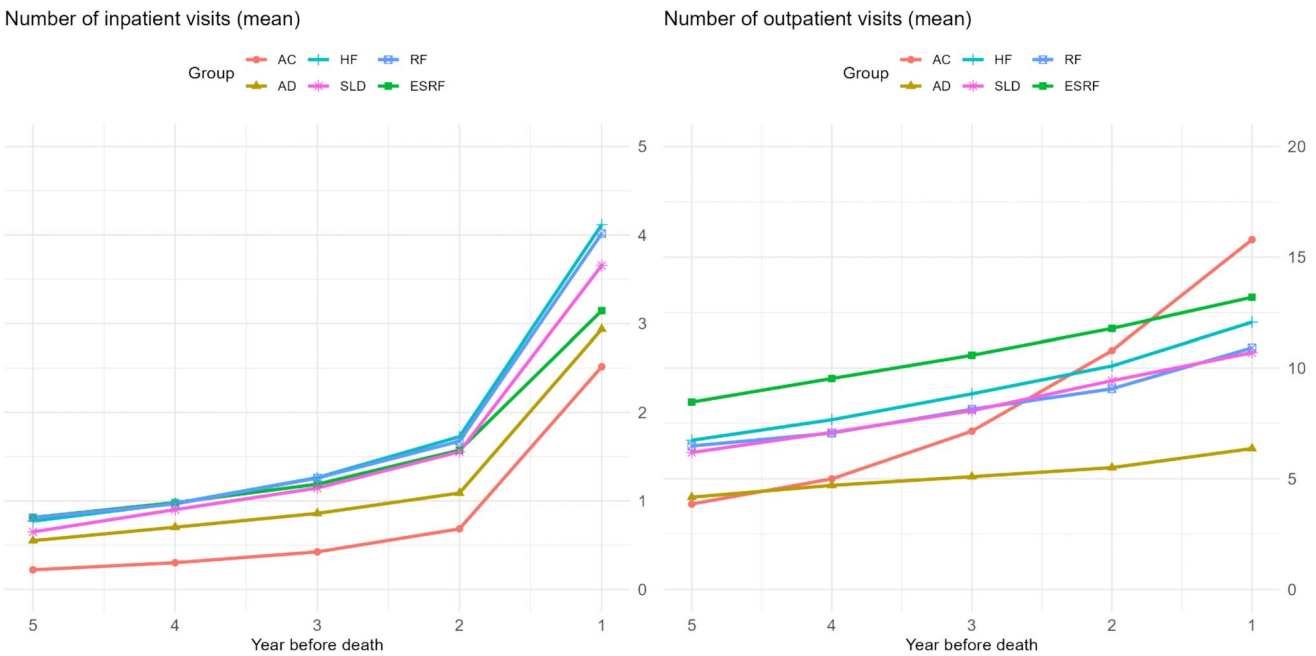

Fig. 3 Yearly trends in inpatient and outpatient healthcare utilization. LOS, length of stay; AC, advanced cancer; AD, advanced dementia; ESRF, end-stage renal failure; HF, heart failure; RF, respiratory failure; SLD, severe liver disease

multidisciplinary interventions may be able to reduce readmission rates in these medically complex patients without increasing cost [37, 38] and can be integrated well before the last year of life to impact their goals of care, symptom burden, and healthcare utilization. A better understanding of the heterogeneity within these multimorbid patients can also lead to the exploration of alternative care pathways centered around meeting patients'

varied needs, which is crucial in improving their quality of life [39]. Further work will explore the identification of distinct HCE archetypes within these clinically complex patients with advanced illnesses to facilitate their segmentation for targeted and tailored intervention.

4.1 Strengths and Limitations

This is the first study to examine HCE trajectories in the last 5 years of life in decedents diagnosed with nonmalignant ESOD. The large cohort of decedents was recruited over multiple years, and the robust inclusion criteria adopted was from several related studies to facilitate corroboration of findings. With the heterogeneity in definition and scope of ESOD, our study provides a rare comparative analysis across the multitude of conditions relevant to the EOL HCE literature.

This study is not without its limitations. Firstly, patients were classified into diagnosis groups retrospectively, using definitions incorporating their healthcare utilization in the last year of life. Our findings, therefore, apply as a description of this cohort of decedents, and the inclusion criteria cannot be extended directly to a prospective study design. While most studies group decedents as cancer and non-cancer decedents on the basis of cause of death [11, 40, 41], we identified patients on the basis of their diagnosis in the last 5 years of life, limiting our ability to directly compare estimates and inferences with other studies on ESOD populations. Nonetheless, our estimate of patients with AC incurring £20,724 in the last year reconciles with that by Kaur et al. [8], suggesting that our study generates sensible estimates of EOL HCE for this cohort. In addition, we did not deconstruct the HCE incurred by a patient with multiple ESODs for proportional attribution to each condition. By including a patient's entire HCE for analysis under each eligible ESOD group, we were able to present complete patient-level estimates of HCE associated with each ESOD. We also focused only on hospital-based costs and were unable to factor in other potential EOL costs such as long term, primary, or home care costs. However, with 62% of deaths occurring within hospitals [42], this study on hospital-based HCE would have accounted for the bulk of healthcare resource use at the EOL. Lastly, we were unable to identify specific procedures associated with high HCE, or account for the role of interaction between ESOD and chronic comorbidity, both of which would be beyond the scope of the current study.

5 Conclusions

The study provides a novel and long-term view of healthcare resource use in a cohort of decedents with cancer and non-cancer advanced illnesses. The findings highlight the relevance of documenting and understanding the resource use patterns in these understudied patient populations in the last 5 years of life. The insight that accumulation of HCE for patients with ESOD starts 3 years prior to their decline could inform national healthcare policy refinement for EOL care and motivate a review of care processes and availability of palliative resources to ensure these patients' clinical needs are met at earlier points along the disease trajectory. With these processes in place, focusing on early recognition of patients with ESOD with a predisposition to incur substantial costs over a prolonged period, such as patients with RF, would then be key to mitigating subsequent increases in EOL costs and supporting the provision of appropriate and efficient care at the EOL. Future work will focus on identifying distinct archetypes of HCE trajectories in ESOD associated with high expenditure over the period prior to death, along with their associated risk factors.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s41669-025-00573-3.

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Declarations

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Conflicts of Interest The authors declare that they have no conflicts of interest.

Availability of Data and Materials The datasets generated and/or analyzed during the current study are not publicly available owing to NHG's data protection policies to ensure data privacy of patients. Statistical code used and aggregate data may be made available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate Exemption from review was granted by the review board of the National Healthcare Group (Domain Specific Review Board Study reference no. 2022/00663), as the research involved analysis of datasets without identifiers. A waiver for obtaining informed consent from patients was hence granted.

Consent for Publication Not applicable.

Author Contributions S.H.X.N., L.T.L.C., M.K.Y.H., A.H.Y.H., T.W.S., and A.H. contributed to the conceptualization of the study and funding acquisition. S.H.X.N. acquired and analyzed the data. S.N.H.X. drafted the article, with critical revision by P.K., T.R.Y., L.T.L.C.,

A.H.Y.H., T.W.S., and A.H. All authors read and approved the current version of the article to be published.

References

1. Fassbender K, Fainsinger RL, Carson M, Finegan BA. Cost trajectories at the end of life: the Canadian experience. J Pain Symptom Manage. 2009;38(1):75–80.
2. Kocot E, Ferrero A, Shrestha S, Dubas-Jakóbczyk K. End-of-life expenditure on health care for the older population: a scoping review. Health Econ Rev. 2024. https://doi.org/10.1186/s13561-024-00493-8.
3. Rosella LC, Kornas K, Bornbaum C, Huang A, Watson T, Shuldiner J, et al. Population-based estimates of health care utilization and expenditures by adults during the last 2 years of life in Canada's single-payer health system. JAMA Netw Open. 2020;3:e201917.
4. Cohen-Mansfield J, Skornick-Bouchbinder M, Brill S. Trajectories of end of life: a systematic review. J Gerontol B Psychol Sci Soc Sci. 2018;73(4):564–72.
5. Scitovsky AA. "The high cost of dying": what do the data show? Milbank Q. 2005;83:825–41.
6. Fukawa T. End-of-life healthcare expenditure for the elderly in Japan. J Epidemiol Public Health Rev. 2016. https://doi.org/10.16966/2471-8211.101. (**ISSN 2471-8211**).
7. Luta X, Diernberger K, Bowden J, Droney J, Howdon D, Schmidlin K, et al. Healthcare trajectories and costs in the last year of life: a retrospective primary care and hospital analysis. BMJ Support Palliat Care. 2020. https://doi.org/10.1136/bmjspcare-2020-002630.
8. Kaur P, Wu HY, Hum A, Heng BH, Tan WS. Medical cost of advanced illnesses in the last-year of life-retrospective database study. Age Ageing. 2021. https://doi.org/10.1093/ageing/afab212.
9. Vestergaard AHS, Ehlers LH, Neergaard MA, Christiansen CF, Valentin JB, Johnsen SP. Healthcare costs at the end of life for patients with non-cancer diseases and cancer in Denmark. PharmacoEcon - Open. 2023;7:751–64.
10. von Wyl V, Telser H, Weber A, Fischer B, Beck K. Cost trajectories from the final life year reveal intensity of end-of-life care and can help to guide palliative care interventions. BMJ Support Palliat Care. 2018;8(3):325–34.
11. van der Plas AG, Oosterveld-Vlug MG, Pasman HR, Onwuteaka-Philipsen BD. Relating cause of death with place of care and healthcare costs in the last year of life for patients who died from cancer, chronic obstructive pulmonary disease, heart failure and dementia: a descriptive study using registry data. Palliat Med. 2017;31(4):338–45.
12. Davis MA, Nallamothu BK, Banerjee M, Bynum JP. Identification of four unique spending patterns among older adults in the last year of life challenges standard assumptions. Health Aff (Millwood). 2016;35(7):1316–23.
13. Diernberger K, Luta X, Bowden J, Fallon M, Droney J, Lemmon E, et al. Healthcare use and costs in the last year of life: a national population data linkage study. BMJ Support Palliat Care. 2024;14:e885–e89.
14. Hazra NC, Rudisill C, Gulliford MC. Determinants of health care costs in the senior elderly: age, comorbidity, impairment, or proximity to death? Eur J Health Econ. 2018;19(6):831–42.
15. Langton JM, Blanch B, Drew AK, Haas M, Ingham JM, Pearson SA. Retrospective studies of end-of-life resource utilization and costs in cancer care using health administrative data: a systematic review. Palliat Med. 2014;28(10):1167–96.
16. Hung P, Hsu SH, Wang S-Y. Associations between end-of-life expenditures and hospice stay length vary by clinical condition and expenditure duration. Value Health. 2020;23:697–704.
17. Murray SA, Kendall M, Boyd K, Sheikh A. Illness trajectories and palliative care. BMJ. 2005;330:1007–11.
18. French EB, McCauley J, Aragon M, Bakx P, Chalkley M, Chen SH, et al. End-of-life medical spending in last twelve months of life is lower than previously reported. Health Aff. 2017;36(7):1211–7.
19. Teraoka E, Kunisawa S, Imanaka Y. Trajectories of end-of-life medical and long-term care expenditures for older adults in Japan: retrospective longitudinal study using a large-scale linked database of medical and long-term care claims. BMC Geriatr. 2021;21(1):403.
20. Hansen AV, Mortensen LH, Trompet S, Westendorp R. Health care expenditure in the last five years of life is driven by morbidity, not age: a national study of spending trajectories in Danish decedents over age 65. PLoS One. 2020;15: e0244061.
21. Tan CC, Lam CSP, Matchar DB, Zee YK, Wong JEL. Singapore's health-care system: key features, challenges, and shifts. Lancet. 2021;398:1091–104.
22. Tan Tock Seng Hospital. Corporate Profile 2024. updated 28 Feb 2024. Available from: https://www.ttsh.com.sg/About-TTSH/Pages/Corporate-Profile.aspx.
23. Khoo Teck Puat Hospital. Corporate Profile 2024. updated 22 Mar 2024. Available from: https://www.ktph.com.sg/about-us/corporate-profile.
24. Gunapal PPG, Kannapiran P, Teow KL, Zhu Z, You AX, Saxena N, et al. Setting up a regional health system database for seamless population health management in Singapore. Proc Singap Healthc. 2016;25:27–34.
25. Singapore Department of Statistics. Consumer price index, 2019 as Base Year. Singstat Table Builder: Government of Singapore; 2020.
26. Singapore Department of Statistics. Key indicators of resident population. Government of Singapore; 2021.
27. Singapore Department of Statistics. Population trends 2023. Government of Singapore; 2023.
28. Singapore Department of Statistics. Average monthly household income from work (excluding employer CPF contributions) among resident employed households. SingStat Table Builder: Government of Singapore; 2023.
29. Cabin RJ, Mitchell RJ. To Bonferroni or not to Bonferroni: when and how are the questions. Bull Ecol Soc Amer. 2000;81:246–8.
30. Malehi AS, Pourmotahari F, Ahmadi K. Statistical models for the analysis of skewed healthcare cost data: a simulation study. Health Econ Rev. 2015. https://doi.org/10.1186/s13561-015-0045-7.
31. RStudio Team. RStudio: Integrated Development for R. PBC, Boston, MA.
32. Iyer A, Goodrich C, Dransfield M, Alam S, Brown C, Landefeld C, et al. End-of-life spending and healthcare utilization among older adults with chronic obstructive pulmonary disease. Am J Med. 2020;133(7):817-24.e1.

33. Hum A, Tay RY, Wong YKY, Ali NB, Leong IYO, Wu HY, et al. Advanced dementia: an integrated homecare programme. BMJ Support Palliat Care. 2020. https://doi.org/10.1136/bmjspcare-2019-001798.
34. Dover Park Hospice. Annual Report 2019-2020. 2020.
35. Pereira MJ, Tay RY, Tan WS, Molina JADC, Ali NB, Leong IYO, et al. Integrated palliative homecare in advanced dementia: reduced healthcare utilisation and costs. BMJ Support Palliat Care. 2023;13(1):77–85.
36. Luta X, Ottino B, Hall P, Bowden J, Wee B, Droney J, et al. Evidence on the economic value of end-of life and palliative care interventions: a narrative review of reviews. BMC Palliat Care. 2021. https://doi.org/10.1186/s12904-021-00782-7.
37. Wu J, Zhang H, Shao J, Chen D, Xue E, Huang S, et al. Healthcare for older adults with multimorbidity: a scoping review of reviews. Clin Interv Aging. 2023;18:1723–35.
38. Morkisch N, Upegui-Arango LD, Cardona MI, Heuvel D, Rimmele M, Sieber CC, et al. Components of the transitional care model (TCM) to reduce readmission in geriatric patients: a systematic review. BMC Geriatr. 2020. https://doi.org/10.1186/s12877-020-01747-w.
39. Murtagh FEM, Preston M, Higginson I. Patterns of dying: palliative care for non-malignant disease. Clin Med. 2004;4(1):39–44.
40. De Schreye R, Deliens L, Annemans L, Gielen B, Smets T, Cohen J. Trends in appropriateness of end-of-life care in people with cancer, COPD or with dementia measured with population-level quality indicators. PLoS One. 2023;18: e0273997.
41. Vestergaard AHS, Christiansen CF, Neergaard MA, Valentin JB, Johnsen SP. Healthcare utilisation trajectories in patients dying from chronic obstructive pulmonary disease, heart failure or cancer: a nationwide register-based cohort study. BMJ Open. 2021;11(11): e049661.
42. Registry of Births and Deaths. Report on registration of births and deaths 2022. 2023.