

Leveraging Clinical Informatics to Address the Quintuple Aim for End-of-Life Care

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Abstract

As the population of older adults grows at an unprecedented rate, there is a large gap to provide culturally tailored end-of-life care. This study describes a payor-led, informatics-based approach to identify Medicare members who may benefit from a Compassionate CareSM Program (CCP), which was designed to provide specialized care management services and support to members who have end-stage and/or life-limiting illnesses by addressing the quintuple aim. Potential participants are identified through machine learning models whereby nurse care managers then provide tailored outreach via telephone. A retrospective, observational cohort analysis of propensity-weighted Medicare members was performed to compare decedents who did or did not participate in the CCP. This program enhanced the end-of-life care experience while providing equitable outcomes regardless of age, gender, and geography and decreased inpatient (-37%) admissions with concomitant reduced (-59%) medical spend when compared to decedents that did not utilize the end-of-life care management program.

Introduction

Although there have been remarkable clinical advancements, the provision of high-quality, end-of-life care remains a critical gap for American adults in the present day. A majority of adults are likely to experience significant discordance and dissatisfaction between end-of-life preferences and an actualized experience. Despite 71% of surveyed adults preferring in-home care¹, only 30% of deaths occur in this setting². Default standard of care for end-of-life support in the United States (US) includes advanced-care planning, palliative care, and/or hospice services. Access and utilization of hospice and palliative care services significantly improves the likelihood of receiving compassionate and goal-concordant end-of-life care. Decedents who receive hospice or palliative care services are more likely to experience greater health-related quality of life; higher patient and caregiver satisfaction; lower symptom burden; and increased likelihood of dying in their preferred place of death³. Hospice and palliative care are considered cost-effective and reduce the use of aggressive, low-value clinical interventions with low or no potential to yield clinical benefit⁴.

Despite well-established benefits, end-of-life care services are vastly underutilized. The National Hospice and Palliative Care Organization recently reported a reduction in Medicare decedents enrolled in hospice at the time of death from 2019 to 2020 (51.6 to 47.8%)⁵. Major barriers to achieving high-quality, end-of-life care are multidimensional and include patient- and provider-level factors, such as lack of patient awareness, failure to accept health status, failure to discuss and/or document patient preferences, and lack of provider comfort⁶.

Perhaps most influential are key structural-level barriers that directly threaten the sustainability of end-of-life care and pose a national healthcare challenge⁷. Centers for Medicare and Medicaid Services (CMS) hospice eligibility requires a principal diagnosis of a life-limiting condition with a prognosis of ≤ 6 months. In addition to general hospice guidelines, additional disease-specific criteria must be present to meet requirements for hospice care. In this biomedical model, eligibility and access to end-of-life services primarily anchor on objective clinical criteria or a “pathogen” and fails to appraise the individual “host” of disease; a human life with distinct set of beliefs, attitudes, and values at this critical timepoint in their life’s journey. This biomedical approach translates to population-wide gaps in equitable access to high-quality, end-of-life care. In 2020, the average days of care for decedents using hospice at the time of death was 97 days with 50% of patients receiving 18 days or less of compassionate end-of-life support⁸.

In addition to widespread barriers imposed by benefit restrictions, there is growing concern that the needs of a rapidly aging population will not be met⁷. It has been estimated that end-of-life care provision would need to double by 2040 to sustain current trends⁸. These projections foreshadow a significant financial burden to an already strained healthcare system. In 2022, the Medicare hospice benefit exceeded \$22 billion dollars, which was an increase of 7.4% in

healthcare expenditures from the previous year⁵. Coupled with a nationwide health care provider shortage, it underscores the need to implement transformative care practices to provide adequate and sustainable care.

Demonstratively, three components are required to close this nationwide gap in end-of-life care: 1) expand eligibility, access, and utilization; 2) improve identification, time-to-engagement, and duration of program services; and 3) create clinical capacity-building of high-quality, competent care providers. As such, a payor-led, informatics-based Compassionate CareSM Program (CCP) was developed with the goal to deliver specialized, end-of-life care management services and support to members who have end-stage and/or life-limiting illnesses in support of the quintuple aim. The primary goal of the CCP is to address the physical, emotional, spiritual, and cultural needs of individuals dealing with a critical illness. For historical context, the CCP first launched in 2004 as a pilot to support the liberalization of hospice benefits for commercially insured members⁹. A critical component of the CCP is the timely and appropriate identification of members most likely to derive benefit from end-of-life services. The CCP leverages interoperability between data warehouses containing medical claims, pharmacy claims, a utilization management system, and data derived from the CMS' Daily Transaction Reply Report¹⁰. A combination of analytical and artificial intelligence methods (i.e., machine learning [ML] and predictive modeling) are applied to identify mortality risk for members within 12 months and trigger nurse care management outreach. Utilization of informatics workflows supports the opportunity to improve and assess population health, specifically Medicare, and advance health equity while enhancing the care experience at end-of-life without negative substantive financial impact.

Since its inception^{11,12}, the CCP continues to test-and-learn novel technological, operational, and clinical enhancements designed to augment the timely identification and enhance end-of-life experiences for this vulnerable population. This study aims to describe an informatics-based approach used to identify individuals likely to benefit from a human-centered, goal-concordant end-of-life care program offered to Medicare members and evaluate quintuple aim outcomes, where possible. The operational framework will be described and a contemporary update on the program's impact will be provided.

Methods

Overview of the Compassionate Care Program framework

The CCP is available to all eligible members of a large national health plan and is operationalized across five key components (Figure 1): 1) a rich and diverse data foundation, with 2) interoperability between multiple internal and external data platforms; 3) application of predictive analytic techniques (i.e., ML) and data science capabilities; 4) a designated platform for nurse care managers; and 5) clinical expertise with specialized cultural competency training to provide compassionate and goal-concordant end-of-life care activities.

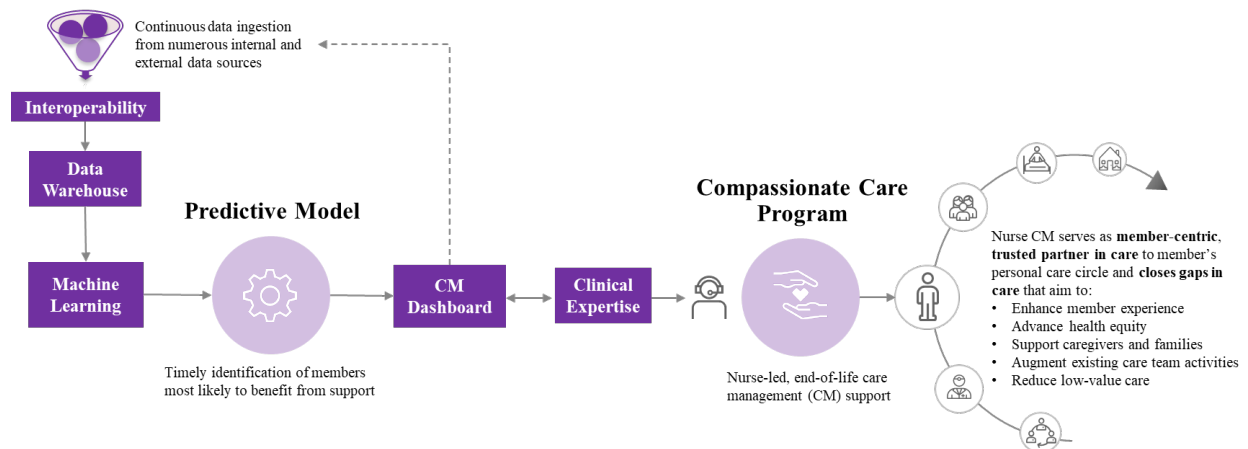


Figure 1. Compassionate Care Program Framework

Key foundational competencies (dark purple) directly enable the identification and delivery of an informatics-based, specialized care management program for members most likely to have unmet need for end-of-life support.

Potential CCP members are identified through a proprietary predictive model that is highly dependent on a rich and diverse data foundation. Model sets are derived from a data warehouse that continuously ingests data from numerous internal and external platforms with interoperability. ML predictive modeling is used to identify and route eligible

members to a nurse care management dashboard. Specialized nurse competency training and member communication permissions enable the delivery of a nurse-led, care management program designed to improve member and payor outcomes. Relevant data sources that map to key outcomes of interest (i.e., care management dashboard data and claims) flow to the data warehouse and facilitate retrospective program analyses.

Data governance and integrity

The CCP model dataset leverages interoperability between multiple internal data sources, including medical claims, pharmacy claims, a utilization management system, a care management platform, and external data sources, including a third-party social determinants of health (SDoH) vendor and the CMS' Daily Transaction Reply Report¹⁰. Analytical methods such as descriptive summary statistics, ML, and visual validation are utilized to conduct data analyses, which involve gathering, synthesizing, and modeling large and complex datasets comprising both structured and unstructured data. The primary goal is to enhance the comprehensibility of the information derived from these datasets, which in turn facilitates improved decision-making. The accuracy, completeness, integrity, validity, and timeliness of these data assets are ensured through rigorous data collection, curation, and quality analysis processes. Relevant CCP outcomes of interest are derived from internal data that are continuously ingested, transformed, and standardized in the data warehouse to facilitate annual and *ad hoc* program evaluation.

CCP prediction model development and performance

Earlier iterations of the CCP prediction model have been previously described^{11,12}; however, the ML model is continuously updated as new data sources, methodologies, and assets are acquired. The model in production during the study timeframe (version 2.1) was developed using an extreme gradient boosting (XGBoost) model; an ensemble learning method based on Gradient Boosting Decision Trees. Feature domains (n=300+) consisted of demographic information, insurance claims, diagnosis codes, biomarkers, laboratory results, healthcare utilization history, gaps in care, SDoH, and pharmacy claims. Model features are initially selected through feature importance ranking within each domain and then combined across domains in subsequent trainings. The dataset used randomized train and test splits and was modeled optimizing for area under the curve and area under precision-recall curve parameters. Version 2.1 of the CCP model yields a positive predictive value of 0.39 and sensitivity of 0.07.

In accordance with internal best practices, algorithmic bias testing is conducted during the initial development of all advanced algorithms prior to use and reviewed annually. Most recent bias testing for the CCP model was conducted on February 21, 2023 with no gender or racial biases detected.

CCP member identification

The predictive model threshold (i.e., likelihood of death in the upcoming 12 months > 48%) is based on member future risk, potential benefit, and care manager capacity. Of note, potential members may also be identified through additional channels, including care management clinical appraisal, health plan's daily review of inpatient admissions, physician referrals, and/or member self-referral. All interested members are eligible for enrollment regardless of predictive algorithm score. All eligible members are securely routed from the data warehouse to an interoperable, in-house, nurse-led care management platform.

Nurse-led care management pathway

The centralized care management platform enables CCP member-facing operations and is delivered by a program-team of nurse care managers. All care managers hold an active, unrestricted registered nurse license; possess at least 3 to 5 years of clinical expertise, often within palliative and hospice care settings; and are required to complete ~105 hours of training following a structured curriculum. The curriculum was developed by a panel of advanced healthcare providers with clinical expertise in end-of-life care coordination. Annual continuing education is coordinated internally. The curriculum delivery format consists of asynchronous and synchronous courses and workshops facilitating competency development in motivational interviewing, cultural competence, and advanced disease management. The expanded scope of practice enables care managers to develop trusting, meaningful, and mutually beneficial relationships between the member, their care team, and their plan sponsor responsible for the coordination of benefits that affords equitable access to these services.

Upon inbound referral to the care management platform, the care manager is notified via a task manager trigger alert and performs standardized workflows for initial member intake, including 1) pre-call research for eligibility, coordination of benefits, and medical chart review; 2) quality dashboard review to identify existing gaps in care; 3) thorough medication review, including medication reconciliation; 4) completes and documents standardized

assessments; and 5) escalates and/or facilitates communication with the provider(s), if necessary. Upon program enrollment, care managers provide ongoing, telephonic-based support, education, and holistic assistance to members, families, and caregivers to navigate difficult issues and decisions related to advanced illness. Initial outreach cadence is every 1-2 weeks and continues thereafter every ≤ 30 days until needs have been met or member requests a preferred frequency. Specific goals of the program are to: 1) provide support and education for members; 2) provide support and education for caregivers and family members caring for members; 3) improve quality of life; 4) support end-of-life decisions; 5) reduce acute hospital stays; 6) assist in completion of advanced directives; 7) address member's pain and other symptoms; and 8) evaluate need for referral or collaboration with other programs.

In addition to the care management platform, care managers leverage a combination of clinical gestalt and technology-enabled capabilities, tools, processes, and workflows to support ongoing care management activities, including documentation standards and templates, system resources, scripts, logic modules, event-driven alerts, evidence-based order sets, patient data summaries, and standardized care plans. These competencies support the quintuple aim to optimize human resource allocation; reduce clinician burnout; and allow the CCP to be effectively scaled.

Study design overview

The CCP framework was leveraged to conduct a retrospective, observational cohort analysis (Figure 2). Administrative claims data were de-identified, aggregated, and analyzed to compare quintuple aim outcomes including healthcare utilization and expenditures in Medicare decedents who were identified by the predictive model and engaged in CCP compared to a propensity-weighted comparison group to identify any disparities.

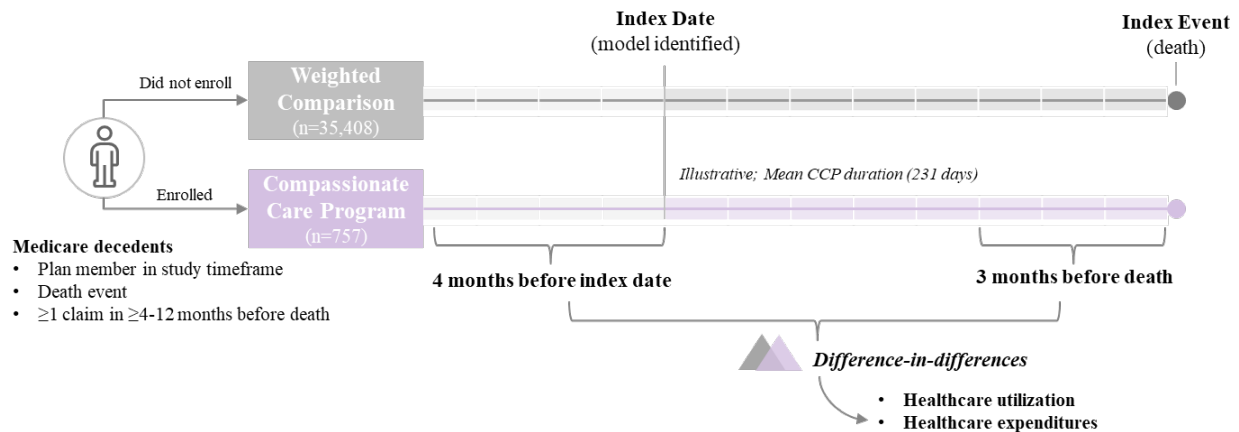


Figure 2. Study Design Overview

The Compassionate Care Program experimentation framework was leveraged to conduct a retrospective analysis of healthcare utilization and expenditures in the three months preceding death versus four months preceding index date (i.e., date identified by prediction model) between CCP participants compared to a propensity-weighted comparison Medicare cohort.

Sample and participants

All participants were enrollees of a Medicare health plan provided by a large national payor who subsequently died (i.e., decedents). Inclusion criteria included: 1) continuous health plan eligibility throughout the study evaluation period, 2) death event, and 3) presence of at least one claim ingestion for the ≥ 4 to 12 months preceding death. Potential participants were excluded if they: 1) did not meet inclusion criteria; 2) were members of a commercial, dual coverage, or indemnity insurance plan; 3) were in a skilled nursing facility, receiving long-term care, or had a recent admission to inpatient hospice prior to engagement; 4) were enrolled in a readmission avoidance care management program; or 5) were targeted for engagement ≥ 33 days from being identified.

The intervention group included members who were identified and enrolled in the CCP for ≥ 4 to 12 months; had ≥ 1 CCP care management engagement touchpoint between January 1, 2017 and December 31, 2019; and subsequently died as identified from the CMS Daily Transaction Reply Report¹⁰. The comparison group included Medicare members who were not identified nor referred to the CCP program during the same period and subsequently died.

Sterling Institutional Review Board reviewed and approved the study (#10796) as an exempt study under 45 CFR 46.104(d)(4). In addition, a waiver of Health Insurance Portability and Accountability Act authorization for use and disclosure of aggregated, de-identified member data was obtained.

Statistical analyses

A retrospective, two-group, difference-in-differences approach was used to estimate the causal effects of CCP participation on health care costs and utilization. CCP and comparison group members were propensity-weighted using an overlap weighting technique previously developed by Li & Li¹³. Propensity-weighting is the best-in-class approach to reduce potential selection bias and confounding variables inherent in studies where clinical equipoise no longer supports a randomized-controlled trial design, as in the case for plan-sponsored benefits¹⁴. Groups were propensity-weighted using proprietary features including sociodemographic (e.g., age, gender, geography including rural, urban, and suburban comparisons), health plan details (e.g., group vs. individual), comorbidities, and medical and pharmacy utilization. Bootstrapping techniques were applied after propensity-weighting to construct 95% confidence interval (95% CI) for each outcome and estimate variability of treatment effect estimates as a proxy for model robustness¹⁵. Following propensity-weighting and bootstrapping, balance between groups was confirmed using a Studentized bootstrap with no statistically significant differences observed across these features, specifically an equity analysis was conducted for sociodemographic covariates.

The study evaluation period was January 1, 2017 to December 31, 2019. The baseline reporting timeframe was defined as four months prior to identification. The outcome reporting timeframe was defined as the three months preceding death compared to four months preceding the index date (i.e., CCP program identification). These time periods were selected as internal data analyses consistently demonstrate end-of-life experiences and healthcare utilization to dramatically diverge during this time frame.

All data were de-identified, aggregated, and analyzed to determine the impact of the CCP on outcomes measures expressed as mean \pm standard error of the mean (SEM). Data derived from the care management dashboard database was used to calculate mean number of days enrolled in CCP preceding death. Claims data were used to calculate sample characteristics, and healthcare utilization and expenditures reported as difference-in-differences (i.e., [CCP participants: last three months before death minus the first four months prior to engagement] minus [Non-CCP participants: during the same time period as participants]). Healthcare utilization was segmented into the following categories and reported as rate per thousand per month (PTPM): a) emergency department (ED) visits; b) inpatient admissions; c) hospice; and d) urgent care utilization. Healthcare expenditures were segmented into the following categories and reported as (PMPM): a) inpatient admission spend; b) total allowed medical spend; c) ED spend; and d) outpatient spend. Medical cost category analysis was conducted by segmenting healthcare expenditures into the following sub-categories: primary care, specialty care, ambulatory visits, home health, mental health, laboratory, radiology, and medical pharmacy.

To mitigate influence of outliers, utilization and expenditures were capped at the 99th percentile. Weighted average treatment effects (WATE) were estimated by bootstrapping the propensity-weighted difference-in-differences for each of the outcome measures and reported as mean and 95% confidence interval for each WATE estimate. To account for the uncertainty of propensity scores, propensity weights were calculated separately for each bootstrap sample (N=200). Statistical significance was defined as $P < 0.05$. All analyses were performed using R version 4.2.0.

Results

Baseline descriptive statistics

Throughout the study period, a total of 10,633 members were identified and outreached for the CCP program of which 4,838 (45% enrolled); 916 (19% of enrolled) died; and 757 met inclusion criteria.

Table 1 details baseline characteristics of intervention (CCP; n=757) and comparison (n=35,408) groups before and after propensity weighting. Prior to weighting (and compared to non-CCP cohort members), CCP members were older ($P < 0.001$), more likely to be male ($P < 0.001$) and reside in rural areas ($P = 0.015$). In addition, CCP members had higher mean inpatient scores ($P < 0.001$) and higher rates of comorbidities such as hypertension, diabetes mellitus, and congestive heart failure (all $P < 0.001$).

After propensity score weighting, both groups exhibited similar characteristics (all $P > 0.440$). On average, the total included sample population (N=36,165) comprised of older adult (mean age, 79.0 years) males (56.9%) and females

(43.1%) with hypertension (>80%) with continuous health plan coverage (mean duration, 21 months); a majority of which residing in rural geographies.

Table 1. Baseline demographic data in unweighted and propensity-weighted cohorts (mean ± SEM)

Characteristic	Unweighted cohort			Propensity-weighted cohort		
	Comparison	CCP	P value	Comparison	CCP	P value
Total Participants, N	35,408	757	-	35,408	757	-
Demographic						
Age, years	79.0±0.1	80.3±0.3	<0.001	80.3±0.2	80.3±0.3	0.455
Male, %	51.6±0.3	64.9±1.8	<0.001	63.0±1.1	62.9±2.0	0.510
Female, %	48.4±0.3	35.1±1.8	<0.001	37.0±1.1	37.1±2.0	0.490
Geographical location						
Suburban, %	26.3±0.2	28.3±1.6	0.125	29.1±1.0	29.0±2.0	0.505
Rural, %	53.2±0.3	48.8±1.7	0.015	48.2±1.0	48.3±2.2	0.440
Urban, %	20.5±0.2	22.9±1.4	0.065	22.7±1.0	22.7±1.9	0.530
Medicare coverage						
Group, %	27.6±0.2	77.5±1.7	<0.001	71.6±0.9	71.6±2.2	0.485
Individual, %	72.4±0.2	22.5±1.7	<0.001	28.4±0.9	28.4±2.2	0.515
Plan duration, months	19.6±0.0	23.7±0.3	<0.001	21.1±0.1	21.1±0.3	0.485
Health status						
Hypertension, %	80.1±0.2	86.2±1.1	<0.001	85.1±0.9	85.2±1.6	0.520
Diabetes mellitus, %	36.0±0.2	39.3±1.8	0.020	38.3±1.1	38.2±1.9	0.515
Congestive heart failure, %	34.2±0.3	45.6±1.7	<0.001	45.3±1.2	45.4±2.1	0.520

Abbreviations: CCP, Compassionate Care Program

^a Proprietary score that predicts likelihood of an acute inpatient admission within 3 months (ranging 0-100%) for all members in the data warehouse

Enhanced care experience provided by nurse-led care management engagement

Decedents engaged in CCP (n=757) received care management services for an average of 231 days preceding death. Relative change in healthcare utilization trends were calculated for study evaluation period (i.e., 3 months preceding death) between groups. Compared to comparison cohorts and reported as difference-in-differences, CCP members had 92.2 PTPM less inpatient admissions (95% CI: 57.1, 130.7) and 66.3 PTPM less hospice elections (95% CI: 50.5, 83.7); however, the majority of between-group divergence was observed in the final month preceding death. There were no between group differences in ED (23.9; 95% CI: 64.3, 9.7) or urgent care (5.7; 95% CI: 14.0, 0.5) utilization.

Nurse-led care management engagement reduces goal-discordant healthcare expenditures

Compared to comparison cohorts and reported as difference-in-differences, CCP members exhibited lower spend on inpatient admissions (-2721.7; 95% CI: -1867.2, -3515.2); higher outpatient spend (351.7; 95% CI: -674.8, -77.9); and lower overall total medical spend (-2417.4; 95% CI: -1595.1, -3287.0) in the study evaluation period. There were no between group differences for ED spend (41.5; 95% CI: -21.0, 102.8).

To better characterize the overall reduction in total medical spend, a difference-in-differences sub-category analysis was conducted over the same timeframe. Notably, there was an observed reduction in primary care (-114.7; 95% CI:

-73.0, -158.2) and specialty care (-271.4; 95% CI: -148.9, -384.8) spend with concomitant increases in ambulatory (57.3; 95% CI: 117.9, 6.6) and home health spend (75.2; 95% CI: 129.2, 31.2). There were no observed changes in medical spend related to mental health (0.3; 95% CI: -0.8, 1.4), laboratory (8.7; 95% CI: -0.8, 18.6), radiology (-28.8; 95% CI: -72.2, 22.5), or medical pharmacy (-75.7; 95% CI: -269.7, 145.2).

Discussion

Principal results

This study characterized outcomes owing to an informatics-based approach used to identify 757 Medicare members for a payor-led, end-of-life care management program (i.e., CCP) in support of the quintuple aim. This nurse-led care management program enhanced the end-of-life care experience and provided equitable outcomes including decreased inpatient (-37%) admissions with concomitant reduced (-59%) medical spend when compared to decedents that did not utilize CCP.

Interpretation of principal results

These findings are directionally similar and of greater magnitude than previously described. The CCP was last evaluated in a study population of Medicare members engaged in CCP (n=299) from January 2014 to June 2015 compared to propensity-matched controls (n=299)¹². CCP participants exhibited PMPM lower total medical spend and PMPM lower inpatient medical spend, compared to controls reported as difference-in-differences. Given that US healthcare expenditures increased on average ~5% year-over-year between study evaluation periods¹⁶, these new findings demonstrate the program's long-term durability of impact. Access to medical and pharmacy claims data eliminates reliance on cost simulation models and provides a real-world benchmark for expected cost savings. This study replicates, and adds to, findings from previous work using similar methodological approaches, which reduces the likelihood of type I error and increases conclusion validity of major findings.

Reductions in total medical spend were largely driven by decreased inpatient spend, which was corroborated by decreased inpatient admissions. Additional medical cost category analyses revealed a significant increase in expenditures related to ambulatory and home health visits. Ambulatory care refers to clinical services received in an outpatient (i.e., non-hospital) setting such as urgent care centers or medical office visits while in-home health refers to care received in the home setting. These data provide a unique insight into *how* and *where* decedents experienced healthcare in their final days of life – in the comfort of their own home, where an overwhelming majority of adults prefer to be cared for¹. Previous efforts to examine the influence of home-based end-of-life care interventions on hospital admissions have been limited and/or underpowered¹⁷. Primary outcomes owing to this study (i.e., shift from hospital-based to home-based care) are directly aligned with patient preferences and reinforce the importance of developing human-centered interventions tailored to reflect the needs of the population.

One unexpected finding was a decrease in hospice use among CCP participants, which conflicts with previous findings demonstrating significant within- and between-group increases in hospice election. Reasons to explain this discordance are unclear. It is possible the results reported in 2009 reflect 'law of initial values' such that initial expansion and liberalization of hospice benefits in 2005 led to relatively greater within-group increases in hospice election (from 28% to 70%)¹¹. More recent analysis in 2019 demonstrated similar findings, albeit of smaller magnitude, with between-group differences in hospice election (58% for control vs. 79% for CCP)¹². It is also plausible that the combination of increased services and support provided by home health care providers; nurse-led, end-of-life care management program, and caregiver-enabled support fulfilled end-of-life care gaps otherwise requiring hospice services. Nevertheless, these findings warrant additional exploration.

Competencies required for success

Payors are uniquely positioned to address known systemic barriers to high-quality care and transform healthcare for a more sustainable future. Benefit liberalization and enhancement for end-of-life services directly enabled equitable access to a no-cost program across a nationwide population of Medicare members at scale. The responsible use of a clinical informatics-enabled approach, fueled by a rich and diverse data foundation and ML techniques, led to timely and appropriate identification of members most likely to derive benefit from these efforts. Interoperability, dedicated platforms, and additional technological capabilities, tools, and processes provide the foundational framework to operationalize the program. Finally, enhanced scope of practice enables nurse care managers to leverage this framework on a centralized platform to apply a human-centered approach for program delivery with the requisite competencies, resources, and compassion this special population deserves.

Major goals of the CCP are realized through the provision of consistent, continuous, and long-term support that reinforces collaboration, communication, and coordination of resources and benefits. Of note, CCP participants were engaged with the program for an average of 231 days preceding death; ~2.5x longer than the national average for comparable end-of-life benefit programs (i.e., hospice)⁵ and 2x longer than previous studies¹². These findings are reassuring and demonstrate durability of CCP impact to address the problem of fragmented care commonly experienced by older adults. In addition, long-term engagement with the program signals member need and satisfaction; studies have been designed to identify patient-reported outcomes regarding program satisfaction and are currently in progress. Although these mixed-methods studies have not been analyzed to date, the program is overwhelmingly well-received by members and their caregivers, and often forgotten, but these nurse care managers are a critical member of the end-of-life care team. Anecdotal feedback suggests that caregivers place greatest value on psychosocial aspects of caregiving (i.e., support when feeling overwhelmed, being present and available as a trusted resource, and help understanding unique scenarios). In addition, caregivers highly value transactional care coordination activities offered through the CCP, such as navigating the healthcare system and coordinating hospice care transition.

Limitations

The application of propensity scoring to evaluate the program impact, including an assessment of equitable outcomes, supports health disparities research¹⁸ and examination of the quintuple aim. This methodology takes into consideration the distribution of multiple confounding covariates (e.g., sociodemographic), as well as the relationship between the health-related outcomes, to establish well balanced groups of comparison while reducing bias and providing generalized effect estimates in a large sample size of 36,165 decedents. For example, members' geography is a key SDoH and contributing factor for disparities identified in end-of-life care. Individuals residing in rural, geographically isolated, and/or areas with high area deprivation index are less likely to receive high-quality, end-of-life care than individuals residing in urban settings^{19,20}. The study population was geographically diverse with representation from rural (~48%), suburban (~29%), and urban (23%) areas and representative sampling ensures study findings can be generalized to the larger US population. Controlling for this confounder, in addition to other sociodemographic, health plan type, comorbidities, and medical and pharmacy utilization covariates, using estimation methods including matching versus weighting are effective; however, this study utilized weighting and unlike matching, there is no guarantee of the overlap assumption and may inflate variance. Additional covariates for future consideration should include demographic variables including race and ethnicity, as disparities and subsequent inequities in access and receipt of care are well described²¹.

Additional limitations include outcomes inferred by pragmatic CCP interventions and utilization of algorithms. RCTs are the gold-standard approach to measure the causal effectiveness of an intervention but are not feasible to conduct in a health plan setting. Retrospective observational studies of member cohorts are a statistically valid approach to test real-world outcomes in a large, heterogeneous population. The prediction model details, and its performance described herein, may be slightly variable across timeframes and member populations given the iterative, test-and-learn approach to model production, which may have resulted in under-reporting of model performance and downstream outcomes specific to this study. ML applications to healthcare are imperfect, and in the context of mortality prediction have the potential to result in ethical implications without proper oversight and expertise²². As such, it is important to note that the CCP prediction model is restricted for CCP identification only, and in combination with nurse-led, care management pathways to ensure appropriate use.

Future directions

Now nearly 20 years since its inception, the CCP continues to build upon its foundational infrastructure and organizational capabilities that have contributed to the program's long-standing success. Existing efforts are in flight to iterate and advance ML model performance and utility. Near-future model inputs will incorporate daily claims data and refresh on a weekly cadence to improve timeliness for identification. Software and hardware advances will allow for real-time monitoring and address performance/feature drift through training/tuning. Additional methodologies are currently being explored such as supervised timeseries deep learning modeling with promising preliminary results. These combined efforts will aim to enhance identification and time-to-engagement for person-centered, end-of-life, care support provided by competency-proficient nurse care managers.

Downstream program efforts will continue to evaluate the quintuple aim and expand the clinical, psychosocial, and cultural competencies of program-dedicated, healthcare providers. Opportunities to continually address existing health disparities to advance health equity will be explored for members, in addition to assessing care team well-being.

Moreover, examples of recently added competency modules include: care of the LGBTQ+ patient; supporting patients with challenging mental and/or behavioral health issues; overview of new treatments in palliative and hospice care; and enhanced support for heart failure, neurological disorders, Alzheimer's disease, dementia, and other chronic diseases. The identification, collection, and reporting of standardized outcomes of most importance for patients plus their caregivers and care team, would be of great public health interest such as "quality of death", pain control, communication, trust, and closure^{23,24}.

Lastly, novel payment and service delivery models such as the Medicare Advantage Value-Based Insurance Design will assess payor and provider performance for person-centered, value-based, hospice care. Such efforts have facilitated the development of an ongoing demonstration project that aims to assess the incremental value of additional supplemental benefits that directly address SDoH and/or enable enhanced care management support, including meals, transportation services, personal emergency response system devices, in-home clinical services, and connected devices²⁵.

Conclusion

The study demonstrates a ML-enabled, compassionate care management program provided enhanced care experience compared to a propensity-weighted comparison cohort. These findings reinforce the promise of clinical informatics to directly enable equitable access to low cost, high-value care across the entire healthcare journey, inclusive of end-of-life.

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Competing Interests

All authors were employed by CVS Health® Corporation at the time of the study. AZ, KJTC, and HY own stock and/or equity in CVS Health. AZ is also employed by Hartford Hospital. The authors have no conflicts germane to this study.

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Data Availability

The data sets generated and/or analyzed during the study are not publicly available due to data use agreements.

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