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Economic Analysis of Hospital Palliative Care: Investigating Heterogeneity by Noncancer Diagnoses

Peter May, Charles Normand, Egidio Del Fabbro, Robert L. Fine, R. Sean Morrison, Isabel Ottewill, Chessie Robinson, and J. Brian Cassel

Abstract

Background. Single-disease-focused treatment and hospital-centric care are poorly suited to meet complex needs in an era of multimorbidity. Understanding variation in palliative care's association with treatment choices is essential to optimizing interdisciplinary decision making in care of complex patients. **Aim.** To estimate the association between palliative care and hospital costs by primary diagnosis and multimorbidity for adults with one of six life-limiting conditions: heart failure, chronic obstructive pulmonary disease (COPD), liver failure, kidney failure, neurodegenerative conditions including dementia, and HIV/AIDS. **Methods.** Data from four studies (2002–2015) were pooled to provide an analytic dataset of 73,304 participants with mean costs $10,483, of whom 5,348 (7%) received palliative care. We estimated average effect of palliative care on direct hospital costs among the treated, using propensity scores to control for observed confounding. **Results.** Palliative care was associated with a statistically significant reduction in total direct costs for heart failure (estimated treatment effect: −$2666; 95% confidence interval [CI]: −$3440 to −$1892), neurodegenerative conditions (−$3523; −$4394 to −$2651), COPD (−$1613; −$2217 to −$1009), kidney failure (−$3589; −$5132 to −$2045), and liver failure (−$7574; −$9232 to −$5916). The association for liver failure patients was statistically significantly larger than for any other disease group. Cost-saving associations were also statistically larger for patients with multimorbidity than single disease for two of the six groups: neurodegenerative and liver failure. **Conclusions.** Heterogeneity in treatment effect estimates was observable in assessing association between palliative care and hospital costs for adults with serious life-limiting illnesses other than cancer. The results illustrate the importance of careful definition of palliative care populations in research and practice, and raise further questions about the role of interdisciplinary decision making in treatment of complex medical illness.

Keywords

palliative care, end of life care, comorbidities, hospital costs, heterogeneity

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Societies and governments face an unprecedented challenge in providing health care for large populations of older people with serious chronic illness and multimorbidity.[1] Single-disease-focused decision making within health systems designed to produce acute, episodic care does not appropriately meet the complex needs of older populations with multiple illnesses.[1–5] Projected future cost curves for this population are unsustainable, making reform a policy priority in the United States and internationally.[6,7]

Palliative care is provided by an interdisciplinary team of specialists in medicine, nursing and psycho-social-spiritual care, serving patients and families facing serious illness.[8] It strives to improve patient-centered communication, care planning, and the management of multiple

Corresponding Author

Peter May, Centre for Health Policy & Management, Trinity College Dublin, 3-4 Foster Place, Dublin, IE 2, Ireland; Telephone: (353) 1 896 4612 (peter.may@tcd.ie).

symptoms associated with such illness.[8] Palliative care is identified in guidelines as having potential benefits across the trajectory of any serious illness for persons of all ages. The World Health Organization recommends palliative care as applicable from early in the course of all life-limiting diseases,[9] and the American Society of Clinical Oncology recommends palliative care concurrently with active treatment from point of metastatic cancer diagnosis regardless of prognosis.[10]

This expansion of palliative care involvement poses new questions for policy, practice, and evaluation. Previously the target population was generally defined as those entering an end-of-life phase, receiving an intervention conceptualized as withdrawal of futile treatment.[11,12] In this context, cost savings from the intervention are inevitable, though modest.[13] Evaluating palliative care earlier in the disease course requires more detailed consideration of both intervention, including upstream palliative involvement, and population, including those with multimorbidity and/or noncancer progressive diseases with different trajectories.[14,15]

Conceptual Framework and Rationale

Kelley and colleagues propose that the amounts and type of care received by a person with serious illness is a function of clinical need, other individual determinants, patient and family preferences, physician attitudes, and local practice (Figure 1).[16] Within this framework, palliative care may affect costs of treatment not only by managing pain and other symptoms and reducing futile treatments but also by informing the choices of attending physicians and by involving patients and families in decision making, including goals-of-care discussions and discharge planning.

How palliative care is associated with changing patterns of treatment for people with life-limiting illness outside of the end-of-life phase will necessarily vary given different prognoses, attending specialisms, and treatment regimens, but this variance is not well understood. Where some early research suggested that patterns could not be changed for an intractably complex, multimorbid minority,[17] more recent work found that the cost-saving estimates are largest for those with higher numbers of complications[18] and comorbidities.[19]

We interpret these results as indicating that palliative care is at least in part multifaceted decision support. Where patients have a single serious disease and clear prognosis, single-disease-focused care is typically more appropriate (although palliative care may still be beneficial). Multimorbidity brings more concurrent medications with effects, side-effects, and possible interactions, and a wider host of clinical voices through multiple attending specialty teams,[20,21] and interdisciplinary decision making may have a greater impact on the course of care. Palliative care may be beneficial for all patients with serious illness but the lack of careful treatment planning in the scenario of multimorbidity makes it more likely the patient will end up in the intensive care unit or receive other interventions that may be burdensome on the patient, futile, and costly.[22]

From an economic perspective, understanding heterogeneity of treatment effects is critical to optimal allocation of scarce resources.[23–25] Such analyses are nevertheless rare across health economics[26] and in palliative care,[27] where most services do not meet staffing recommendations.[28] While a difference has been shown in estimated cost savings in cancer and noncancer populations,[29] variation across specific noncancer diagnoses has not yet been evaluated. Clarifying treatment effect heterogeneity for noncancer patients can both inform optimal allocation of existing capacity and also contribute to wider understanding of interdisciplinary decision making in care for complex medical illness in the era of multimorbidity.

Aim and Hypotheses

To estimate the association between palliative care and hospital costs by primary diagnosis and multimorbidity for adults with one of six life-limiting conditions: heart failure, respiratory failure including chronic obstructive pulmonary disease (COPD), end-stage liver disease,

Centre for Health Policy and Management (PM, CN, IO) and The Irish Longitudinal Study on Ageing (PM), Trinity College Dublin, Dublin, Ireland; Cicely Saunders Institute of Palliative Care, Policy & Rehabilitation, King's College London, London, UK (CN); Massey Cancer Center, Virginia Commonwealth University, Richmond, Virginia (EDF, JBC); Baylor Scott & White Health, Dallas, Texas (RLF, CR); Department of Medicine and Department of Medical Humanities, Texas A&M University College of Medicine, Bryan, Texas (RLF); Department of Geriatrics and Palliative Medicine, Icahn School of Medicine at Mount Sinai, Mount Sinai, New York (RSM); James J Peters VA Medical Center, The Bronx, New York (RSM). The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: PM was supported by the International Access, Rights and Empowerment (IARE) fellowship program, which is funded by The Atlantic Philanthropies (Grant #24611). RSM received support from the Mount Sinai Older Adults Independence Center (P30AG028741), the National Institute on Aging (NIA) (R24AG044300), and the National Palliative Care Research Center. The funding agreements ensured the authors' independence in designing the study, interpreting the data, writing, and publishing the report.

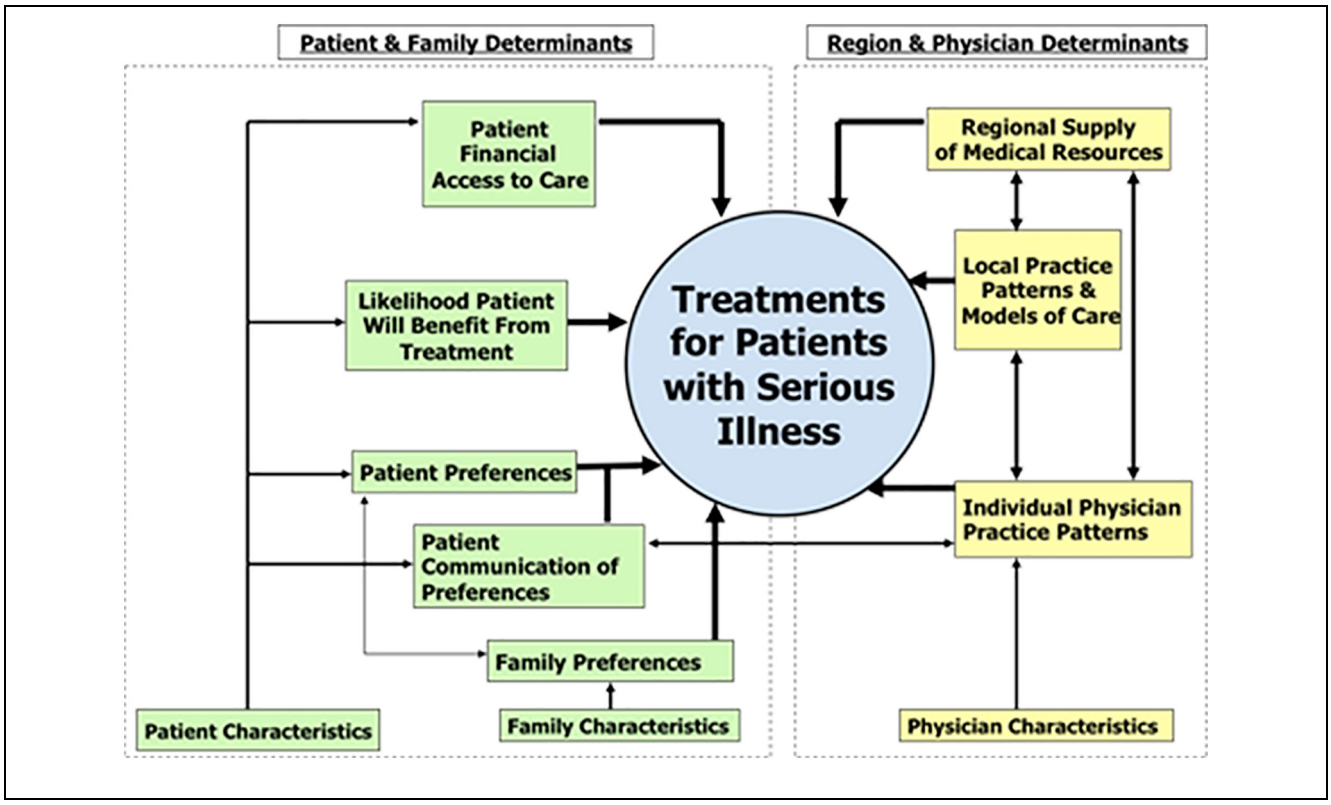

Figure 1 Conceptual model for treatment of patients with serious illness.[16]

end-stage kidney disease, selected neurodegenerative conditions including dementia, and HIV/AIDS.

We hypothesized that in comparisons by diagnosis, estimated cost savings would be greatest for end-stage liver disease, where prognosis is poor and high-intensity treatments are commonplace. We hypothesized that in comparisons by multimorbidity, estimated cost savings would be greatest for those with multimorbidity, where interdisciplinary decision making is most effective in changing treatment choices from usual care.

Methods

Study Design and Participants

Previously we have reported a systematic database search (to December 2017) and meta-analysis of six hospital palliative care cost studies.[29] In this article, we pooled data from four of these studies,[30–33] excluding the others for enrolling only cancer patients[34] and due to data access restrictions.[35]

The four pooled studies share methodological fundamentals: retrospective cohort studies of routinely collected data for single-index hospital admissions that (excluding cancer patients) enrolled adults with one of six diagnoses identified via hospital *International Classification of Diseases, Ninth Revision* (ICD-9), codes at admission. These diagnoses were identified as palliative care relevant for research purposes: progressive, life-limiting conditions often accompanied by high symptom burden, frequent hospitalizations, and decisions about further treatment.[30,36] Patients admitted for trauma or organ transplant were excluded. Data were collected from 2002 to 2015; study characteristics are summarized in Table 1.[29]

In primary analysis, we grouped patients into six groups according to primary diagnosis. In secondary analysis, we divided each of the six diagnostic groups into two according to multimorbidity status (≤ 1 |$2 \leq$ on the Elixhauser index[37]).

Variables

Dependent Variable. In primary analysis, outcomes of interest were total direct hospital costs and length of stay (LOS) in hospital. In secondary analysis, we focused on total direct hospital costs only.

Table 1 Four Datasets Included in Meta-Analysis: Overview of Study Characteristics

	Morrison (2008)[30]	Morrison (2011)[31]	McCarthy (2015)[32]	May (2017)[33]
Study summary				
Design	Retrospective cohort	Retrospective cohort	Retrospective cohort	Retrospective cohort
Data sources	Routine hospital databases	Routine hospital databases; Medicaid patients only	Routine hospital databases	Routine hospital databases
Control for bias	Propensity scores	Propensity scores	Propensity scores	Propensity scores
Years of data collection	2001–2004	2003–2007	2011–2014	2007–2015
State(s) (all studies US)	California; Kentucky; Minnesota; New York; Ohio; Wisconsin	New York	Texas	Virginia
Primary dx: Heart failure	17,095	1689	6513	2877
Primary dx: Neurodegenerative	2759	125	171	262
Primary dx: COPD	14,897	2365	5367	118
Primary dx: Kidney failure	4777	809	730	66
Primary dx: HIV/AIDS	2003	580	435	50
Primary dx: Liver failure	5279	1513	2316	508
Total subjects	46,810	7081	15,532	3881
Received PC ≤ 3 days	3%	3%	3%	5%
Live discharges	92%	94%	96%	98%
Sites (#)	8	4	5	1
Setting	Five Community and 3 academic hospitals	One community hospital, 2 academic medical centers, 1 safety-net hospital	Four Community and 1 academic hospital	High-volume tertiary care medical center and academic hospital

COPD, chronic obstructive pulmonary disease; ICD-9, *International Classification of Diseases, Ninth Revision.*

Sampling: All four studies used a fixed list of life-limiting illnesses identified as relevant for palliative care research purposes. See Appendix Part 1 for ICD codes. In original reporting, three studies removed long-stay outliers from their samples ex ante;[30–32] one study also included all eligible patients on each admission during the study period (so some subjects had multiple admissions).[32] We retained long-stay outliers as their removal has been shown to bias results and inflate treatment effect estimates.[17] We did not include subjects on a return admission to minimize possible bias from double-counting of some patients. Instead we accessed original study data in each case, excluded those with a primary cancer diagnosis, and retained all other subjects for their first admission in the study period where they met the baseline criteria (i.e., an ICD-9 code as listed in the appendix).

Table 2 Baseline Characteristics and Summary Outcomes, by Primary Diagnosis

	All	Heart	Neuro	COPD	Liver	Kidney	HIV/AIDS
N	73,304	28,174	3317	22,747	9616	6382	3068
Baseline							
Age	64.8 (66)	70.8 (15)	71.1 (17)	64.6 (16)	54.1 (13)	61.2 (17)	44.1 (10)
Male	47%	47%	44%	41%	57%	50%	66%
Medicaid	20%	12%	10%	19%	33%	22%	60%
Medicare	60%	72%	73%	60%	29%	64%	20%
Elixhauser	3.0 (1.7)	3.3 (1.7)	2.0 (1.4)	2.8 (1.6)	2.8 (1.7)	3.4 (1.6)	2.4 (1.6)
Walraven	7.4 (7.2)	8.6 (7.3)	3.8 (5.3)	5.5 (6.1)	10.2 (8.6)	7.9 (6.3)	5.1 (7.5)
Treatment							
Received PC	8%	8%	12%	5%	7%	8%	14%
PC day	9.4 (13)	9.4 (14)	6.0 (8)	8.2 (12)	10.4 (13)	11.6 (17)	12.0 (13)
Outcomes							
Direct costs ($)	10,483 (22,350)	10,913 (23,416)	10,330 (17,034)	7420 (13,557)	15,111 (33,125)	11,062 (22,146)	13,688 (24,818)
LOS	8.2 (10)	8.3 (10)	9.7 (11)	7.0 (8)	8.8 (11)	8.9 (12)	10.6 (12)
Died	7%	7%	8%	4%	10%	8%	11%

COPD, chronic obstructive pulmonary disease; LOS, length of stay; PC, palliative care.
For continuous/count variables: Mean (standard deviation). Medicare/Medicaid: Principal payer; reference case = any other payer. Elixhauser/Walraven: illness burden indices.[37,43] Received PC: had a palliative care consultation at any time during admission; PC day: days from admission to first palliative care interaction. Direct costs: total direct cost of index admission. LOS: length of stay in hospital during index admission. Died: during index admission.

Direct costs were extracted from each hospital site's accounting database at the time of the original studies and reflect the specific dollar cost to the hospital of relevant staffing, equipment, pharmaceuticals, and procedures for each subject.[38] Excluded were indirect costs, sometimes known as overheads, which reflect the patient's "share" of fixed costs such as hospital buildings, facilities, and maintenance. We included only direct costs as those that the intervention could plausibly have affected in the window of analysis (e.g., by reducing tests or shortening stay and so staff burden). Inclusion of indirect costs risks inflating estimated treatment effects because in accounting systems these are typically calculated as a proportion of direct costs. Thus, an intervention that reduces direct costs will also appear in analysis to have reduced indirect costs, but these will still exist from the hospital to pay from other sources. We standardized all costs to 2015, the final year of data collection, using the Consumer Price Index.[39]

Intervention Variable. Primary exposure variable was binary: Did the subject receive a palliative care consultation within three days of admission?

Palliative care consultations are delivered by a physician-led interdisciplinary team including a nurse and social worker. The team becomes involved in the care of patients at the invitation of the attending physician and advises on pain and symptom management, and initiates goals-of-care discussions and discharge planning.[40,41] Palliative care team involvement was identified by stand-alone databases operated by programs.[42]

Additional Independent Variables. Additional independent variables were those factors collected at admission that we hypothesized could be associated with both treatment and outcome, and that were available in all four datasets. These are listed in Table 2. We calculated comorbidity count on the Elixhauser index, a list of 31 chronic conditions: congestive heart failure; cardiac arrhythmia; valvular disease; pulmonary circulation; peripheral vascular disorders; uncomplicated hypertension; complicated hypertension; paralysis; other neurologic disorders; chronic pulmonary disease; uncomplicated diabetes; complicated diabetes; hypothyroidism; renal failure; liver disease; peptic ulcer disease; AIDS/HIV; lymphoma; metastatic cancer; solid tumor without metastasis; rheumatoid arthritis; coagulopathy; obesity; weight loss; fluid/electrolyte disorders; blood loss anemia; deficiency anemia; alcohol abuse; drug abuse; psychoses; and depression. Conditions were identified via ICD-9 code in hospital records. Each condition is dichotomous (absent = 0 | present = 1), and each subject's Elixhauser total is the sum of 31 dichotomous scores.[37]

Additionally we calculated each subject's propensity for in-hospital mortality based on characteristics at admission using the van Walraven index.[43] This modifies

the Elixhauser scoring system, attributing each of the 31 conditions a score (range: −7 to +12) that captures each condition's association with hospital death. In the context of well-known problems controlling for mortality in seriously-ill populations with routine data,[44] we considered this a superior approach to excluding or explicitly controlling for observed hospital death in the sample due to endogeneity concerns.[45]

Finally, we included year of admission as a predictor in regression and in propensity score calculation to control for practice changes over time of the studies.

Bias. We balanced treatment and comparison groups on observed covariates hypothesized to be associated with treatment and outcome (Table 2).[46,47] Prior to estimating treatment effects, we assessed common support, balance of covariates within propensity score blocks, and balance of covariates after weighting the sample.[48] For details, see Appendix Part 2. Within each analytic subsample defined by diagnosis and/or multimorbidity, we calculated new propensity scores using the covariate balancing propensity score method, creating inverse-probability-of-treatment-weights from the estimated propensity score for analyses.[49] Propensity scores were calculated in R.[50]

Statistical Methods

Estimating treatment effect for a given sample. We used generalized linear models (gamma distribution, log link) and bootstrapped standard errors (1000 reps) to estimate the marginal average treatment effect on the treated (ATET), the average effect of treatment on the outcome of interest for those who received PCC, holding all other values constant and applying sample-specific propensity score weights. Regressions were performed in Stata (version 12).[51] For all tests, $P < 0.05$ was considered as significant ex ante.

Comparing treatment effect estimates. Each regression output evaluating association between treatment and outcome represented an ATET distribution which has a reported mean, bootstrapped standard error, 95% confidence interval (CI), and sample size. To compare the estimates for each of the six disease groups, we compared the ATET distributions using one-way analysis of variance (ANOVA), which takes into account the mean, variance, and sample size of each ATET distribution. Where the ANOVA test statistic was significant, post hoc Tukey HSD tests were used to assess each of the head-to-head comparisons for significance (15 head-to-head comparisons for each outcome of interest).

To compare the treatment effect estimates of single disease (Elixhauser index $\leq$ 1) and multimorbid (2 $\leq$ Elixhauser index) subgroups within each diagnosis, we compared the ATET distributions using independent *t* tests.

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Results

Descriptive and Outcome Data

There were 73,304 in the analytic sample (Table 2), of whom 28,174 (38%) had a primary diagnosis of heart disease, 3317 (5%) had a neurodegenerative condition, 22,747 (31%) had COPD, 9616 (13%) had liver disease, 6382 (9%) had kidney disease, and 3068 (4%) had HIV/AIDS.

Summary outcome measures are also presented in Table 2. In the overall sample, 8% (range: 5% to 14%) received palliative care during the admission and 7% (4% to 11%) died before discharge. Mean total direct costs of admission were $10,483 and average LOS was 8.2 days.

Main Results

Primary analyses are presented in Table 3. Palliative care had a statistically significant association with lower total direct costs for five diagnostic groups: heart failure (ATET: −2666; 95% CI: −3440 to −1892), neurodegenerative (−3523; −4394 to −2651), COPD (−1613; −2217 to −1009), kidney failure (−3589; −5132 to −2045), and liver failure (−7574; −9232 to −5916). Each of these diagnostic groups also had a statistically significant association with reduced LOS. The equivalent associations for HIV/AIDS were not significant in either case. Additional details of regression output are provided in Appendix Part 3.

The ANOVA test statistic evaluating difference between estimates by diagnostic group was significant for costs but not for LOS. Post hoc evaluation in Table 4 finds that the estimated association was statistically significantly larger for liver failure than each of the other five diagnoses, and that no other disease-to-disease comparison was significantly different.

Secondary analyses are presented in Table 5. For COPD and liver failure, which each exhibited a significant

Table 3 Primary Analyses: Estimated Treatment Effects on Direct Costs (US$) and LOS (Days), by Primary Diagnosis

				Total Direct Costs ($)			LOS (Days)		
Diagnosis	**All (*N*)**	**CG (*n*)**	**TG (*n*)**	**ATET ($)**	**95% CI**	**One-Way ANOVA**	**ATET (days)**	**95% CI**	**One-Way ANOVA**
Heart failure	28,174	27,340	834	**−2666**	**−3440 to −1892**	***F*(5, 1953) = 5.3,**	**−1.20**	**−1.77 to −0.64**	*F*(5, 1953) = 2.2,
Neurodegenerative	3317	3124	193	**−3523**	**−4394 to −2651**	***P* < 0.0005**	**−2.76**	**−3.40 to −2.12**	*P* = 0.05
COPD	22,747	22,332	415	**−1613**	**−2217 to −1009**		**−1.13**	**−1.66 to −0.60**	
Kidney failure	6382	6226	156	**−3589**	**−5132 to −2045**		**−2.32**	**−3.18 to −1.46**	
HIV/AIDS	3068	2944	124	−2564	−6311 to 1184		−1.07	−2.97 to 0.84	
Liver failure	9616	9379	237	**−7574**	**−9232 to −5916**		**−1.57**	**−2.36 to −0.78**	

ATET, average treatment effect on the treated; CG, comparison group, including all other subjects; CI, confidence interval; COPD, chronic obstructive pulmonary disease; LOS, length of stay; TG, treatment group, receiving palliative care within three days of admission.

Table 4 Tukey HSD Post Hoc Evaluations for ANOVA Test in Primary Cost Analysis

	Heart Failure versus	**Neurodegen versus**	**COPD versus**	**Kidney versus**	**HIV/AIDS versus**
Neurodegenerative	−857; *P* = 0.93				
COPD	+1053; *P* = 0.62	+1910; *P* = 0.36			
Kidney failure	−923; *P* = 0.93	–66; *P* = 0.99	–1976; *P* = 0.41		
HIV/AIDS	+102; *P* = 0.99	+959; *P* = 0.98	–951; *P* = 0.96	+1025; *P* = 0.97	
Liver failure	**−4908; *P* < 0.0005**	**−4051; *P* = 0.003**	**−5961; *P* < 0.0005**	**−3985; *P* = 0.007**	**−5010; *P* = 0.0007**

COPD, chronic obstructive pulmonary disease.
$p<0.05$

Table 5 Secondary Analyses: Estimated Treatment Effects on Direct Costs, by Primary Diagnosis and Elixhauser Total (ET).

Diagnosis		**All (*N*)**	**CG (*n*)**	**TG (*n*)**	**ATET ($)**	**95% CI**	***t* Test**
Heart failure	ET ≤ 1	3813	3715	98	**−2407**	**−3308 to −1507**	*t* = 0.6; df = 832; *P* = 0.54
	2 ≤ ET	24,361	23,625	736	**−2787**	**−3644 to −1931**	
Neurodegenerative	ET ≤ 1	1320	1245	75	**−2427**	**−3376 to −1477**	***t* = 2.3; df = 191; *P* = 0.02**
	2 ≤ ET	1997	1879	118	**−4424**	**−5869 to −2978**	
COPD	ET ≤ 1	4440	4380	60	−990	−2366 to 387	*t* = 1.0; df = 413; *P* = 0.32
	2 ≤ ET	18,307	17,952	355	**−1771**	**−2467 to −1076**	
Kidney failure	ET ≤ 1	739	729	10	**−4268**	**−6710 to −1827**	*t* = 0.4; df = 154; *P* = 0.71
	2 ≤ ET	5643	5497	146	**−3705**	**−5356 to −2054**	
HIV/AIDS	ET ≤ 1	970	943	27	−731	−2602 to 1140	*t* = 1.0; df = 122; *P* = 0.33
	2 ≤ ET	2098	2001	97	−3655	−9261 to 1951	
Liver failure	ET ≤ 1	2216	2175	41	−2780	−5657 to 96	***t* = 3.7; df = 235; *P* < 0.0005**
	2 ≤ ET	7400	7204	196	**−9330**	**−11244 to −7416**	

ATET, average treatment effect on the treated; CG, comparison group, including all other subjects; CI, confidence interval; COPD, chronic obstructive pulmonary disease; TG, treatment group, receiving palliative care within three days of admission.
$p<0.05$

association in the overall sample (Table 3), the estimated cost association was only significant for multimorbid subsamples and not single-disease groups. In comparing the results by multimorbidity status within each disease group, significant differences were observed for only two of the six diagnostic groups: liver failure and neurodegenerative. In each case the estimated cost association was larger for the multimorbid group than those with a single disease.

Discussion

Key Results

In estimating palliative care's association with lower hospital costs for adults with life-limiting illnesses other than cancer, heterogeneity in treatment effect estimates was observable. The intervention was associated with reduced costs and LOS for five of six primary diagnoses (Table 3), and the cost-saving estimate was significantly larger for liver failure than for other disease groups (Table 4). The treatment effect estimate was also significantly larger for multimorbid patients than those with a single disease, where the primary diagnosis was liver failure or neurodegenerative (Table 5). For COPD and liver failure, the intervention was only significantly associated with lower costs for those with multimorbidity.

These primary results were in line with our hypotheses. The estimate that cost savings were significantly larger for liver disease than other diagnostic groups may be explained by that group's high propensity for intensive care unit admission and other invasive treatments. Notably, liver disease was both the youngest and the highest cost diagnostic group (Table 2), implying higher intensity treatment under usual care and greater potential for changing patterns of treatment. The significant association with reduced LOS for each diagnostic group with a significant cost-saving estimate was consistent with prior studies and our hypotheses that palliative care does not simply reduce intensity of treatment or futile care, but changing patterns and expediting hospital discharge, possibly through goals-of-care discussions and transition planning.[52]

The secondary finding that there was an interaction between primary disease and multimorbidity—savings were estimated to be greater by multimorbidity status for some disease groups but not others—demonstrates further the presence of heterogeneity in estimates, and the need for better understanding of who benefits most from palliative care when. The lack of significant association by multimorbidity for four disease groups was not in line with our hypotheses, suggesting that the relationships are more complicated; it is not simply that palliative care is more effective the higher the disease burden. Rather, treatment effect may be contingent on both primary diagnosis and multimorbidity count, and potentially the presence or interaction of specific combinations of conditions.

Limitations

This study uses observational data so causation cannot be claimed. While we controlled for some observed confounders using propensity score weights, other important confounders (e.g., race) were excluded as not available in all data sets. Additionally unobserved confounding may be an important factor in results. We could not identify a valid instrumental variable in these data to manage unobserved confounding. Propensity scores may exacerbate bias from unobserved confounding.[53] We therefore re-ran our primary analyses without propensity scores. Results were substantively similar. For full details see Appendix Part 4.

We specified our exposure variable as palliative care within 3 days of admission. No clinical guidelines exist to inform such a cutoff but incorporating timing is essential to the accuracy and usefulness of effect estimates as well as reducing risk of a false negative.[34] Patients may vary in responsiveness to palliative care involvement and preferences for changing treatment pathways at different times in an admission and optimally the treatment variable would be modelled continuously to capture this. Moreover, there are factors hidden to investigators that were observable to physicians during clinical practice, for example, likelihood that certain treatments will lead to poor outcomes for certain patients. Reported associations may therefore be overestimated, if patients who received palliative care were more likely to benefit that those who did not in ways that our data do not capture. We used our chosen approach on the basis that, all else held constant, earlier consults will have a larger effect.[54] Our results were robust to alternative cut-offs.

We used routinely collected data, which leads to crude classification of patient diagnosis and need. Optimal approaches to identifying treatment effect heterogeneity in this context require multidimensional classification of need according to age, diagnosis, multimorbidity, and physical and cognitive impairments. Additionally, the data were collected over a long time period during which there has been rapid growth in palliative care activity in large US hospitals as well as changing attitudes among primary attending physicians toward palliative care.[55] Future studies examining these questions would optimally

extract data from a larger population (more hospitals, or systems) in a shorter time period to maximize representativeness of current practice. However, this analysis represents the first such of its kind and advances the evidence on this research question.

Our analyses were restricted to single index hospital admissions from the provider perspective. In the context of recommendations for palliative care from point of diagnosis, future research must investigate economic effects across the disease trajectory.[56] Nevertheless, hospital costs account for most health care utilization among the seriously ill and are therefore a valid subject of enquiry in their own right.[57,58] We included only direct costs in our outcome of interest, and since indirect costs are a function of direct costs this decision does not substantively effect results. Long-run analyses of how treatment patterns change hospital costs should incorporate indirect costs since in principle in the long run these costs can be saved, for example, by closing buildings, redeploying staff.

We examined only association between treatment and costs, but full economic evaluation incorporates intervention effect on costs and on outcomes.[56] From an economic perspective, scarce palliative care capacity should be prioritized for those groups for whom cost-effects are largest only on an assumption that outcome effects are equal across diagnostic groups. We are not aware of any study to examine heterogeneity of clinical outcomes, and this work is essential before evidence of heterogeneity could be used as a basis for clinical practice guidelines.

Interpretation and Future Research

Our rationale for pursuing this enquiry was twofold. First, understanding heterogeneity of treatment effect estimates maximizes the usefulness of health economic studies to inform service planning and resource allocation,[23–25] and relevant evidence is currently limited in palliative care. Second, such evidence as does exist in palliative care points to an interesting and potentially powerful insight: that interdisciplinary decision making has the most impact among the most complex patients, who account disproportionately for costs while experiencing poor outcomes and unmet need in systems originally designed to provide acute, episodic care.[22]

With regard to staff and service planning within hospital settings, we estimated significant cost savings for five different diagnostic groups for whom palliative care referral rates are currently low as well as substantive heterogeneity of estimated association between treatment and costs. Expanding palliative care access according to national guidelines could reduce costs of serious illness patients in hospital. In assessing the association between disease burden and estimated treatment effect, we found that it was not simply the case that multimorbid patients were associated with larger treatment estimates than single-disease patients. Future research is required to understand when and for whom to provide palliative care interventions improve patterns of treatment.

Such research could examine the interaction of specific diseases and combinations of diseases, and how observed effects vary by age given the well-known complexities of delineating years lived, years to death, and costs in the last year of life.[59,60] However, this will require very large samples, particularly for diagnoses where prompt palliative care referral at admission is less common. Recent advances in machine learning may indicate the most efficient way to progress this research agenda.[27,61] The particular drivers of estimated savings, with respect to both expedited discharge and reduced intensity of care, would also be valuable. Given that palliative care is a multifaceted intervention and different models of care have reported different treatment effect estimates,[33,62] such analyses must delineate the effect of components, which also may vary by population.[25]

Perhaps most important in an era of multimorbidity during which people will live months and years with life-limiting illness is to widen the scope of enquiry. This requires moving beyond single index hospital admissions to establish how interventions—and specific components of interventions—affect costs and outcomes across the disease trajectory.

Conclusion

In estimating palliative care's association with hospital costs for adults with noncancer diagnoses, substantive heterogeneity in treatment effect estimates was observable. Improving outcomes and lowering costs for people with serious medical illness is widely recognized as a policy priority, yet understanding of when and for whom interventions change patterns of care remains formative. Further research is required to inform allocation of scarce capacity currently and consider future application of interdisciplinary decision making alongside usual care in treatment of complex medical illness.

Authors' Note

Each study was approved by the lead site's institutional review board at the time of the original study, and this pooled analysis was additionally approved by the ethics committee of Trinity College Dublin Centre for Health Policy and Management.

Since only routine data were collected, this study does not qualify as human subjects research and did not require patient consent. Primary ethical consideration was data security and patient anonymity, which were protected by robust measures and written agreements between participating centers.

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ORCID iD

Peter May https://orcid.org/0000-0001-8501-6500

Supplemental Material

Supplementary material for this article is available on the *Medical Decision Making Policy & Practice* website at https://journals.sagepub.com/home/mpp.

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