Does modality matter? Palliative care unit associated with more cost-avoidance than consultations

Peter May, PhD1, Melissa M. Garrido, PhD2,3, Egidio Del Fabbro, MD4, Danielle Noreika, MD4, Charles Normand, DPhil1, Nevena Skoro, MPH5, and J. Brian Cassel, PhD4

1Trinity College Dublin, Ireland 2James J. Peters VA Medical Center, Bronx, NY, USA 3Icahn School of Medicine at Mount Sinai, NY, USA 4Virginia Commonwealth University School of Medicine, Richmond, VA, USA 5Virginia Commonwealth University Massey Cancer Center, Richmond, VA, USA

Abstract

Context—Inpatient palliative care is associated with reduced costs, but the optimal model for providing inpatient palliative care is unknown.

Objectives—To estimate the effect of palliative care consultations (PCC) and care in a palliative care unit (PCU) on cost of care, in comparison with usual care (UC) only and in comparison with each other.

Methods—Retrospective cohort study, using multinomial propensity scoring to control for observed confounding between treatment groups. Participants were adults admitted as inpatients between 2009 and 2015 with at least one of seven life-limiting conditions who died within a year of admission (N=6,761).

Results—Palliative care within 10 days of admission is estimated to reduce costs compared to UC in the case of both PCU (−$6333; 95% CI: −7871 to −4795; p<0.001) and PCC (−$3559; −5732 to −1387; p<0.001). PCU is estimated to reduce costs compared to PCC (−$2774; −5107 to −441; p=0.02) and LOS compared to UC (−1.5 days; −2.2 to −0.9; p<0.001). The comparatively larger effect of PCU over PCC is not observable when the treatment groups are restricted to those who received palliative care early in their admission (within six days).

Conclusions—Both PCU and PCC are associated with lower hospital costs than usual care. PCU is associated with a greater cost-avoidance effect than PCC except where both interventions are provided early in the hospitalization. Both timely provision of palliative care for appropriate patients and creation of more PCUs may decrease hospital costs.
Introduction

Individuals with life-limiting illnesses, dementia, and functional impairment are at risk of poor pain and symptom management, low satisfaction and fragmented care, and account disproportionately for healthcare utilization\(^1\). Palliative care is a multi-disciplinary specialty treating patients with serious and life-limiting illness by managing symptoms, facilitating autonomy and providing information\(^3\). In order to improve the care of patients with serious life-limiting illness, a better understanding of the optimal models for providing inpatient palliative care is necessary\(^4\).

Palliative care provision in the United States is predominantly hospital-based with two distinct models of provision: palliative care consultation (PCC) and palliative care unit (PCU)\(^5\). The PCC model typically comprises a multidisciplinary team of specialists, who become involved in the care of a patient at the invitation of a primary attending physician or team\(^3\). The PCC team provides expert pain and symptom assessment and recommendations for management, and facilitates goals-of-care discussions and discharge planning with a view to patient-centered, medically-appropriate decision-making. The PCU approach shares these goals but takes overall control of patient care with specialist nurses and other staff, training, and protocols. 95% of hospital-based palliative care programs have a PCC only, with the remaining 5% offering both PCC and PCU services\(^6\), although presence of a PCU rises to 23%–32% among cancer centers\(^7\).

Most prior research has been conducted on either PCC or PCU in isolation, with little comparison of the two modalities\(^9\). A national comparative study of family satisfaction from the differing models of hospital care found that both are associated with improvements compared to usual care, and that PCUs may bring larger improvements than PCCs\(^10\). With respect to economic impact, multiple observational studies of PCC programs have reported a pattern of reduced cost of hospital admission compared to usual care\(^12\)–\(^14\). Fewer studies have examined PCU association with cost of hospital admission, but reduced utilization has been reported for this model also\(^15\)–\(^17\). There is little comparative evidence of the economic effects of the PCC and PCU models\(^10\).

The aim of this study is to address this gap in the literature. We used a large retrospective cohort dataset from a single hospital system in the United States to analyze the association between usual care, PCC and PCU and the utilization outcomes of in-hospital costs and length of stay. The results can inform optimal organization of hospital care for seriously-ill patients and suggest new research questions.

Methods

Study design

This is a retrospective cohort study using administrative data from the Virginia Commonwealth University (VCU) Health System between 2009 and 2015.

In our primary analysis we estimated the association between in-hospital utilization and models of palliative care. We specified two outcomes of interest (direct cost of care, LOS),
and a treatment variable with three levels: usual care (UC) only, PCC, and PCU. We used propensity scores to control for observed patient characteristics associated with palliative care use and outcomes\textsuperscript{18}.

In our secondary analysis we extended this framework to evaluate how the findings of our primary analysis are affected by intervention timing.

**Setting**

VCU Health System is an academic, safety-net medical center and faculty practice. The main hospital has 774 beds and approximately 36,000 discharges per year including a wide range of tertiary and quaternary services such as trauma, solid organ transplants, and stem cell transplants. The 11-bed PCU opened in 2000 and is open to acute adult patients (no hospice or children) transferred from other units or admitted directly from the emergency department or outpatient clinics. The PCC includes physician, advance practice registered nurse, social work, chaplain, and palliative care fellows. The PCU additionally includes a nurse manager, nurse clinician, specialty trained nurses, a volunteer coordinator, volunteers, and a psychologist and allows more open access to family and other caregivers. The program has been accredited with Joint Commission advanced certification since 2012, which indicates consistency of multi-specialty care between the PCC and PCU\textsuperscript{19,20}. The PCC and PCU serve about 1,330 unique adult patients per year, including about 400 unique patients in the PCU.

**Participants and sample size**

Patients were eligible for this study if they were admitted as an inpatient at the study site during the study period, were over 18 years of age, had a diagnosis of at least one of seven potentially life-limiting conditions (cancer (excluding benign malignancies), heart failure, chronic obstructive pulmonary disease (COPD), liver failure, kidney failure, AIDS/HIV and selected neurodegenerative conditions), and were recorded by the hospital database or the Social Security Death Index as dying within 365 days of admission.

Patients were excluded if they had previously been admitted as an inpatient during the study period, if their admission involved a transplant, or if specific conditions recorded during the admission indicated trauma.

Conditions and transplant procedures were identified through ICD-9 codes attached to the admission (see Appendix). Our final sample size was 6,761 (Figure 1).

**Variables**

**Dependent variables**—The primary dependent variable was direct cost of hospital admission. Direct costs are those attributable to specific staffing, equipment, pharmaceuticals and procedures during an inpatient stay\textsuperscript{21}, and are thus the most reliable indicator of resource utilization. An additional dependent variable of interest was LOS.

**Independent variables**—The primary independent variable was a treatment variable with three levels: UC, PCC, and PCU (Figure 1). Patients who received palliative care in a PCU
within 10 days of admission were placed into the PCU group; patients who received
palliative care from a PCC within 10 days of admission but who were not admitted to a PCU
were placed into the PCC group; and those who received palliative care for the first time
after more than 10 days in hospital were placed in the UC group with all patients who did
not receive palliative care before discharge. Details on treatment group definition are
provided in the Appendix. To investigate heterogeneity of effect by timing, we
performed secondary analyses with alternate definitions of treatment (PC within 2 days of
admission, 4 days of admission, etc.).

Additional independent variables were those hypothesized to be associated with likelihood
of PC receipt and outcomes: age (years); sex; race (black; white; neither black nor white);
insurance status (Medicare [Medicare fee-for-service or Medicare Managed Care],
Medicaid/none [Medicaid, Medicaid Managed Care, self-pay, or unable to pay] and other);
primary diagnosis (noncancer, solid tumor, hematological tumor); first-day admission to the
intensive care unit (ICU) or surgery; and number of comorbidities (Elixhauser index)
(Table 1). For race, insurance and primary diagnosis, categories were condensed from a
larger number of sub-categories; in each case we aimed to minimize information loss while
ensuring sufficient sample sizes for matching.

Data sources/measurement

Direct costs were extracted from the hospital accounting database and reflect the cost in US$ to
the hospital of providing care during the admission. Costs were standardized to 2015,
final year of data collection, using the Consumer Price Index.

Receipt of palliative care was determined through a free-standing database operated by the
palliative care program documenting all patient encounters. All other independent variable
data were extracted from hospital administrative databases.

The study is covered under VCU IRB protocol HM14959 and all data were de-identified
prior to analyses.

Bias

Patient characteristics, including illness severity, are likely to be associated with likelihood
of PCU or PCC receipt, and utilization. To control for selection bias, we weighted the three
treatment groups on all variables in Table 1 using propensity scoring. In order to balance
observed patient characteristics across all three levels of our treatment variable, we
estimated a multinomial propensity score model with the covariate balancing propensity
score method (CBPS) and created inverse-probability-of-treatment-weights (IPTWs) from
the estimated propensity score.

Prior to estimating our results we evaluated balance between treatment groups for the overall
sample (see Table 1 and Appendix) and across the distribution of the propensity score [data
available from authors].
In addition, we performed multiple sensitivity analyses on our results to check their robustness to use of propensity scores, late-PC outliers, proximity to death, and model selection (see Appendix).

**Statistical methods**

We estimated our results by regressing in-hospital utilization (direct cost of hospital care or LOS) on our treatment variable and other independent predictors (Table 1) in our weighted sample. Generalized Linear Models (GLMs) with a gamma distribution and a log link were used for both outcomes.

We estimated association between in-hospital utilization for the PCC group compared to the UC group, and the PCU group compared to the UC group. In both cases we estimated the average treatment effect (ATE) with bootstrapped standard errors. In addition, we estimated the ATE of the PCU group compared to the PCC group; this estimate allows us to explore whether PCU would have any additional cost-savings compared to PCC.

In our secondary analysis we examined whether ATEs are larger for earlier interventions than for later interventions. We redefined membership of the treatment groups according to whether the subject first received palliative care within eight, six, four and two days of admission. This gives four new three-level treatment variables in which patients who received the intervention later than the threshold were progressively excluded from the treatment groups. For each treatment variable we re-ran the primary analysis to estimate the ATE on direct costs for the PCC group compared to the UC group, the PCU group compared to the UC; and the PCU group compared to the PCC group. Where the treatment variable was redefined according to timing in secondary analyses, new propensity scores were calculated and applied.

No patient in our final analytic sample had missing data in any field in Table 1, in direct costs or LOS, or in receipt and timing of palliative care.

Propensity scores were calculated in R; all other analyses were performed in Stata (version 12).

**Role of the Funding Source**—Funding sources had no role in the design, conduct, or reporting of this study.

**Results**

**Descriptive data**

Our sample included 6,761 patients with life-limiting illnesses who died within one year of hospital admission. Of the sample, 5,622 (83%) received usual care, 538 (8%) received a PCC, and 601 (9%) received care in the PCU (Figure 1). Patients in our weighted sample had a mean age of 64 and a mean of 3.5 comorbidities (Table 1). A majority (61%) of patients had a primary diagnosis of something other than the seven life-limiting illnesses (i.e., they were eligible for inclusion because one of the seven life-limiting conditions was...
coded as a secondary diagnosis); the second most prevalent primary diagnosis was cancer (21%).

**Main Results**

In multivariable models within our weighted sample, both PCU and PCC were associated with lower costs of hospital care compared to usual care only: the ATE for PCU is −$6333 (95% CI: −7871 to −4795; p <0.001) and for PCC −$3559 (−5732 to −1387; p<0.001) (Table 2). PCU was associated with shorter LOS than usual care (1.5 days (−2.2 to −0.8; p<0.001)); the corresponding estimate for PCC was not statistically significant. In addition, patients who received PCU had significantly lower hospital care costs than patients who received PCC: −$2774 (−5107 to −441; p=0.02). Length of stay did not differ significantly by model of palliative care provision.

**Secondary Results**

In analyses that incorporated timing of first palliative care encounter, we found a stronger association between both interventions and costs when palliative care was provided earlier in the hospitalization than when it was provided later (Figure 2): where the patient received a PCC within two days of admission, the ATE versus usual care was −$10,506 compared to −$3559 within 10 days. Similarly, a patient receiving care in the PCU had greater cost savings compared to usual care when palliative care was provided within two days (ATE=−$11,628) than within ten days (−$6333).

PCU is estimated to have a statistically significant cost-saving impact above that of PCC only when we include patients whose first interaction with palliative care occurs later in the hospitalization (within 8 days or 10 days); for palliative care within 10 days of admission the ATE is −$2773. When PCU is compared to PCC within six days of admission only, there is not a significant difference in cost-savings across modalities.

**Sensitivity analyses**

We performed sensitivity analyses to check robustness of results to use of propensity scores, late-PC outliers, proximity to death, and model selection. Results were substantively similar (see Appendix). Of note, the estimated reduction in LOS with palliative care compared to usual care only increased in size and statistical significance for earlier interventions. Thus, although PCC within 10 days of admission was not found to have a significant association with LOS (Table 2), this does not imply that there is no association between intervention and outcome: earlier PCC interventions were significantly associated with reduced LOS.

**Discussion**

Specialist palliative care for hospitalized patients takes two forms: consulting on cases anywhere in the hospital (PCC), or caring for patients in a dedicated unit (PCU)\(^{37}\). Most prior research has been conducted on one model in isolation, with little comparison of the two. Our analyses address this evidence gap.
Both PCC and PCU are associated with lower hospital costs, compared to usual care. PCU is also associated with shorter LOS, compared to usual care. Both models are associated with greater cost reduction when occurring earlier in the admission. These findings support and extend the outcomes shown in a recent prospective, observational trial\cite{13,14}. A comparison of the cost-effects of PCU and PCC finds that PCU is associated with a significantly larger effect when later interventions are included in analyses, but there is no difference when the treatment groups are restricted to those who received palliative care early in the admission (within six days).

There are at least two possible mechanisms to explain the greater association of the PCU than the PCC with in-hospital utilization when the treatment group is broadly defined to include treatments late in the admission. First, consultations are just that: independent assessments and recommendations for care. A reason for operating a PCU is to have more complete control over care, for example over medications and their dosages. Second, the PCU employs nurses who are specially trained, and most patients they care for are receiving palliative care. In contrast, nurses on other units (oncology, cardiology, ICUs, general medicine) generally have less training and interest in palliative care, and only a fraction of their patients will be palliative-appropriate.

One unexpected result is that there is no significant difference in estimated cost-effect between PCC and PCU when both interventions are provided very early in the admission. A possible interpretation is that the first 48 hours is both the most resource-intensive period of a standard hospitalization and the point at which most consequential treatment decisions are made\cite{38}; the earliest interventions therefore have the greatest scope to reduce unnecessary costs\cite{23}, and our results suggest that both early PCC and PCU do so to a similar extent. As the hospitalization progresses there is lower day-to-day utilization and lower scope to reduce costs, and the cost-effect of PCU persists in a way that PCC does not because the dedicated nature of the care gives staff the opportunity and autonomy to make the few remaining decisions that can impact costs and LOS. Further research is required to examine this question in detail.

The alternative explanation for our findings is that, despite our efforts at controlling for confounding, patients admitted or transferred to the PCU have goals of care that are more completely focused on palliation than those who receive PCC only. In other words, a retrospective cohort study may be inadequate for separating selection effects from treatment effects. The only way to resolve that is through a randomized controlled trial (RCT), similar to prior studies comparing PCC versus usual care\cite{39,40}, or with geriatric units compared to usual care\cite{41-43}. An RCT of PCU versus PCC would be complex but not impossible. This would necessitate preliminary work to ascertain the feasibility of identifying patients who could be cared for appropriately in either setting, and the acceptability of randomizing patients to the two settings.

Pending such research, this study suggests that both PCU and PCC are associated with reduced hospital costs and LOS relative to usual care, and that PCU may be associated with greater cost-reductions than PCC. One prior study compared the PCU and PCC for family satisfaction with care, finding similar results to those published here: both modalities were
associated with family perceptions of better care, and a greater impact of PCU over PCC\textsuperscript{11}. Together, these studies indicate that delivering palliative care via a dedicated unit may both improve care and reduce costs for some patients.

**Limitations**

As an observational study, the conclusions of these analyses should be interpreted as associations rather than causation. Observed confounding was minimized through the use of propensity score weights and sensitivity analyses tested questions about the assignment to the three groups. In particular, the use of multinomial propensity scoring to estimate the comparative effectiveness of PCC and PCU with a three-level treatment variable is a novel and important feature of this work. However, it is important to acknowledge that the observed confounders did not include all baseline variables for which we would like to control such as disease progression, performance status, physician-judged prognosis, prior utilization and medications and access to social and family supports.

Another limitation is that this study cannot explain what mechanisms are responsible for differences in effects between PCU and PCC, which can only be answered with further research. In principle hospital interventions can save money by reducing intensity and/or length of stay. Prior research has suggested that PCC achieves cost-savings through a combination of these factors\textsuperscript{44}. In addition, this study reports data from a single site and may not generalize to other hospitals or health care systems. However, our sample was socio-demographically diverse and included patients with a variety of progressive, life-limiting diagnoses such as solid and hematological cancers, heart failure, COPD, HIV/AIDS, neuro-degenerative diseases, liver failure, and kidney failure. In addition, costs beyond the inpatient episode were not included in our analyses. This approach, however, facilitates comparison with other estimates of cost-savings associated with inpatient palliative care. Further research should explore the post-discharge costs incurred by payers and patients.

**Conclusions**

Both forms of specialist palliative care – consultations and specialized units – were found to be associated with reduced costs of inpatient care for patients with a variety of progressive, life-limiting diseases. PCU is associated with greater effect on cost, and some effect on length of stay, in comparison with PCC-only cases, except when the treatment groups are restricted to those who received palliative care within six days of admission, in which case there is no significant difference. Further research should be done to replicate and extend these findings.

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Appendix

1 Eligibility criteria

Subjects for this study were eligible if they had one of seven life-limiting conditions (cancer, heart failure, COPD, AIDS/HIV, selected neurodegenerative, renal failure, liver failure) and excluded if their primary diagnosis indicated trauma or if they received a transplant during their admission. Conditions, traumas and transplant procedures were identified through ICD-9 codes from the hospital database. Specific ranges of ICD-9 codes for these factors are provided in Appendix Table 1.

2 Defining treatment by timing

In defining a palliative care treatment variable for economic analysis of a hospital inpatient admission; failure to do so increases risk of a type II error and generates results that are neither robust nor useful (1, 2). However, there are no clinical guidelines on which to define the appropriateness of an intervention with respect to timing.

In order to define our treatment variable by timing ex ante, we created multiple treatment variables differentiated by timing (membership of either PCC or PCU group required first PC contact within two days, four days, six days….20 days of admission (3, 4)) and compared these treatment variables in two ways. First, we created propensity scores for each of the treatment variables, calculated balance for each propensity score, and compared balance of the propensity scores for each treatment variable (i.e. a measure of observed bias) (5). Second, we ran regression models with direct cost of admission as the dependent variable, each treatment variable and a fixed list of predictors (Appendix Table 2), applying propensity score weights. Model performance was evaluated on measures of information loss (6)), and estimation error (7, 8).

Defining the intervention groups as having a first interaction with palliative care within 10 days of admission performed strongest in evaluations of propensity score and estimation error; there were no relevant differences between treatment variables on measures of information loss [data available from authors].

This method then prompts a new question regarding subjects who received palliative care after more than 10 days: should they be moved to the control group, or excluded from the analysis altogether? The former approach minimizes information loss but risks biasing
results; the latter approach excludes subjects from the sample on an arbitrary if reasoned basis. In this study we retain late-consult outliers as controls in the main analysis and check robustness of results where they are excluded (see section 4 of this Appendix).

3 Propensity scoring

The primary analytic sample prior to propensity scoring is presented in Appendix Table 2.

Mean absolute standardized difference is 9% (range: 0–32%) compared to 2% (0–5%) in Table 1 in main manuscript.

4 Sensitivity analyses

In the main manuscript we estimate the association between costs of hospital care, and two models of palliative care (PCC and PCU) for adult inpatients with serious illness, compared to usual care (UC) only. These analyses have four conclusions:

1. Timely PCC is cost-saving compared to UC
2. Timely PCU is cost-saving compared to UC
3. Earlier treatment is associated with larger cost-saving effects in both cases
4. PCU is cost-saving compared to PCC, except for the earliest interventions when there is no difference.

Our methods in the paper employed two methods that merit verification: first, we recoded late-PC outliers as controls (for the justification, see Section 2 of this Appendix) and second we curtailed our sample by outcome (those who died within a year of admission) to limit unobserved heterogeneity and focus on a palliative care population. Additionally, it is wise to check results derived using propensity scores in an unweighted analysis since in some cases these can compound unobserved heterogeneity (9).

Therefore we performed sensitivity analyses to check robustness of our results to use of propensity scores, approach to late-PC outliers and patient proximity to death. Where samples were redefined overall or within treatment groups, a new sample-specific propensity score was calculated. The results are provided in three subsequent figures, imitating Figure 2 from the main manuscript. Our conclusions in the main manuscript hold in all cases.

Additionally we checked result sensitivity to an OLS model and with high utilization outliers removed [data not shown]. Our main conclusions are not substantively affected.
Appendix Figure 1.
Rerunning Figure 2 (main manuscript) without propensity scores

Appendix Figure 2.
Rerunning Figure 2 (main manuscript) with late-PC outliers removed from sample (instead of recoded as controls)

Appendix Figure 3.
Rerunning Figure 2 (main manuscript) using only patients who died within 730 days of admission (instead of 365 days)

Appendix Table 1
ICD-9 codes for identifying conditions, trauma and transplant in defining the sample

| Conditions      | ICD-9 codes                                                                 |
|-----------------|------------------------------------------------------------------------------|
| Cancer          | 140.x–172.x, 174.x–209.3x, 209.7x, 230.x–239.x, v58.0x (radiation), and v58.1x (chemo) [Thus generally 140–239 plus radiation & chemotherapy, but excluding benigns 209.4x–209.6x, 210.x – 229.x, and ‘other skin’ 173.x] |
| Heart failure   | 398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 428.x |
| COPD            | 416.8, 416.9, 490.x – 505.x, 506.4, 508.1, 508.8                               |
| AIDS/HIV        | 042.x, 043.x, 044.x                                                          |
| Neurodegenerative | 290.x, 294.1.x, 294.2.x, 330.x – 337x                                      |
| Renal           | 070.22, 070.23, 070.32, 070.33, 070.44, 070.54, 070.6, 070.9, 456.0–456.2, 570.x, 571.x, 572.2–72.8, 573.3, 573.4, 573.8, 573.9, V42.7 |
| Liver           | 403.01, 403.11, 403.91, 404.02, 404.12, 404.92, 585.x, 586.x, 588.0, V42.0, V45.1x, V56.x |
| Trauma          | As primary dx 348.1, 800.x–904.x, 925.x–929.x, 940.x–959.x, 994.0, 994.1     |
### Conditions

| ICD-9 codes       | Transplant |
|-------------------|------------|
| Bone marrow / stem cell: | 41.00 – 41.09 |
| Heart:            | 37.50 – 37.59 |
| Lung:             | 33.50 – 33.59 |
| Heart-lung:       | 33.60 – 33.69 |
| Kidney:           | 55.60 – 55.69, 52.80 |
| Liver:            | 50.50 – 50.59 |

### Appendix Table 2

Analytic sample in primary analysis (N=6,761), prior to matching

|                        | Usual Care (n=5,622) | Palliative Care Consult (n=538) | Palliative Care Unit (n=601) | Absolute standardized difference |
|------------------------|----------------------|-------------------------------|-------------------------------|---------------------------------|
|                        | Mean     | SD      | Mean    | SD      | Mean    | SD      | UC v PCC | UC v PCU | PCC v PCU |
| Age                    | Years    |         |         |         |         |         |          |          |            |
| Gender                 | Female   | 44%     | 44%     | 48%     | 39%     | 4%      | 4%       | 1%       |            |
| Race                   | Black    | 45%     | 43%     | 39%     | 4%      | 4%      | 10%      | 7%       |            |
|                       | White    | 51%     | 53%     | 57%     | 3%      | 12%     | 8%       |          |            |
|                       | Neither  | 4%      | 4%      | 4%      | 1%      | 4%      | 4%       |          |            |
| Primary payer          | Medicare | 57%     | 57%     | 53%     | 0%      | 7%      | 8%       |          |            |
|                       | Medicaid/None | 20%   | 19%     | 21%     | 3%      | 3%      | 6%       |          |            |
|                       | Other    | 23%     | 24%     | 26%     | 2%      | 6%      | 3%       |          |            |
| Primary dx             | Noncancer | 75%  | 73%     | 63%     | 4%      | 25%     | 22%      |          |            |
|                       | Cancer: solid | 20% | 25%     | 34%     | 11%     | 32%     | 21%      |          |            |
|                       | Cancer: heme | 5%   | 3%      | 3%      | 14%     | 11%     | 3%       |          |            |
| ICU                    | On admission | 32% | 35%     | 28%     | 8%      | 7%      | 15%      |          |            |
| Surgery                | On admission | 16% | 11%     | 6%      | 15%     | 32%     | 15%      |          |            |
| Comorbidities          | Elixhauser index | 3.5 | 1.7     | 3.7     | 1.6     | 3.7     | 1.6      | 15%      | 13%        | 3%        |

**Notes**

For legend, see Table 1 in main manuscript.

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Summary

This is the appendix to our research article ‘Costs of care for hospitalized adults with life-limiting illness: a comparison of palliative care consultation teams and palliative care units’.

It covers four issues:

1. List of ICD-9 codes used in applying eligibility criteria re: presence of life-limiting conditions, trauma and transplant.
2. Detailed justification of treatment definition with respect to timing re: receipt of palliative care within 10 days of admission.
3. Summary of unweighted sample for comparison with weighted, matched sample (Table 1 in main manuscript).
4. Sensitivity analysis of primary results.
Figure 1. Selection of participants for analytic sample
Transplant and trauma codes identified via ICD codes (see Appendix). Dates of death identified through hospital system and Social Security Death Index (SSDI); ‘No death date’ therefore may indicate patient was still alive at end of study period or that patient has died in circumstances not recorded by VCU or SSDI. Patients who died more than 365 days after admission were excluded to minimize unobserved heterogeneity at baseline and restrict sample to those with palliative care needs; to check robustness of results to curtailing sample by outcome, including theoretical possibility that palliative care interventions impact one-year survival, we performed sensitivity analyses on samples who died within 90 days and 730 days of admission (see Appendix). PCC and PCU patients whose first interaction with PC was after more than 10 days in hospital were removed from treatment groups because late-treatment outliers increase risk of type II error; they were included as controls to avoid information loss of exclusion from analysis altogether. For a more detailed explanation of...
how treatment groups were defined according to PC timing, and sensitivity analyses with late-PC outliers excluded altogether, see Appendix.
Figure 2. Estimated treatment effect of PCC and PCU on direct hospital costs compared to UC only, by intervention timing
Each data point represents the ATE of the intervention compared to UC only where first PC interaction was within x days and x is given on the x axis. All ATEs in Figure 2 are statistically significant (p<0.005).
Figure 3. Estimated treatment effect of PCU on direct hospital costs compared to PCC, by intervention timing

Each data point represents the ATE of PCU compared to PCC where first PC interaction was within x days and x is given on the x axis. ATEs in Figure 3 are statistically significant (p<0.05) only where 8<=x.
### Table 1

Analytic sample in primary analysis (N=6,761), following matching

|                      | Usual Care (n=5,622) | Palliative Care Consult (n=538) | Palliative Care Unit (n=601) | Absolute standardized difference |
|----------------------|-----------------------|---------------------------------|-------------------------------|----------------------------------|
|                      | Mean | SD    | Mean | SD    | Mean | SD    | UC v PCC | UC v PCU | PCC v PCU |
| **Age** Years        | 63.9 | 14.4  | 63.9 | 14.2  | 64.2 | 14.5  | 0%       | 2%       | 2%        |
| **Gender** Female    | 45%  | 46%   | 45%  | 4%    | 45%  | 2%    | 1%       | 1%       |            |
| **Race** Black       | 44%  | 43%   | 45%  | 2%    | 4%   | 1%    | 3%       |          |            |
| **White**            | 52%  | 52%   | 51%  | 2%    | 51%  | 1%    | 3%       |          |            |
| **Neither**          | 4%   | 4%    | 4%   | 0%    | 4%   | 1%    | 0%       |          |            |
| **Primary payer**    |       |       |       |       |       |       |         |          |            |
| Medicare             | 56%  | 57%   | 56%  | 0%    | 0%   | 1%    |          |          |            |
| Medicaid/None        | 20%  | 20%   | 21%  | 1%    | 1%   | 2%    |          |          |            |
| Other                | 23%  | 24%   | 23%  | 1%    | 1%   | 1%    | 1%       |          |            |
| **Primary dx**       |       |       |       |       |       |       |         |          |            |
| Cancer: solid        | 21%  | 22%   | 21%  | 2%    | 2%   | 4%    |          |          |            |
| Cancer: heme         | 5%   | 5%    | 4%   | 3%    | 3%   | 3%    |          |          |            |
| Heart failure        | 6%   | 5%    | 4%   | 3%    | 10%  | 7%    |          |          |            |
| COPD                 | 2%   | 1%    | 1%   | 7%    | 6%   | 1%    |          |          |            |
| AIDS/HIV             | 1%   | 0%    | 1%   | 4%    | 2%   | 2%    |          |          |            |
| Neurological         | 1%   | 1%    | 1%   | 4%    | 0%   | 4%    |          |          |            |
| Liver                | 5%   | 5%    | 3%   | 1%    | 9%   | 10%   |          |          |            |
| Kidney               | <1%  | <1%   | <1%  | 6%    | 6%   | 0%    |          |          |            |
| Other                | 60%  | 61%   | 66%  | 1%    | 13%  | 12%   |          |          |            |
| **ICU**              |       |       |       |       |       |       |         |          |            |
| On admission         | 32%  | 33%   | 32%  | 2%    | 1%   | 1%    |          |          |            |
| **Surgery**          |       |       |       |       |       |       |         |          |            |
| On admission         | 15%  | 16%   | 16%  | 1%    | 3%   | 2%    |          |          |            |
| **Comorbidities**    |       |       |       |       |       |       |         |          |            |
| Elixhauser index     | 3.5  | 1.7   | 3.6  | 1.6   | 3.5  | 1.6   | 3%       | 0%       | 3%        |

**Notes**

Absolute standardized differences (ASD) measure the imbalance between groups on baseline characteristics, taking into account both means and variances. ASD<10% is a rule of thumb for adequate balance in propensity score matching. SD: Standard deviation. SES: Socioeconomic status. COPD: Chronic obstructive pulmonary disease. ICU: Intensive Care Unit.

Primary payer: ‘Medicare’ includes Medicare and Managed Medicare; ‘Medicaid/None’ includes Medicaid, Managed Medicaid, Self-Pay, and uninsured, unable to pay, and not qualified for Medicaid; ‘Other’ incorporates all other insurers.

Primary diagnosis of ‘Other’ indicates a secondary diagnosis of at least one of the seven life-limiting illnesses and a primary diagnosis of none of these.
ICU and Surgery: ‘On admission’. Patient visited ICU or underwent surgery on day of hospital admission.
Table 2

Average treatment effect estimates (PC within 10 days of admission) on in-hospital utilization

|                           | Direct cost of hospital care | Length of hospital stay |
|---------------------------|------------------------------|-------------------------|
|                           | ATE ($)                      | P value                 | 95% CI       | ATE (days) | P value | 95% CI |
| Palliative care compared to usual care only |                              |                         |              |            |         |        |
| PCC                       | −3559                        | <0.001                  | −5732 to −1387 | −0.8       | 0.07    | −1.8 to 0.1 |
| PCU                       | −6333                        | <0.001                  | −7871 to −4795 | −1.5       | <0.001  | −2.2 to −0.9 |
| PCU compared to PCC        |                              |                         |              |            |         |        |
| PCU                       | −2774                        | 0.02                    | −5107 to −441 | −0.7       | 0.20    | −1.7 to 0.4 |

ATE: Average treatment effect. CI: Confidence Interval.

Mean cost of admission for UC patients was $23877. The ATEs for PCC and PCU compared to UC only therefore imply cost-savings of 15% and 27% respectively. Mean cost of admission for PCC patients was $19443. The ATE for PCU compared to PCC therefore implies cost-savings of 14%.