Journal of Cancer Policy 12 (2017) 16–20

Contents lists available at ScienceDirect

Journal of Cancer Policy

journal homepage: www.elsevier.com/locate/jcpo

Original Research

High-cost cancer imaging: Opportunities for utilization management

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ARTICLE INFO

Article history:
Received 1 August 2016
Accepted 12 December 2016
Available online 14 December 2016

Keywords:
Diagnostic imaging
Utilization
Radiology
Medical oncology
Evidence-based practice

ABSTRACT

Objectives: To retrospectively evaluate utilization of high-cost cancer imaging to clarify the extent to which variations in provider preferences drive imaging utilization.
Study design: At a United States academic cancer center, 4,605 patients were identified with 29,740 oncologist ordered tomographic imaging studies. Patients' dates of death ranged from January 2000 through December 2014. Imaging was restricted to CT, MR, and PET/PET-CT. Outcome variables were total imaging per patient and total imaging per patient by a single oncologist. The number of ordering oncologists per patient, patients receiving imaging in the final year of life, and patients receiving imaging ordered by a high-ordering oncologist were the predictors of interest.
Methods: Zero-truncated negative binomial regressions were used to model collective and individual oncologist per patient imaging counts, with the exposure period defined as the number of days from diagnosis to death.
Results: Patients with imaging ordered by one of the high-ordering medical oncologists predicted nearly a two-fold increase in total images from diagnosis to death (IRR, 1.93; 95% CI, 1.67–2.23). Increasing numbers of providers (2, 3, 4+ ordering oncologists) were associated with greater collective per patient imaging (IRRs 1.65, 2.19, 2.33). Mean imaging intensity increased in a linear manner as temporal proximity to death decreased, from 12 months pre-mortem to death, and imaging in the final year of life was associated with greater per patient imaging (IRR, 0.25; 95% CI, 0.23–0.27).
Conclusion: These findings suggest heterogeneous provider ordering preferences and lapses in care coordination are drivers of high-cost cancer imaging utilization.

1. Introduction

The costs of cancer care are escalating, both domestically and internationally, calling into question the long-term sustainability of health systems and health care practices in high-income countries [1,2]. The escalating costs of diagnostic technologies have continued to exceed increases in other cancer care expenditures, drawing greater attention to utilization patterns of high-cost tomographic imaging [3–5]. The extent to which benefits are derived from greater rates of imaging utilization has not been studied extensively in oncology, but studies have generally been unable to confirm benefits from increased tomographic imaging and associated treatments during the end of life [6,7]. Given that one-third of end-of-life cancer care expenditures concentrate in the last month due to escalating treatment aggressiveness [8], exploration of imaging intensity within this period may reveal opportunities to improve healthcare value through the elimination of imaging that does not lead to improved outcomes.

2. Patients and methods

We conducted a retrospective analysis of cancer patients' tomographic imaging utilization from diagnosis to death at an academic comprehensive cancer center in California to explore variations in oncologist ordering. Collective and individual oncologist imaging rates per patient were the outcomes of interest. Collection of data for this study was approved by the institutional review board and did not require patient consent.

2.1. Study population and data sources

The radiology information system (RIS) at an academic comprehensive cancer center was queried to identify all computed tomography (CT), magnetic resonance (MR), and positron emission tomography (PET) records containing an ICD-9 code associated with malignant neoplasm. Data retrieved from the RIS records included patient medical record number, social security number,

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http://dx.doi.org/10.1016/j.jcpo.2016.12.004
2213-5383/

gender, race, date of birth, date of imaging study, ordering provider, and exam description, which indicated imaging modality.

Patients with oncologic imaging studies were matched to California Department of Public Health death records, and deceased patients with dates of death from January 2000 to December 2014 were matched to the cancer center's institutional registry to provide clinical and treatment variables. Patients were classified by year of death into one of three 5-year ranges (i.e. 2000–2004, 2005–2009, and 2010–2014) to account for changes in imaging modality availability and utilization trends [9–11].

2.2. Provider identification

To focus our analysis on oncologists with long-term affiliation with the cancer center, we excluded imaging studies if ordered by an oncologist with fewer than 50 patients expiring between January 2000 and December 2014. The resulting oncologists' practice areas were identified as medical oncology, surgical oncology, or radiation oncology. Imaging ordered by non-oncologists was not included in the study sample.

We generated several provider related variables, including: (1) A categorical variable for number of ordering oncologists per patient for which patients were classified as having one, two, three, or four or more ordering oncologists; (2) a dichotomous variable denoting whether patients were imaged in their final year of life; and (3) a dichotomous variable denoting whether patients received imaging ordered by one of the high-ordering oncologists. High-ordering oncologists were defined as oncologists who imaged at least 50 patients and were above the 90th percentile of mean per patient imaging intensity.

2.3. Outcomes

The primary outcomes of our regression models were total imaging per patient, referred to herein as collective ordering; and total imaging ordered per patient by a single oncologist, referred to herein as individual ordering. Collective ordering was defined as the sum of CT, MR, and PET image counts for a given patient from diagnosis to death. Individual ordering was defined as total imaging within unique combinations of patients and ordering providers. To provide further insight into oncologic imaging utilization in the end of life, mean per-patient imaging intensity in 3-month treatment periods from 12 months pre-mortem to death were calculated. Zero values (i.e. no imaging in a 3-month period) were included in the calculation of the means.

2.4. Statistical analysis

Zero-truncated negative binomial regressions were used to model collective and individual oncologist per patient imaging counts, with the exposure period defined as the number of days from diagnosis to death. In addition to provider variables, independent variables for patient characteristics included TNM stage at diagnosis, cancer recurrence, year of death range, and treatment counts (surgery, radiation, and chemotherapy). Both models were adjusted for sex, age at death, race, and cancer type. Regression results were reported as incident rate ratios (IRRs). Kruskal-Wallis tests were used to assess variation between three year-of-death time periods, as well as variation in per patient imaging counts between oncologist practice areas. All statistical analyses were conducted using Stata SE version 13.1 (StataCorp LP, College Station, Texas).

Table 1
Patient Demographics and Characteristics.

	Total Patients	N *4605*	% *100%*
Age at Death			
	18–39	297	6%
	40–64	2198	48%
	65 +	2110	46%
Sex			
	Male	2378	52%
	Female	2227	48%
Race			
	White	3415	74%
	Black	265	6%
	Asian	664	14%
	Pacific Islander	113	2%
	Other/Unknown	148	3%
Cancer Type			
	Head, Neck, & Throat	303	7%
	Gastrointestinal	1359	30%
	Respiratory	988	21%
	Bone, Skin, & Connective Tissue	501	11%
	Breast	364	8%
	Male Reproductive	171	4%
	Female Reproductive	419	9%
	Kidney & Bladder	184	4%
	Endocrine & Neuroendocrine	52	1%
	Brain & CNS	31	1%
	Blood & Lymphatic	233	5%
Year of Death			
	2000–2004	775	17%
	2005–2009	1431	31%
	2010–2014	2399	52%
TNM Stage at Diagnosis			
	I	602	13%
	II	750	16%
	III	1157	25%
	IV	2096	46%
Cancer Recurrence			
	Cancer recurrence	1266	27%
	Single case without remission	3339	73%
Ordering Oncologists per Patient			
	1 Oncologist	3112	68%
	2 Oncologists	1090	24%
	3 Oncologists	305	7%
	4 or More Oncologists	98	2%
Imaging in the Final Year of Life			
	Imaging Ordered	3457	75%
	No Imaging Ordered	1148	25%

Table 2
Patient Frequency Distribution of Total Treatments by Treatment Type.

	Number of Treatments						
	0	1	2	3	4	5	6
Surgery	2156	2368	60	19	2	0	0
Radiation	2658	1851	76	15	3	2	0
Chemotherapy	1300	3044	177	49	22	8	5

3. Results

3.1. Descriptive statistics

The patient population was comprised of 4,605 patients with 29,740 tomographic imaging studies ordered by oncologists. CT accounted for 67.5% of tomographic imaging (n = 20,083); MR accounted for 19.5% (n = 5,782); and PET accounted for 13% (n = 3,875). Patient demographics and cancer characteristics may be found in Table 1. Table 2 provides frequencies of surgery, radiation, and chemotherapy treatments. All patients had at least one of the three treatment types. Mean tomographic imaging intensity from diagnosis to death was 6.46 imaging studies per patient [standard deviation (SD) = 7.89], and mean imaging in the final year of life