Patient Risk Factor Profiles Associated with the Timing of Goals-of-Care Consultation Before Death: A Classification and Regression Tree Analysis

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Abstract

Background: Early palliative care consultation to discuss goals-of-care ("PCC") benefits seriously ill patients. Risk factor profiles associated with the timing of conversations in hospitals, where late conversations most likely occur, are needed.

Objective: To identify risk factor patient profiles associated with PCC timing before death.

Methods: Secondary analysis of observational study was conducted at an urban, academic medical center. Patients age 18 years and older admitted to the medical center, who had PCC, and died July 1, 2014 - October 31, 2016 were included. Patients admitted for childbirth or rehabilitation, and patients whose date of death was unknown were excluded. Classification and Regression Tree modeling was employed using demographic and clinical variables.

Results: Of 1,141 patients, 54% had PCC "close to death" (0–14 days before death); 26% had PCC 15–60 days before death; 21% had PCC >60 days before death (median 13 days before death). Variables associated with receiving PCC close to death included being Hispanic or "Other" race/ethnicity intensive care patients with extreme illness severity (85%), with age <46 or >75

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increasing this probability (98%). Intensive care patients with extreme illness severity were also likely to receive PCC close to death (64%) as were 50% of intensive care patients with less than extreme illness severity.

Conclusions: A majority of patients received PCC close to death. A complex set of variable interactions were associated with PCC timing. A systematic process for engaging patients with PCC earlier in the care continuum, and in intensive care regardless of illness severity, is needed.

Introduction

As medicine advances and providers are increasingly able to alter the normal dying process with life-extending treatments, patients with serious illness and their families are tasked with making difficult decisions about end-of-life (EOL) care.[1] Although less aggressive EOL care is often preferred[2–4] and is associated with higher quality of EOL,[5–10] evidence suggests almost 20% of critical care patients receive futile treatment (as perceived by their physicians)[11] and up to 38% of patients receive non-beneficial treatments near EOL.[12] To help providers better understand patient preferences and enable patients to make informed decisions, the National Academy of Medicine recommends healthcare providers engage seriously ill patients in goals-of-care discussions.[13] Goals-of-care discussions, including those that occur during palliative care consultation, are associated with less aggressive treatments and lower use of intensive care,[6,13–17] lower 30-day readmission rates and hospitalizations,[6,13,15,16,18] fewer in-hospital deaths and greater hospice use,[6,14–16,19,20] more goal-concordant patient care,[6,17,19,21,22] and higher quality EOL care.[6,23] Goals-of-care discussions are also associated with lower EOL costs,[15,24–29] with one recent study finding an average savings of over $6000 per patient.[15]

The timing of these conversations matters.[30–34] Earlier care planning conversations are associated with higher quality outcomes[6,23,35,36] including earlier enrollment in hospice and palliative care,[37] whereas discussions closer to death are associated with increased risk of aggressive care, hospital death, and intensive care unit (ICU) admission.[6] Each additional day from hospital admission to care planning conversation is associated with a 4% increased risk of aggressive interventions and in-hospital death and 19% greater odds of ICU admission.[6] Despite the benefits of having early goals-of-care discussions in hospital settings where late discussions are likely to occur, patient risk factor profiles associated with the timing of these discussions are unknown. The purpose of this study was to identify risk factor profiles associated with patients receiving palliative care consultations to discuss goals-of-care (hereafter called "PCC") 0–14 days before death ("PCC close to death"), 15–60 days before death ("moderately-timed PCC"), and more than 60 days before death ("early PCC").

Methods

Study Design

We conducted a secondary analysis of a retrospective cohort study of patients admitted to the Hospital of the University of Pennsylvania, a 776-bed, urban, academic medical center[15] that serves a socioeconomically and racially diverse patient area composed of 46% African Americans, 36% Whites, 9% Asians, and 6% Hispanics.[38] Its interdisciplinary palliative care team is well-established and predominantly operates as a consultation service. Two-thirds of the team's consultations involve goals-of-care discussions.[15] The parent study (N=41,363) found PCC was associated with significant reductions in future acute care utilization and costs among a propensity-matched cohort of patients with serious illness, but did not explore PCC timing.[15] For our study, supplementary data from the center's electronic records (Medicaid status, days between PCC and patient death) was matched to unique patient identifiers.

Study Sample

Our study included patients 18 and over who were admitted July 1, 2014-October 31, 2016 (study period), received PCC specifically to discuss goals-of-care, and died during the study period. Consistent with palliative care experts' broad definitions of serious illness,[39,40] our study defined serious illness as any condition that carries an elevated risk of mortality or has burdensome symptoms or treatments requiring hospitalization.[39] All patients in our sample were hospitalized for acute medical conditions and died within a 2.25 year window, reflecting the serious nature of their illness. Patients were included if they died in the hospital system while on hospice or not on hospice, died outside the hospital while on hospice affiliated with the medical center, or died outside the hospital system but had been seen by a provider affiliated with the medical center who updated the patient's medical record to reflect their death. Patients who were admitted for childbirth or rehabilitation were excluded, as were patients who died in community hospitals whose deaths were not updated in the medical center's records.

Traditional statistical power analyses do not apply to CART modeling,[41,42] but our sample was sufficient because it was greater than the recommended 100 participant minimum.[42] This study was approved by the University of Pennsylvania institutional review board (45 CFR 46.104) and followed strict procedures to ensure patient data privacy, security, and ethics. All data were deidentified before sharing, password protected, and stored on an encrypted network.

Study Measures

The primary outcome of interest was number of days between a patient's first inpatient PCC during the study period and patient death, categorized into three non-overlapping levels of data: PCC close to death, defined as 0–14 days before death; moderately-timed PCC, defined as 15–60 days before death; and early PCC defined as more than 60 days before death. Timing categories were based on Medicare hospice data, which shows 41% of patients on hospice received 0–14 days of care (28% received seven or fewer days of care, presumably in the last week of life), 26% received 15–60 days of care, and 33% received

more than 60 days of hospice care.[37] Although the literature suggests early palliative care referral may be defined as more than 90 days before death,[33] consultations occurring in that timeframe predominantly occur in outpatient settings.[33] Because this study focuses on goals-of-care conversations occurring during inpatient hospitalization, the time parameters are shorter and were defined with other inpatient goals-of-care studies in mind.[14,43]

Correlates used to identify risk factor profiles included sociodemographic and clinical characteristics of age, gender, self-reported race/ethnicity, Medicaid status, primary diagnosis, All-patient refined diagnosis-related group (APR-DRG) Severity of Illness (the extent of physiologic decomposition), APR-DRG Risk of Mortality (the likelihood a patient will die), use of intensive care, intensive care greater than six says (to indicate high acuity), visitation by Oncology team, source of referral to palliative care, and acute care utilization in the prior 30 days. All variables were recorded at the time of index hospitalization, the hospitalization when PCC first occurred. APR-DRG Severity of Illness and Risk of Mortality have four subcategories (minor, moderate, major, extreme) that are assigned by health system software based on diagnoses and procedures coded during hospitalization, and take into account comorbidities, disease stage, and disease interactions.[15,44,45] End-of-life acute care costs (direct acute care costs incurred in the health system during and following index hospitalization to death), discharge to hospice, DNR documentation, and changes in goals-of-care are also described.

Data Analysis

Descriptive statistics and measures of central tendency were used to characterize the variables and describe the sample based on PCC timing before death (SAS v. 9.4) (Table 1). Chi-squared tests were performed to examine associations between categorical variables. Kruskal-Wallis tests and analysis of variance (ANOVA) tests were performed for the distributions of continuous measures by PCC timing, as appropriate. Specialist referral data was missing for one patient. This patient was included in the study. No other data were missing.

To show how independent variables, or risk factors, interact to create associations with the outcome of PCC timing,[46] classification and regression tree (CART) modeling using SAS JMP software was applied with variables of interest. This novel method is increasingly used in health research.[47–49] The software randomly divided the dataset into training (N = 571), validation (N = 285), and test (N = 285) sets. Due to random division, these sets were similar and did not significantly differ across variables (Table 2). In the first step, training the decision tree, CART software recursively divided the training data one variable at a time to generate a series of splits that best identified the probability of PCC timing.[50] The software chooses where to split variables based on where the division most accurately homogenizes the outcome variable while minimizing the model's misclassification rate, a process that results in subgroups more homogenous in the outcome of PCC timing than the original sample.[46,51] The software provides a tree for the training set but does not provide separate trees for the test set or the validation set. In the second step, the software used the validation set to identify the tree that optimally balanced complexity and prediction accuracy, evidenced by the highest generalized R-squared value. Because

Risk of Mortality increases as patient death nears and is a known correlate of PCC timing, it dominated the most optimal model, leading us to exclude it from the model.[52] After rerunning both steps without this variable, we then selected a tree with a prediction accuracy similar to the most optimal tree and clinically meaningful patient profiles that could help us achieve our primary aim of describing patients most likely to receive PCC close to death. Finally, we used the test set to further evaluate performance of the decision tree. Additional goodness of fit testing does not apply to CART modeling. The prediction accuracy rate was 58.8% for the training set, 54.4% for the validation set, and 54.7% for the test set. For descriptive purposes, EOL costs defined as all direct acute care costs incurred during index hospitalization to time of death, as coded for billing, were also assessed.

Results

The sample included 1,141 patients who received PCC before dying during the study period (Table 1). Over half (54%) received PCC within 14 days of dying (n=612), 26% received PCC 15–60 days before death (n=292), and only 21% received PCC more than 60 days before death (n=237). Patients received PCC a median 13 days before death. Of the 40.6% of patients who died during index admission, 89.4% changed their goals-of-care during or following PCC.

Similar to the predictive error in the test data (53.7%), CART demonstrated 54.7% accuracy identifying the timing outcome (CI 48.8%, 60.6%) (Table 3), likely because the model only accurately identified patients who received PCC close to death (sensitivity, 88.2%). Although the model did not effectively identify patients who had early PCC or moderately-timed PCC (sensitivity 1.7% and 27.4%, respectively), it effectively identified which patients did *not* receive early or moderately-timed PCC (specificity 99.1% and 82.1%, respectively), which is a clinically important population. Unmeasured variables and smaller sample sizes for early and moderately-timed PCC groups may have contributed to these findings.

Risk factor profiles associated with patients likely to receive PCC close to death are illustrated in Figure 1. There were multiple terminal risk factor profiles associated with high probability of PCC close to death (65–98% probability). African American and White ICU patients with extreme illness severity were more likely to have PCC close to death (66%). Intensive care patients with extreme illness severity who self-identified as Hispanic, "Other" or Unknown race/ethnicity were most likely to have PCC close to death (85%), a probability that increased to 98% among young and advanced-age patients (ages 18–45, 56–70, >75 years old). Patients with extreme illness severity who did not receive ICU care; had a primary diagnosis other than heart failure, respiratory disorder, or "Other" condition and were not hospitalized 30 days prior; and were young or advanced-age (<40 or >75 years old) had 96% probability of PCC close to death. On the other hand, patients with less than extreme illness severity who did not receive ICU care were least likely to receive PCC close to death (24%). Patients with extreme illness severity who did not receive ICU care, with a primary diagnosis other than heart failure, respiratory disorder, or "Other" condition, and were hospitalized 30 days prior were also less likely than average to have PCC close to death (43%). It is unknown if these findings represent a case of reverse causation or if other

factors are involved. Finally, it is important to note that 67% of ICU patients with extreme illness severity and 50% of ICU patients with less than extreme illness severity received PCC within 14 days of dying.

During index hospitalization, patients spent a median 11 days hospitalized (IQR 6–22 days, P<0.0001), 3 days in the ICU (IQR 0–11 days, P<0.0001), and incurred mean direct costs of $51,000 (SD $93,302; P=0.02). Index hospitalization utilization and costs were generally highest among patients with PCC close to death. Timing groups differed in age (P=0.04), race/ethnicity (P=0.02), primary diagnosis (P=0.006), Severity of Illness (P<0.0001), Risk of Mortality (P < 0.0001), ICU during index hospitalization (P<0.0001), ICU >6 days during index hospitalization (P<0.0001), and Oncology services during index hospitalization (P=0.03). Eighty-percent of PCC patients changed their goals-of-care during PCC, with rates increasing closer to death (P<0.0001). Do-not-resuscitate (DNR) documentation during index hospitalization (timing before or after PCC unknown) also increased closer to death (early PCC 26%, PCC 15–60 days 59%, PCC close to death 86%, P<0.0001). Discharge to hospice was lowest for patients with early PCC (10.1%) and higher for patients with moderately-timed PCC (32.5%) and PCC close to death (31%) (P<0.0001), but did not account for patients who died in the hospital.

Discussion

The model effectively identified which patients received PCC close to death and which patients did *not* receive more optimally-timed PCC, enabling clinicians to identify and target patients who are not getting more timely consultations and develop interventions that better support such patients' needs. The model was not able to accurately identify which patients received early or moderately-timed PCC, possibly because relatively few patients received early PCC and because already small sample sizes for these groups diminished in the context of variable interactions. Variables not included in our model may have improved the model's ability to identify patients likely to receive moderately-timed or early PCC. Future studies should include other potential correlates of PCC timing, such as health literacy, religiosity, immigrant status, primary language, and family dynamics.[53–55] Research is also needed to better understand which patients receive PCC early and why.

Patients in our study received PCC a median 13 days before dying, which is less than the national median length of hospice care (24 days).[56] This timing is problematic because shorter hospice enrollment is associated with lower quality EOL care, inadequate pain control, and unmet patient and family needs.[57–59] To give patients and families adequate time to consider EOL care preferences, our findings suggest clinicians need to engage patients with serious illness in goals-of-care discussions earlier in the illness trajectory. In our study, over half the patients who had early PCC changed their goals-of-care, indicating earlier conversations are relevant and appropriate. Research illuminating when and why patients changed their goals is needed.

In our study, 50% of ICU patients with less than extreme illness severity and 67% of ICU patients with extreme illness severity received PCC close to death, suggesting coordination of PCC is needed in the ICU regardless of illness severity. This finding supports evidence-

based recommendations to involve PCC in the ICU.[13,60,61] One recent study found patients in the neuro-ICU who received PCC were more likely to change goals-of-care to less invasive care, receive fewer procedures in the last 48 hours of life, and receive better symptom management.[62] Another study found involving PCC in the ICU increased advance care planning and decreased use of aggressive interventions.[63] Consulting palliative care earlier in the ICU stay gives patients and families more time to benefit from goals-of-care discussions and the improvements in symptom and care management that follow. Research into systematic processes for involving PCC early in the ICU admission, such as those developed using evidence-based triggers and machine learning, are recommended.[60,64,65] Early evidence suggests systematic processes increase PCC in the ICU,[64] possibly reducing disparities that result from referral-driven care.

The interaction of illness severity, ICU care, and race/ethnicity reveals a need for systematic integration of PCC and more culturally effective care for patients with diverse backgrounds. It is unknown why ICU patients who self-identified as Hispanic or "Other" racial/ethnic minority demonstrated such a high probability for receiving PCC close to death. Hispanics and other racial/ethnic minorities endure disparities in access to care and experiences throughout the care continuum that may influence when they first receive PCC.[53,54,66–70] For example, providers are less likely to have EOL discussions[71] and less likely to discuss prognosis[72] with Hispanics and other racial/ethnic minorities, possibly influencing their health literacy and receptivity to PCC.[53] Other factors such as religiosity, family dynamics, and socio-cultural preferences may also contribute to PCC timing.[53–55] More research is needed to better understand barriers to early PCC with severely ill Hispanics and other racial/ethnic minorities, and how clinicians can overcome such barriers to better support racial/ethnic minorities with serious illness.[66–68] Improved communication and earlier involvement with PCC may help reduce well-known disparities in EOL care among Hispanic patients and other minorities.[16,55,66,73,74]

Our study employed a broad definition of serious illness, which allowed analysis of a wider population of patients who can benefit from PCC. We included patients with established serious illnesses like cancer, heart failure, and organ failure but also included patients hospitalized with acute complications from other diseases such as cardiovascular disease or chronic conditions such as diabetes or frailty, and patients with brain injury or other medically complex conditions. At the time of index admission when PCC first occurred, 93% of patients in our study had major or extreme APR-DRG Severity of Illness and 88% had major or extreme APR-DRG Risk of Mortality, underscoring the appropriateness of PCC in a wide population of acutely ill hospitalized patients.[75–80] Evidenced by the high proportion of patients in our study who changed their goals-of-care during index admission (79.7%), PCC benefits myriad patient types. Although goal changes were especially high close to death (93%), half of patients who died more than 60 days after PCC also changed their goals during index admission. These findings imply PCC is useful earlier in illness trajectories. Research is needed to understand how early PCC influences care decision-making among different types of hospitalized patients, specifically patients with understudied conditions, chronic or multiple comorbidities, or a history of frequent hospitalization.

Finally, this medical center treats a high number of severely ill patients transferred from other regional hospitals, which may have contributed to the majority of patients receiving PCC close to death. Although timing improvements can be made in acute care settings using systematic triggers for inpatient PCC among eligible patients,[64,65,81–83] poor access to PCC in the community likely contributes to late timing. Increased access to community-based palliative care models would improve the time between PCC and death and help meet patient before inpatient hospitalization.[84,85]

Limitations

As a secondary analysis, we were unable to assess relevant socioeconomic, religious, and cultural variables not in the dataset. Some unavailable variables may be salient in risk factor profiles associated with the timing of PCC or be important confounding factors, influencing results. The study was, however, able to assess Medicaid use, which can be considered a proxy for socioeconomic variables because its eligibility is based on income. In addition, the index PCC may have occurred before some of the correlates, such as ICU admission or the assignment of severity of illness or risk of mortality, making conclusions about chronology unfeasible but still resulting in relevant insights.

Second, our study does not include patients whose date of death is not recorded in the system database. Patients who received PCC but whose death information was not available may have had shorter or longer durations between consultation and death. The variables measured may be distributed differently across the groups and may be associated with timing differently. We were unable to differentiate between patients who died in the health system and those who died outside the system but whose death information was updated by affiliated providers; and were unable to assess any differences in demographic or clinical factors between patients whose deaths occurred in-system versus those whose deaths occurred outside the system. If there were differences in these sub-populations, we were unable to account for them. Given most care stays within this large, integrated health system and 64% of patients with PCC in the parent study were known to have died (not all PCC patients likely died during the study), we believe our sample included most patients who died during the study period.

Finally, our study examined a single academic medical center with high acuity and a well-established palliative care team, possibly limiting generalizability of results. Willingness to engage in goals-of-care conversations and referral patterns to PCC may differ in other systems. Despite these limitations, our study increases understanding of risk factor profiles associated with PCC timing.

Conclusions

Identifying patients at risk for goals-of-care consultation close to death is a public health priority. All patients should have time to adequately understand prognosis and consider care options, but our research found most patients receive PCC within 14 days of dying. A complex set of factors was associated with PCC timing before death. Understanding risk factor profiles associated with PCC timing may help clinicians initiate these discussions

earlier with patients at-risk for late conversations and enable patients to make informed decisions consistent with preferences. Our results suggest PCC can benefit a wide population of seriously ill hospitalized patients and that systematic integration of PCC in the ICU and earlier communication with extremely ill Hispanic and Other racial/ethnic minority patients is needed to reduce disparities that may result from referral-driven care.
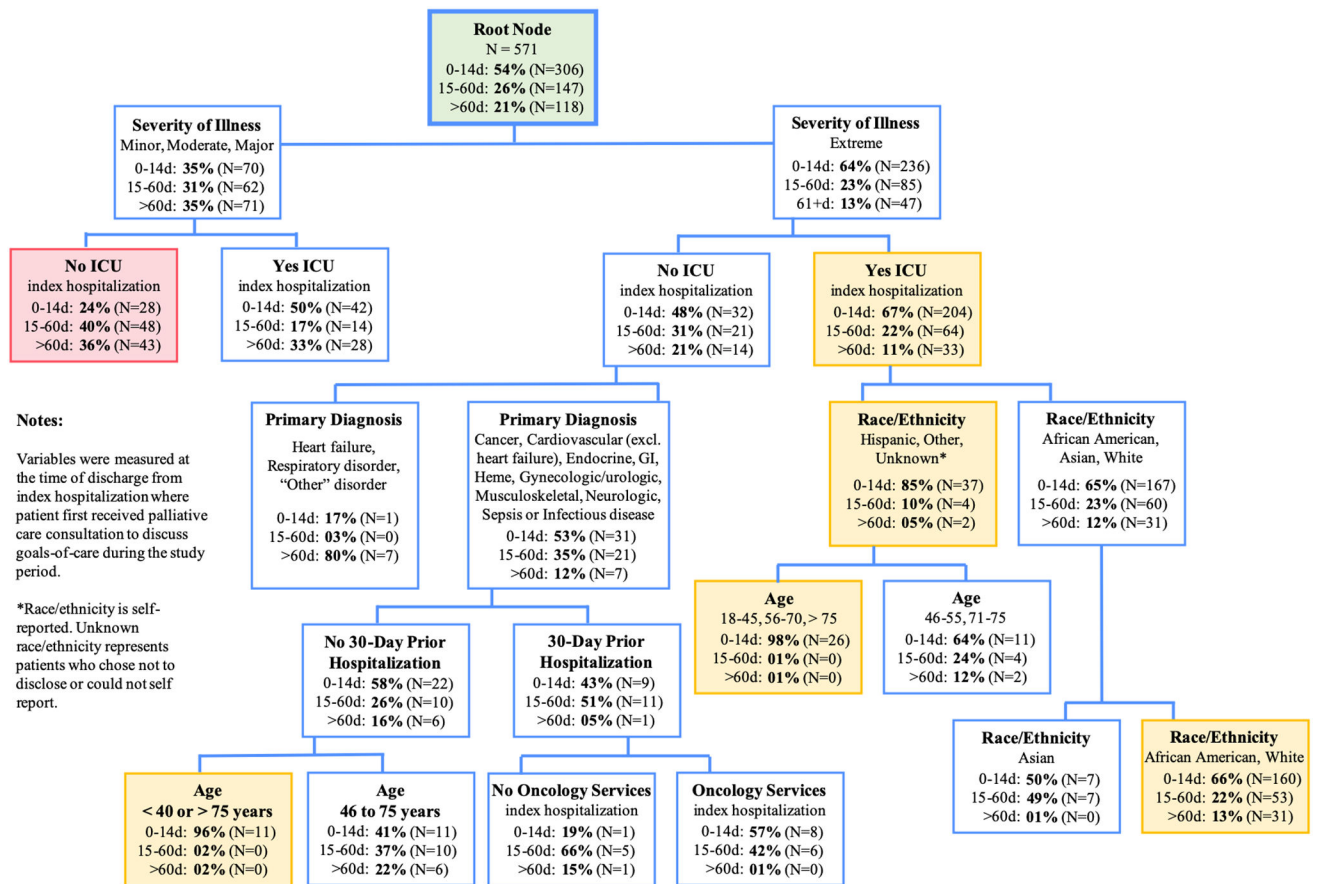
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Root Node
N = 571
0-14d: **54%** (N=306)
15-60d: **26%** (N=147)
>60d: **21%** (N=118)

Severity of Illness
Minor, Moderate, Major

0-14d: **35%** (N=70)
15-60d: **31%** (N=62)
>60d: **35%** (N=71)

Severity of Illness
Extreme

0-14d: **64%** (N=236)
15-60d: **23%** (N=85)
61+d: **13%** (N=47)

No ICU
index hospitalization
0-14d: **24%** (N=28)
15-60d: **40%** (N=48)
>60d: **36%** (N=43)

Yes ICU
index hospitalization
0-14d: **50%** (N=42)
15-60d: **17%** (N=14)
>60d: **33%** (N=28)

No ICU
index hospitalization
0-14d: **48%** (N=32)
15-60d: **31%** (N=21)
>60d: **21%** (N=14)

Yes ICU
index hospitalization
0-14d: **67%** (N=204)
15-60d: **22%** (N=64)
>60d: **11%** (N=33)

Notes:

Variables were measured at the time of discharge from index hospitalization where patient first received palliative care consultation to discuss goals-of-care during the study period.

*Race/ethnicity is self-reported. Unknown race/ethnicity represents patients who chose not to disclose or could not self report.

Primary Diagnosis
Heart failure, Respiratory disorder, "Other" disorder

0-14d: **17%** (N=1)
15-60d: **03%** (N=0)
>60d: **80%** (N=7)

Primary Diagnosis
Cancer, Cardiovascular (excl. heart failure), Endocrine, GI, Heme, Gynecologic/urologic, Musculoskeletal, Neurologic, Sepsis or Infectious disease

0-14d: **53%** (N=31)
15-60d: **35%** (N=21)
>60d: **12%** (N=7)

Race/Ethnicity
Hispanic, Other, Unknown*

0-14d: **85%** (N=37)
15-60d: **10%** (N=4)
>60d: **05%** (N=2)

Race/Ethnicity
African American, Asian, White

0-14d: **65%** (N=167)
15-60d: **23%** (N=60)
>60d: **12%** (N=31)

No 30-Day Prior Hospitalization
0-14d: **58%** (N=22)
15-60d: **26%** (N=10)
>60d: **16%** (N=6)

30-Day Prior Hospitalization
0-14d: **43%** (N=9)
15-60d: **51%** (N=11)
>60d: **05%** (N=1)

Age
18-45, 56-70, > 75
0-14d: **98%** (N=26)
15-60d: **01%** (N=0)
>60d: **01%** (N=0)

Age
46-55, 71-75
0-14d: **64%** (N=11)
15-60d: **24%** (N=4)
>60d: **12%** (N=2)

Age
< 40 or > 75 years
0-14d: **96%** (N=11)
15-60d: **02%** (N=0)
>60d: **02%** (N=0)

Age
46 to 75 years
0-14d: **41%** (N=11)
15-60d: **37%** (N=10)
>60d: **22%** (N=6)

No Oncology Services
index hospitalization
0-14d: **19%** (N=1)
15-60d: **66%** (N=5)
>60d: **15%** (N=1)

Oncology Services
index hospitalization
0-14d: **57%** (N=8)
15-60d: **42%** (N=6)
>60d: **01%** (N=0)

Race/Ethnicity
Asian
0-14d: **50%** (N=7)
15-60d: **49%** (N=7)
>60d: **01%** (N=0)

Race/Ethnicity
African American, White
0-14d: **66%** (N=160)
15-60d: **22%** (N=53)
>60d: **13%** (N=31)

Figure 1.
Classification and Regression Tree Showing Risk Factor Profiles of Patients Likely to Have Palliative Care Consultation to Discuss Goals-of-Care Within 14 days of Death

Table 1.

Description of Study Population: Patients Who Received Palliative Care Consultation to Discuss Goals-of-Care (PCC) Before Death, by Number of Days Between PCC and Death

		Total	PCC 0–14 days before death	PCC 15–60 days before death	PCC > 60 days before death	P value
		N = 1,141	N = 612 (53.6%)	N = 292 (25.6%)	N = 237 (20.8%)	
Median number of days between PCC and death (IQR)		13.0 (4.0–46.0)	5.0 (2.0–8.0)	28.0 (20.0–39.5)	135.0 (89.0–281.0)	<0.0001
Age (years)	18–39	6.6%	6.4%	6.8%	6.8%	
	40–45	3.7%	3.6%	4.4%	3.0%	
	46–50	3.9%	3.4%	5.1%	3.8%	
	51–55	9.1%	7.8%	9.6%	11.8%	
	56–60	12.9%	13.2%	13.0%	11.8%	0.037
	61–65	13.6%	13.4%	14.4%	13.1%	
	66–70	16.1%	15.0%	20.2%	13.9%	
	71–75	13.1%	12.6%	14.7%	12.2%	
	>75	21.0%	24.5%	11.6%	23.6%	
Gender	Male	46.6%	55.2%	51.0%	51.5%	0.40
	Female	53.4%	44.8%	49.0%	48.5%	
Self-identified Race/Ethnicity	African American/Black	25.0%	22.4%	28.4%	27.4%	
	Asian	3.8%	3.3%	3.8%	5.1%	
	Hispanic	2.2%	2.1%	2.1%	2.5%	0.02
	White	59.3%	60.0%	59.6%	57.4%	
	Other	3.2%	3.1%	2.7%	4.2%	
	Unknown/Chose not to disclose	6.5%	9.2%	3.4%	3.4%	
Medicaid	Yes	10.3%	9.3%	10.3%	13.1%	0.27
	No	89.7%	90.7%	89.7%	86.9%	
Primary Diagnosis	Cancer	33.2%	31.2%	37.0%	33.8%	
	Cardiovascular disorder / Heart failure	20.3%	22.9%	16.8%	18.1%	0.006
	Endocrine disorder	1.9%	2.0%	2.7%	0.8%	
	GI disorder	7.1%	5.2%	9.2%	9.3%	

		Total	PCC 0–14 days before death	PCC 15–60 days before death	PCC > 60 days before death	P value
		N = 1,141	N = 612 (53.6%)	N = 292 (25.6%)	N = 237 (20.8%)	
	Gynecologic or urologic disorder	2.8%	2.8%	3.8%	1.7%	
	Infectious disease and Sepsis	14.0%	15.4%	11.6%	13.5%	
	Neurologic disorder	6.9%	8.3%	6.5%	3.8%	
	Respiratory disorder	7.1%	7.0%	6.5%	8.0%	
	Other	6.6%	5.2%	5.8%	11.0%	
APR-DRG Severity of Illness	Minor	1.6%	1.1%	1.7%	2.5%	**<0.0001**
	Moderate	5.5%	3.6%	6.2%	9.7%	
	Major	28.1%	18.6%	34.6%	44.7%	
	Extreme	64.8%	76.6%	57.5%	43.0%	
APR-DRG Risk of Mortality	Minor	3.0%	1.8%	4.5%	4.2%	**<0.0001**
	Moderate	8.8%	4.1%	11.3%	17.7%	
	Major	29.8%	22.7%	34.2%	42.6%	
	Extreme	58.5%	71.4%	50.0%	35.4%	
Acute care hospitalization 30 days prior to index hospitalization	Yes	23.0%	21.6%	27.4%	21.5%	0.124
	No	77.0%	78.4%	72.6%	78.5%	
ICU care during index hospitalization	Yes	67.0%	77.6%	55.1%	54.4%	**<0.0001**
	No	33.0%	22.4%	44.9%	45.6%	
ICU care > 6 days during index hospitalization	Yes	40.3%	46.1%	37.3%	29.1%	**<0.0001**
	No	59.7%	53.9%	62.7%	70.9%	
Specialist who referred patient to Palliative Care for PCC (one patient had a missing value)	Cardiology	10.8%	10.5%	13.1%	8.9%	0.35
	Gynecology/Oncology	3.9%	4.4%	4.1%	2.1%	
	General Medicine/Hospitalist	13.3%	13.6%	14.8%	11.0%	
	Neurology	7.3%	6.2%	7.6%	9.7%	
	Oncology	34.6%	34.0%	31.3%	40.5%	
	Pulmonary	9.8%	10.1%	10.3%	8.4%	
	Surgery	17.9%	19.1%	16.8%	16.0%	
	Other	2.4%	2.1%	2.1%	3.4%	
Visited by Oncology during index hospitalization	Yes	30.0%	27.3%	36.0%	29.5%	**0.03**

		Total	PCC 0–14 days before death	PCC 15–60 days before death	PCC > 60 days before death	P value
		N = 1,141	N = 612 (53.6%)	N = 292 (25.6%)	N = 237 (20.8%)	
	No	70%	72.7%	64%	70.5%	
Median days spent hospitalized during index hospitalization (IQR)		11.0 (6–22)	9.0 (5–17)	16.0 (7–27.5)	11.0 (7–24)	**<0.0001**
Median ICU days during index hospitalization (IQR)		3.0 (0–11)	5.0 (1–11)	1.5 (0–13)	1.0 (0–7)	**<0.0001**
Median direct acute care costs during index hospitalization (IQR)		$26,005 ($12,908–$59,889)	$28,330 ($13,635–$58,476)	$27,542 ($11,572–$75,175)	$21,397 ($12,357–$47,064)	0.18
Median EOL direct acute care costs *(index hospitalization plus future acute care costs in health system until death)* (IQR)		$31,082 ($14,880–$67,035)	$28,333 ($14,200–$58,476)	$34,113 ($14,484–$77,510)	$37,326 ($18,461–$89,057)	**0.0001**
Changed goals-of-care during PCC index hospitalization (% yes)		79.7%	93.0%	75.7%	50.2%	**<0.0001**
DNR documented during index hospitalization	Yes	66.9%	86.3%	59.2%	26.2%	**<0.0001**
	No	33.1%	13.7%	40.8%	73.8%	
Discharged to hospice [1]	Yes	27.1%	31%	32.5%	10.1%	**<0.0001**
	No	72.9%	69%	67.5%	89.9%	

[1] From index hospitalization including PCC. Chi-squared test of association was used to test differences among percentage variables. Kruskal-Wallis tests and analysis of variance (ANOVA) were performed for the distributions of continuous measures by PCC timing, as appropriate.

Table 2.

Comparison of Patients Randomly Assigned to Classification and Regression Tree (CART) Training, Validation, and Test Sets (Patients Who Received Palliative Care Consultation to Discuss Goals-of-Care Before Death)

		Total	Patients in CART Training Set	Patients in CART Validation Set	Patients in CART Test Set	P value
		N = 1,141	N = 571 (50%)	N = 285 (25%)	N = 285 (25%)	
Age (years)	18–39	6.6%	6.1%	8.8%	5.3%	
	40–45	3.7%	4.6%	2.8%	2.8%	
	46–50	3.9%	4.0%	5.3%	2.5%	
	51–55	9.1%	9.1%	9.1%	9.1%	
	56–60	12.9%	12.6%	11.9%	14.4%	0.263
	61–65	13.6%	14.0%	13.3%	13.0%	
	66–70	16.1%	13.7%	17.9%	19.3%	
	71–75	13.1%	13.0%	14.7%	11.6%	
	>75	21.0%	22.9%	16.1%	22.1%	
Gender	Male	46.6%	44.8%	47.7%	49.1%	0.452
	Female	53.4%	55.2%	52.3%	50.9%	
Self-identified Race/Ethnicity	African American/Black	25.0%	24.2%	27.4%	24.2%	
	Asian	3.8%	4.2%	2.1%	4.6%	
	Hispanic	2.2%	2.3%	2.5%	1.8%	0.497
	White	59.3%	60.6%	57.5%	58.6%	
	Other	3.2%	2.5%	3.2%	4.9%	
	Unknown/Chose not to disclose	6.5%	6.3%	7.4%	6.0%	
Medicaid	Yes	10.3%	11.0%	10.5%	8.8%	0.588
	No	89.7%	89.0%	89.5%	91.2%	
Primary Diagnosis	Cancer	33.2%	31.9%	32.6%	36.5%	
	Cardiovascular disorder / Heart failure	20.3%	22.2%	18.9%	17.9%	0.382
	Endocrine disorder	1.9%	2.1%	2.1%	1.4%	
	GI disorder	7.1%	6.3%	6.3%	9.5%	

		Total	Patients in CART Training Set	Patients in CART Validation Set	Patients in CART Test Set	P value
		N = 1,141	N = 571 (50%)	N = 285 (25%)	N = 285 (25%)	
	Gynecologic or urologic disorder	2.8%	2.5%	2.5%	3.9%	0.42
	Infectious disease and Sepsis	14.0%	14.0%	17.5%	10.5%	
	Neurologic disorder	6.9%	6.8%	7.0%	7.0%	
	Respiratory disorder	7.1%	6.8%	7.4%	7.4%	
	Other	6.6%	7.4%	5.6%	6.0%	
APR-DRG Severity of Illness	Minor	1.6%	1.2%	1.1%	2.8%	0.238
	Moderate	5.5%	6.1%	3.9%	6.0%	
	Major	28.1%	28.2%	29.5%	26.7%	
	Extreme	64.8%	64.4%	65.6%	64.6%	
APR-DRG Risk of Mortality	Minor	3.0%	3.3%	1.8%	3.5%	0.305
	Moderate	8.8%	9.3%	6.3%	10.2%	
	Major	29.8%	28.0%	34.7%	28.4%	
	Extreme	58.5%	59.4%	57.2%	57.9%	
Acute care hospitalization 30 days prior to index hospitalization	Yes	23.0%	24.7%	22.8%	20.0%	0.904
	No	77.0%	75.3%	77.2%	80.0%	
ICU care during index hospitalization	Yes	67.0%	67.4%	66.0%	67.4%	0.887
	No	33.0%	32.6%	34.0%	32.6%	
ICU care > 6 days during index hospitalization	Yes	40.3%	41.0%	39.3%	40.0%	
	No	59.7%	59.0%	60.7%	60.0%	
Specialist who referred patient to Palliative Care for PCC (one patient had a missing value)	Cardiology	10.8%	11.4%	10.9%	9.5%	0.336
	Gynecology/Oncology	3.9%	3.9%	2.8%	4.9%	
	General Medicine/Hospitalist	13.3%	11.9%	17.6%	11.9%	
	Neurology	7.3%	7.2%	6.3%	8.4%	
	Oncology	34.6%	35.2%	35.9%	32.3%	
	Pulmonary	9.8%	9.8%	8.8%	10.2%	
	Surgery	17.9%	18.7%	13.7%	20.4%	
	Other	2.4%	3.0%	2.5%	1.1%	

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		Total	Patients in CART Training Set	Patients in CART Validation Set	Patients in CART Test Set	P value
		N = 1,141	N = 571 (50%)	N = 285 (25%)	N = 285 (25%)	
Visited by Oncology during index hospitalization	Yes	30.0%	28.7%	32.3%	30.2%	0.561
	No	70%	71.3%	67.7%	69.8%	

[1] From index hospitalization including PCC.

Chi-squared test of association was used to test differences among percentage variables.

Table 3.

Classification and Regression Tree (CART) model performance for identifying profiles associated with the timing of palliative care consultation for goals-of-care (PCC) before death.

Sample	Statistic	Value
PCC patients who died during the study period	Root node error	0.537
	Accuracy (95% Confidence Interval)	0.547 (0.488, 0.606)
	P-Value [Acc >NIR]	0.384
Patients with PCC 0–14 days before death	Sensitivity	0.882
	Specificity	0.326
	Positive predictive value	0.603
	Negative predictive value	0.705
Patients with PCC 15–60 days before death	Sensitivity	0.274
	Specificity	0.821
	Positive predictive value	0.345
	Negative predictive value	0.767
Patients with PCC > 60 days before death	Sensitivity	0.017
	Specificity	0.991
	Positive predictive value	0.333
	Negative predictive value	0.794

*
The P-value represents the probability that model accuracy is higher than the no information rate (NIR). Sensitivity represents the proportion of patients correctly identified in the model as having had PCC in the associated timeframe. Specificity represents the proportion of patients that did not have PCC in the associated timeframe and were correctly identified in the model. Positive predictive value is the proportion of patients who actually received PCC in the associated timeframe out of all patients identified in the model as having received PCC in that timeframe. Negative predictive value is the proportion of patients who actually did not receive PCC in the associated timeframe out of all those identified in the model as having not received PCC in that timeframe.