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Palliative care and imaging utilisation for patients with cancer

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Abstract

Objective: This observational study explores the association between palliative care (PC) involvement and high-cost imaging utilization for cancer patients during the last three months of life.

Methods: Adult cancer patients who died between 1/1/2012 - 5/31/2015 were identified. Referral to PC, intensity of PC service use, and non-emergent oncologic imaging utilization were determined.

Associations between PC utilization and proportion of patients imaged and mean number of studies per patient (mean imaging intensity [MII]) were assessed for the last three months and last month of life. Similar analyses were performed for randomly matched case-control pairs (n=197). Finally, the association between intensity of PC involvement and imaging utilization was assessed.

Results: 3,784 patients were included, with 3,523 (93%) never referred to PC and 261 (7%) seen by PC, largely before the last month of life (61%).

Similar proportions of patients with and without PC referral were imaged during the last three months, while a greater proportion of PC patients were imaged in the last month of life. PC involvement was not associated with significantly different MII during either time frame.

In the matched-pairs analysis, a greater proportion of patients previously referred to PC received imaging both in the period between first PC encounter and death as well as the last month of life. MII remained similar between PC and non-PC groups.

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COMPETING INTERESTS:

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Finally, intensity of PC services was similar for imaged and non-imaged patients in the final three and one month of life. During these time periods, increased PC intensity was not associated with decreased MII.

Conclusions: PC involvement in end-of-life oncologic care was not associated with decreased use of non-emergent, high-cost imaging. The role of advanced imaging in the PC setting requires further investigation.

Keywords

Palliative care; End of life care; Oncology; Imaging; Resource utilization

INTRODUCTION:

Health care expenditures related to cancer care continue to rise due to increasing intensity of care and treatment costs [1-3]. Across all cancers, it is estimated that costs are greatest during the initial therapy phase and during the last 12 months of life [4 5]. Recent studies indicate that even with a relatively modest 2% annual growth rate for costs during these two phases of cancer care, net expenditure between 2010 and 2020 will rise by 39% to a total exceeding $173 billion [1 2].

End-of-life oncologic care has become a critical area of utilization management research due to unabated annual increases in intensity and cost of care without demonstrated commensurate improvement in quality of life [6-9]. As such, there is now particular focus to both decrease costs and improve quality of care, as exemplified by the Triple Aim and the value-based Oncology Care Model proposed by the Centers for Medicare and Medicaid Services (CMS) [10].

Though imaging overall accounts for only approximately 6% of total cost of cancer-related care, total computed tomography (CT), positron emission tomography (PET), and magnetic resonance (MR) imaging expenditures are estimated to increase twice as fast as total cancer care [5 11]. Furthermore, use of such high-cost imaging modalities is rising faster among stage IV cancer patients compared with early stage patients, including during the last month of life [12]. However, the benefit of intense imaging regimens to patient outcomes has proven difficult to assess, and treatment changes associated with imaging findings have not clearly benefited patients at the end of life [12 13]. As in past attempts to control costs, both the federal government and other payers have shown interest in understanding the value of imaging and more strictly controlling unnecessary high-cost imaging [11 13 14].

Palliative care (PC) is a medical discipline that helps patients with serious illness, including advanced cancer, in the inpatient and/or outpatient through a holistic approach that strives to address all facets of suffering[15]. Using a team-based approach (consisting of physicians, nurses, social workers, and chaplains at our institution) alongside curative medical treatment teams, the PC team focuses on assisting with symptom management, clarifying patients' goals for medical care and ensuring they are followed, and helping both patients and caregivers cope with serious illness [15 16]. The National Consensus Project for Quality PC has developed guidelines for the delivery of PC that encompass the physical, psychological,

social, spiritual, cultural, ethical, and legal aspects of care [17] with the ultimate aim "to help [the patient] feel as good as possible, for as long as possible [16]."

A growing body of research shows that PC referral for advanced cancer patients improves quality of life and patient satisfaction, while also decreasing total cost of care and possibly increasing survival. A recent meta-analysis found that cost savings associated with PC referral for hospitalized patients was greater for those with cancer and higher illness burden [18]. In fact, there is a temporal association between earlier PC referral, in both inpatient and outpatient settings, and better end-of-life outcomes with decreased costs [19-25]. Proposed reasons for the demonstrated financial benefits include more appropriate health care utilization at the end of life, such as reduced hospitalizations, decreased medical services, and earlier hospice care referral [19 22]. The impact of PC involvement on advanced imaging use during the end-of-life has not been extensively studied.

In this study, we evaluated the association between the level of PC service utilization and high-cost imaging utilization during the end-of-life period (defined here as the final three months of life) for a tertiary care center oncologic patient cohort. We hypothesized that PC referral would be associated with decreased use of high-cost imaging during the end-of-life, with earlier PC involvement resulting in greater impact on advanced imaging use.

METHODS:

We retrospectively analyzed cancer patients' advanced imaging utilization (including CT, MRI, and PET scans) at a single academic comprehensive cancer center to assess the association between PC referral and high-cost imaging utilization at the end of life, defined here as the final three months of life. In addition, a matched pairs design was used to further delineate differences in utilization associated with PC referral.

This study was approved by the institutional review board and did not require patient consent.

Study population and data sources

The medical center's institutional cancer registry provided the records of adult cancer patients with death dates between January 1, 2012 and May 31, 2015. Patients with fewer than 365 days between diagnosis and death were excluded from this study to avoid biasing assessment of end-of-life imaging utilization through inclusion of staging imaging.

Using medical record numbers (MRNs), patients were matched to records from the institutional radiology information system to calculate tomographic imaging utilization (i.e. computed tomography [CT], magnetic resonance [MR], and positron emission tomography [PET]). All study patients had at least one non-emergent cancer imaging study completed at the medical center between 2000 and 2015. This criterion was used to minimize the number of study patients who may get most or all radiology studies outside of our institution. Finally, because PC may not be involved in the decision-making during emergent medical presentations (e.g. visits to the Emergency Department), we focused on non-emergent oncologic imaging utilization. To ensure the study focused specifically on non-emergent

oncologic imaging, imaging studies were included only if they contained an ICD-9-CM diagnostic code indicating malignant neoplasm (i.e. 140.xx-209.xx, 230.xx-234.xx, 235.xx-239.xx).

Both departmental records of office visits and institutional electronic health record were matched by MRN to the study dataset to identify patients receiving either inpatient or outpatient PC. A licensed physician then manually reviewed the institutional electronic health record for each PC patient and recorded the precise date for every PC encounter with a certified physician or nurse. In this paper, patients with at least one PC encounter are referred to colloquially as “PC patients” and the time of PC referral is synonymous with the first encounter with a PC clinician.

Furthermore, clinical documentation in the electronic record was carefully reviewed for each PC encounter and the following data was manually collected: inpatient versus outpatient setting, any concomitant cancer-related therapy (chemotherapy or radiation) any palliative cancer-directed therapy (chemotherapy or radiation given explicitly for symptom control rather than survival intent), and the frequency in which the assessment/plan addressed each of the 8 specific domains of PC delivery described in guidelines from The National Consensus Project for Quality Palliative Care, including: 1. Structure and Processes of care; 2. Physical Aspect of Care; 3. Psychiatric and Psychological Aspects of Care; 4. Social Aspects of Care; 5. Spiritual, Religious, and Existential Aspects of Care; 6. Cultural Aspects of Care; 7. Care of the Patient Nearing the End of Life; 8. Ethical and Legal Aspects of Care. [17]

For each individual PC patient, the average number of domains addressed per encounter with the clinical PC team was calculated. This was used as representative metric of PC involvement for a patient and is referred to as “PC visit intensity.”

Matched pairs

Within the entire cohort, 261 PC patients and 2,737 non-PC patients were available for matching. Case-control pairs were matched[26] 1:1 by sex, race, age at death (range), and ICD-O-3 diagnostic code for primary cancer. Age was classified into one of three ranges to improve match sample size within contextually useful age classifications: (1) 18 to 39, (2) 40 to 64, and (3) 65 or older. 197 matched-pairs were identified, resulting in 394 total study subjects for the matched pairs analysis.

Statistical Analysis

Chi-square tests were used to assess variation in proportion of patients imaged in the last three months and last month of life based on PC referral status prior to these periods respectively. Wilcoxon rank-sum tests were also applied to evaluate differences in mean number of studies per patient (mean imaging intensity [MII]) among those who were imaged. Secondary analyses were performed based on imaging modality (CT, MRI, or PET). Patients referred to PC in the final month of life were excluded from these analyses because, with the data available for this time period, we were unable to definitively determine which imaging studies were performed after the first PC encounter rather than before.

A matched-pairs design was used to further compare utilization between PC and non-PC patients in the time period between PC referral and death, as well as during the last month of life. Imaging between PC referral and death for the matched patient without PC was calculated by summing the imaging during the same relative time period, based on number of days from PC referral to death. McNemar's test for paired proportions and Wilcoxon rank-sum tests for unpaired comparison of mean imaging intensities among imaged patients were used to assess variation based on PC status. Secondary analysis based on imaging modality (CT, MRI, or PET) was also performed.

Finally, PC intensity was assessed within the context of imaging utilization during the final three months of life and the final month of life. The mean PC visit intensity was measured among those who were and were not imaged within each time period. The mean PC visit intensity was similarly calculated for patients at or below the 75th percentile of imaging intensity and those above the 75th percentile. Wilcoxon rank sum tests were used to compare means.

All data management and analyses were conducted using StataSE version 14.2 (StataCorp, College Station, Texas).

RESULTS:

The distribution of patient characteristics by PC referral status may be found in Table 1; there was no significant variation in the distribution of characteristics between PC classifications. The majority of decedents included in the analyses were never referred to PC (93%, n = 3,523). In both palliative and non-PC groups, patients were predominantly aged 40 to 64 and 65 and older. The study population was primarily white (PC patients 68%, n = 177; non-PC 76%, n = 2684). Gastrointestinal cancer was the most common, accounting for approximately 26% of non-PC patients and 28% of the PC cohort.

Among the patients referred to PC (7%, n = 261), 25% were referred more than 1 year before death (n=66), 28% were referred 3 to 12 months pre-mortem (n=72), 19% were referred 1 to 3 months pre-mortem (n=50), and 28% were referred in the final month of life (n=73). The PC patients had a total of 1,580 PC encounters, of which 60% were inpatient and 40% were outpatient (Table 2). Chemotherapy or radiation treatment was ongoing during 17% (n=272) of the encounters and palliative chemotherapy or radiation was ongoing at the time of 13% (n=206) of the encounters. The domains of care most commonly addressed in each encounter were Domain 2: Symptoms and Physical Health (89%; n=1405) and Domains 7–8: End of life and ethical/legal issues (83%; n=1303). Domain 1: Coordination of Care was the domain least frequently addressed in a PC encounter (10%; n=159).

The overall proportion of patients imaged in their final three months of life was not significantly different between patients without PC referral and those with initial PC visit three or more months prior to death. By imaging modality, CT imaging alone was received by a larger proportion of PC patients in the final three months of life (36% vs 27%,

p=0.0234). There was also no significant variation in total mean imaging intensity or mean imaging intensity based on imaging modality (Table 3a).

A greater proportion of patients with first PC visit prior to the final month of life were imaging in the last month of life compared to those without PC referral (24% vs 17%, p=0.0055). On further analysis by imaging modality, only the proportion of patients receiving CT imaging in the final month of life was significantly different based on PC status (22% vs 13%, p=0.0004). Wilcoxon rank-sum test revealed no significant variation in mean imaging intensity in the final month of life the two groups (Table 3b).

Among the matched pairs, the mean number of days from PC referral to death was 218, with a standard deviation of 239 days, a minimum of 0 days, a 25th percentile of 32 days, a median of 114 days, a 75th percentile of 358 days, and a maximum of 1114 days. The proportion of patients imaged and mean imaging intensity between first PC encounter and death for the matched-pairs cohort are described in Table 4a. Among the 197 matched pairs, between PC referral and death a significantly greater proportion of PC patients received advanced imaging studies (56% vs. 22%, p<0.0001), including CT imaging (11% vs. 3%, p=0.0002) and PET imaging (15% vs. 10%, p=0.0009) compared with non-PC patients. However, Wilcoxon rank-sum test did not show a significant difference in total mean imaging intensity from time of PC referral to death between palliative and non-PC patients (p>0.05). Similarly, there was no difference in mean imaging intensity between the groups based on imaging modality.

The proportion of patients imaged and mean imaging intensity during the last month of life for the matched-pairs cohort are described in Table 4b. Among the 197 matched pairs, between the time of first PC encounter and death a significantly greater proportion of PC patients received advanced imaging studies (28% vs. 14%, p=0.0071), including CT imaging (25% vs. 9%, p=0.0016), and MR imaging (10% vs. 6%, p<0.0001), compared with non-PC patients. However, between the two groups Wilcoxon rank-sum test did not show a significant difference in total mean imaging intensity in the final month of life (p>0.05). Similarly, there was no difference in mean imaging intensity based on imaging modality.

Finally, PC visit intensity based on imaging utilization and imaging intensity during the final 3 months of life and final month of life are described in Table 5A and Table 5B respectively. Among patients referred to PC 3 months or more before death, mean PC visit intensity (i.e. number of domains addressed during a PC encounter on average) was greater for those who received imaging in the final 3 months of life compared with those who did not (2.31 vs. 1.64, p=0.0002). And among the patients who did receive imaging in the final three months, PC visit intensity was similar regardless of imaging intensity (p>0.05). Among patients referred to PC before the last month of life, PC visit intensity was significantly greater for patients did receive imaging during the final month of life (1.92 vs. 1.07, p<0.0001). PC visit intensity was also higher for patients with imaging intensity above the 75th percentile during the last month of life (1.89 vs. 1.21, p=0.0015).

DISCUSSION:

In the United States' growing national conversation regarding health care cost containment, end-of-life oncologic care is of particular interest as expenditures continue to rise without clear benefit including to patient quality-of-life [6-9]. As such, current national incentive models and guidelines have shifted to emphasize earlier involvement of PC as a means to not only improve quality of life, patient satisfaction, and possibly survival, but also to help contain costs associated with low-value care [10 19]. Imaging accounts for the fastest growing component of total costs for advanced cancer patients in the US, including during the last month of life [5 11 12]. To our knowledge, this observational, exploratory study is the first to investigate the association between PC referral and advanced, high-cost imaging utilization in this population.

Prior research has suggested that earlier referral to PC for cancer patients is associated with improved resource utilization at the end of life and attendant cost savings [24]. However, in the presented analysis, contrary to our initial hypothesis, PC involvement in patient care did not result in decreased imaging utilization at the of end-of-life. Within the final three months of life, the proportion of patients undergoing advanced imaging studies and the mean number of studies per patient were similar between those without PC referral and those referred to PC three or more months before death. In fact, a greater proportion of patients with PC referral prior to the last month of life received advanced imaging in the final month of life compared to those never referred to PC. Still, the mean number of studies per patient in the final month of life was similar regardless of PC status.

Matched pairs analyses were additionally performed to account for limitations in the primary analysis, including the inability to account for the time between PC referral and the end-of-life period analyzed (last three months or one month of life). In this analysis, PC involvement again was not associated with decreased imaging. Instead, a greater proportion of patients with PC referral had advanced imaging, including CT and PET imaging, in the time from first PC referral to death. Among the matched pairs, a larger portion of PC patients also underwent advanced imaging, including CT and MRI, during the last month of life. However, total mean imaging intensity and mean imaging intensity by modality remained similar between PC and non-PC patients.

It is conceivable that varying degrees of PC involvement would differentially affect the use of non-emergent advanced imaging at the end of life. To further investigate this, we studied the association between imaging and PC intensity using the number of PC domains (per The National Consensus Project for Quality Palliative Care) addressed during encounters as a marker of intensity ("PC visit intensity"). In this analysis, PC visit intensity was similar whether or not a patient was imaged in the last 3 or 1 month of life. Moreover, PC visit intensity did not defer based on imaging intensity during the last three months of life, while greater PC visit intensity was associated with greater imaging intensity in the last month of life.

Counter to our hypothesis, neither referral to PC nor the intensity of PC involvement upon referral was associated with reduced utilization of non-emergent high-cost cancer

imaging in the last three months and final month of life. In fact, using every metric of PC care involvement that we studied, a greater extent of PC care delivery was associated with similar to increased delivery of imaging services. Lending support to this conclusion, two recent studies from Italy describe an increasing frequency of diagnostic imaging studies for end-stage oncologic patients in the 90 days prior to hospice admission with commensurate increases in cost [27 28]. This suggested trend toward increased imaging despite PC involvement requires further study in large multicenter and multinational cohorts.

It is conceivable that the high incidence of imaging utilization among PC patients may reflect a broader trend in patients' overall utilization levels. A recent study of Medicare beneficiaries' utilization of health care services in the final year of life identified 48.7% of the decedent beneficiaries as belonging to a high persistent spending trajectory in the final year of life, and indicated this group's spending pattern appeared to be set in motion long before the end of life and was associated with multiple chronic conditions [29]. However, an imaging utilization study using the trajectory modeling method of Davis et al. found the imaging utilization in the final three months of life was no different between high persistent and low persistent spending trajectories, while patients with early and late rising spending in the final year of life were much more likely to be imaged [30]. Notably, the aforementioned study used a subset of the patients included in the present study's dataset. Given previous findings, it may be that patients referred to PC have steadily increasing costs during the end of life and are good candidates for imaging utilization reduction, rather than high persistent utilization patients who are more likely to have multiple chronic conditions for which they've been undergoing treatment for a prolonged period of time.

Clearly there can be many goals to imaging in advanced cancer patients, including cancer monitoring, investigation of new signs or symptoms, or work-up of an acute process, and it can be difficult to untangle these goals with utilization data. For example, in our cohort PC visits most commonly addressed Domain 2: Symptoms and Physical Health and Domains 7–8: End of life and ethical/legal issues; and it is conceivable that cross-sectional imaging may help address issues relevant to these domains.

However, there tellingly was no significant decrease in use of PET imaging, a modality employed only to monitor cancer, for PC patients during the end-of-life period compared to non-PC patients. In fact, the matched pairs analysis showed a greater proportion of PC patients received PET imaging in the last month of life. Moreover even among PC patients, a greater intensity of PC involvement was not associated with decreased oncologic imaging. Doctors are quite good at predicting survival in advanced cancer patients [31], and presumably high-cost imaging for monitoring of the malignancy is largely unnecessary for advanced cancer patients referred to PC.

As PC becomes more integrated in end-of-life cancer care teams, increased attention to patient goals of care and minimizing excessive resource utilization is important. Particular attention to advanced imaging use in this population is warranted given the associated rapidly escalating costs. The value of high-cost imaging to help align patients' care plans with their goals must be studied.

There are several limitations to our exploratory study. In addition to the referral bias at our center, the number of patients referred to PC was relatively small. But this is in keeping with the relatively limited access to PC in California (approximately 67–74% of hospitals offered PC programs between 2011–2015)[32] and the relatively low rate of hospice use among Medicare beneficiaries in California (in 2015, 40–45% of eligible patients were enrolled in hospice. at the time of death)[33]. Furthermore, though PC is rapidly growing, there continues to be very high variability in the number of eligible cancer patients referred to PC [34 35].

The patients in this cohort had a mixture of both inpatient and/or outpatient PC encounters between the time of referral to death. Because all patient encounters were included, the impact of the treatment setting on imaging utilization was not differentiated.. A minority of patients were undergoing some sort of treatment (curative intent and/or palliative) and the effect of treatment on imaging intensity was not evaluated. Additionally, the intensity of PC was based on manual review of care domains addressed in encounters as documented in the electronic medical record, which may be prone to user and/or reviewer biases and errors.

Further, our analysis was limited by excluding patients referred to PC during the final month of life. However, this was necessary as, for this subset of patients, we were unable to definitively determine which imaging studies were performed after the first PC encounter rather than before.

Non-emergent imaging studies with indication for evaluation of known malignancy were included in this study based on ICD coding. It is possible that the indications were incorrect and studies for emergent indications were included. Patients referred to our tertiary care center also may obtain additional care outside of the network that is not captured in this analysis. The matched-pairs analysis should help equalize some this variation between patients referred to and not referred to PC. We were unable to account for temporal effects of PC intervention.

Future multicenter studies should further investigate the impact of PC involvement on advanced imaging utilization in large oncologic cohorts. These studies must also assess how demographic factors, clinical variables, clinical setting, and temporal differences in PC referral influence end-of-life imaging.

Notably, it is not known whether patient demand and/or clinician recommendation led to the imaging studies assessed in our study. In order to better understand the value of the imaging obtained, potential intangible benefits associated with imaging that are unrelated to cost must also be understood. Patient, family, physician, and/or cultural drivers could all be contributing to the imaging utilization pattern seen in our study.

Finally, it will be important to better understand the role that imaging plays in the setting of PC and the potential choices and decisions that may depend on imaging. Continued imaging during the end-of-life period could contribute to decision-making that impacts overall health care utilization and ultimately decreases total cost of care. Perhaps imaging is being used to guide use of other services and promote care plans consistent with patient goals and preferences.

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Table 1:

Distribution of patient characteristics by palliative care status

	No palliative care	Received Palliative Care	Overall
	% (n)	% (n)	% (n)
	100% (3523)	100% (261)	100% (3784)
Sex			
Male	54.2% (1909)	45.2% (118)	53.6% (2021)
Female	45.8% (1614)	54.8% (143)	46.4% (1750)
Age Group			
18 to 39	6.1% (212)	8% (21)	6.2% (233)
40 to 64	41.8% (1452)	54% (141)	42.7% (1593)
65 and older	52.1% (1809)	37.9% (99)	51.1% (1908)
Race			
White	76.2% (2684)	67.8% (177)	75.6% (2861)
Black	6.4% (227)	8% (21)	6.6% (248)
Asian	11.6% (409)	17.6% (46)	12% (455)
Pacific Islander	2.7% (96)	5.4% (14)	2.9% (110)
Unknown	3% (107)	1.1% (3)	2.9% (110)
Cancer Type			
Head, Neck, & Throat	4.7% (167)	3.4% (9)	4.7% (176)
Gastrointestinal	26.2% (923)	28% (73)	26.3% (996)
Respiratory	11.3% (399)	13.4% (35)	11.5% (434)
Bone, Skin, & Connective Tissue	13.5% (474)	13% (34)	13.4% (508)
Breast	6.3% (221)	16.9% (44)	7% (265)
Male Reproductive	5.5% (194)	8% (21)	5.7% (215)
Female Reproductive	7.1% (249)	9.6% (25)	7.2% (274)
Kidney & Bladder	5.9% (207)	2.3% (6)	5.6% (213)
Endocrine & Neuroendocrine	15.3% (538)	3.8% (10)	14.5% (548)
Brain & CNS	1.7% (60)	0.4% (1)	1.6% (61)
Blood & Lymphatic	2.6% (91)	1.1% (3)	2.5% (94)
Time of PC Referral			
>3 months pre-mortem	---	53% (138)	---
1-3 months pre-morten	---	19% (50)	---
Last month of life	---	28% (73)	---

Percentages and totals shown are column values.

Table 2.

Descriptive Statistics of Palliative Care Encounters

Total PC Encounters	**100% (1,580)**
Type	
Inpatient	59.9% (934)
Outpatient	40.1% (626)
Visit Time Period	
More than 1 year before death	14.4% (228)
12-3 months pre-mortem	32.3% (510)
3-1 months pre-mortem	22.6% (357)
Final month of life	30.7% (485)
Chemo or Radiation	17.2% (272)
Palliative Chemo or Radiation	13.0% (206)
Domains of Care	
Domain 1: Coordination of care	10.1% (159)
Domain 2: Symptoms, physical health	88.9% (1405)
Domain 3: Psychological	40.8% (644)
Domain 4: Social issues	31.3% (494)
Domain 5-6: Spiritual & Cultural	27.6% (436)
Domain 7-8: End of life & Ethical/legal	82.5% (1303)

Percentages and totals shown are column values.

Table 3a:

Proportion imaged and mean imaging intensity in the final 3 months of life

Palliative Care Referral	Tomographic Imaging *% (mean)*	CT[a] *% (mean)*	MR *% (mean)*	PET *% (mean)*
Not referred to palliative care (n=3,523)	36% (2.9)	27% (2.6)	16% (1.6)	8% (1.1)
Referred to palliative care prior to final 3 months of life (n=138)	43% (2.7)	36% (2.4)	13% (1.8)	9% (1.0)

Proportions of patients imaged and meaning imaging intensity in the final three months of life, both total and by imaging modality, based on palliative care referral. Percentages denote the proportion of patients within a given palliative care classification who received at least one study of a given imaging modality. The values in parentheses denote mean number of imaging studies per patient among those who received at least one study of a given imaging modality.

[a]Chi-squared test of proportions of patients imaged, p=0.0234

Table 3b:

Proportion imaged and mean imaging intensity in the final month of life

	Tomographic Imaging	CT	MR	PET
Palliative Care Referral Status	*% (mean)* [a]	*% (mean)* [b]	*% (mean)*	*% (mean)*
Not referred to palliative care (n=3,523)	17% (2.3)	13% (2.2)	6% (1.3)	2% (1.0)
Referred to palliative care prior to final month of life (n=188)	24% (2.2)	22% (1.8)	6% (1.9)	2% (1.2)

Proportions of patients imaged and meaning imaging intensity in the final month of life, both total and by imaging modality, based on palliative care referral. Percentages denote the proportion of patients within a given palliative care classification who received at least one study of a given imaging modality. The values in parentheses denote mean number of imaging studies per patient among those who received at least one study of a given imaging modality.

[a] Chi-squared test of proportions of patients imaged, p=0.0055

[b] Chi-squared test of proportions of patients imaged, p=0.0004

Table 4a:

Matched-pairs analysis of imaging utilization during from palliative care referral to death

	Tomographic Imaging	CT	MR	PET
Palliative Care Referral	*% (mean)* [c]	*% (mean)* [b]	*% (mean)*	*% (mean)* [a]
Not referred to palliative care (n=197)	22% (6.2)	3% (1.6)	17% (4.1)	10% (2.5)
Referred to palliative care (n=197)	56% (6.2)	11% (1.5)	49% (4.0)	15% (2.7)

Among the matched pairs, proportions of patients imaged and mean imaging intensity between palliative care referral and death, or the same relative time period for the non-palliative care patient in each pair. Percentages denote the proportion of patients within a given palliative care classification who received at least one study of a given imaging modality. The values in parentheses denote mean number of imaging studies per patient among those who received at least one study of a given imaging modality.

[a] McNemar's test for paired proportions of patients imaged, p=0.0009

[b] McNemar's test for paired proportions of patients imaged, p=0.0002

[c] McNemar's test for paired proportions of patients imaged, p<0.0001

Table 4b:

Matched-pairs analysis of imaging utilization during the last month of life

	Tomographic Imaging	CT	MR	PET
Palliative Care Referral	*% (mean)* [a]	*% (mean)* [b]	*% (mean)* [c]	*% (mean)*
Not referred to palliative care (n=197)	14% (2.0)	9% (2.2)	6% (1.2)	2% (1.0)
Referred to palliative care (n=197)	28% (2.6)	25% (2.1)	10% (1.7)	2% (1.2)

Among the matched pairs, proportions of patients imaged and mean imaging intensity in the final month of life based on palliative care referral. Percentages denote the proportion of patients within a given palliative care classification who received at least one study of a given imaging modality. The values in parentheses denote mean number of imaging studies per patient among those who received at least one study of a given imaging modality.

[a] McNemar's test for paired proportions of patients imaged, p=0.0071

[b] McNemar's test for paired proportions of patients imaged, p=0.0016

[c] McNemar's test for paired proportions of patients imaged, p<0.0001

Table 5A:

Palliative Care Intensity by Imaging Utilization and Imaging Intensity, Final 3 Months of Life

Imaging Utilization in Final 3 Months	Mean Domains per Visit (SD)	p-value
Not Imaged In Final 3 Months	1.64 (1.51)	0.0002
Imaged in Final 3 Months	2.31 (1.40)	
Imaging Intensity in Final 3 Months	**Mean Domains per Visit (SD)**	**p-value**
Below 75th Percentile (<=3 studies)	1.91 (1.54)	0.0695
Above 75th Percentile (>3 studies)	2.27 (1.27)	

Table 5B:

Palliative Care Utilization and Intensity by Imaging Utilization and Imaging Intensity, Final Month of Life

Imaging Utilization in Final Month	Mean PC Visit intensity (SD)	p-value
Not Imaged In Final Month	1.07 (1.38)	<0.0001
Imaged in Final Month	1.92 (1.28)	
Imaging Intensity in Final Month	**Mean PC Visit Intensity (SD)**	**p-value**
Below 75th Percentile (<=3 images)	1.21 (1.40)	0.0015
Above 75th Percentile (>3 images)	1.89 (1.31)	