CURRENT ONCOLOGY
A Canadian Cancer Research Journal

ORIGINAL ARTICLE

Contextualizing the use of oncologic imaging within treatment phases: imaging trends and modality preferences, 2000–2014

T.P. Copeland MPP,* J.M. Creasman MSPH,† D.J. Seidenwurm MD,‡ and B.L. Franc MD*

ABSTRACT

Background In the present study, we retrospectively evaluated the use of tomographic imaging in adult cancer patients to clarify how recent growth plateaus in the use of tomographic imaging in the United States might have affected oncologic imaging during the same period.

Methods At a U.S. academic cancer centre, 12,059 patients with dates of death from January 2000 through December 2014 were identified. Imaging was restricted to brain and body computed tomography (CT), brain and body magnetic resonance (MR), and body positron-emission tomography (PET) with and without superimposed CT. Trends during the staging (1 year after diagnosis), monitoring (18–6 months before death), and end-of-life (final 6 months before death) phases were analyzed.

Results Comparing the 2005–2009 with the 2010–2014 period, mean intensity of PET imaging increased 21% during staging ($p = 0.0000$) and 27% during end of life ($p = 0.0019$). In the monitoring phase, mean intensity for CT brain, CT body, and MR body imaging decreased by 26% ($p = 0.0133$), 11% ($p = 0.0118$), and 26% ($p = 0.0008$), respectively. Aggregate mean intensity of imaging increased in the 13%–27% range every 3 months from 18 months before death to death, reaching 1.43 images in the final 3 months of life. Patients diagnosed in the final 18 months of life had an average of 1 additional image during both the 3 months after diagnosis ($p = 0.0000$) and the final 3 months before death ($p = 0.0000$).

Conclusions Imaging increased as temporal proximity to death decreased, and patients diagnosed near death received more staging imaging, suggesting that imaging guidelines should consider imaging intensity within the context of treatment phase. Despite the development, by multiple organizations, of appropriateness criteria to reduce imaging utilization, aggregate per-patient imaging showed insignificant changes. Simultaneous fluctuations in the intensity of imaging by modality suggest recent changes in the modalities preferred by providers.

Key Words Radiology, tomographic imaging, oncologic imaging, imaging trends, staging, end of life, evidence-based practice, imaging guidelines

Curr Oncol. 2017 Apr;24(2):e99-e105 www.current-oncology.com

INTRODUCTION

Cancer care expenditures in the United States have risen steadily since the early 2000s, driven by increases in both cancer treatment intensity and cost of care[1,2]. Although oncologic imaging has been estimated to account for only 6% of total cancer-related expenditures, the absolute cost of imaging is rising[2], with total expenditures for computed tomography (CT), positron-emission tomography (PET), and magnetic resonance (MR) imaging increasing at twice the rate of total cancer expenditures from 1999 to 2006[3].

Despite increases in the use of high-cost oncologic imaging from the 1990s to the early 2000s[3,4], growth in imaging volume and expenditures both flattened between 2005 and 2008, particularly for MR imaging and nuclear medicine[5]. Regulations targeting the use of imaging in Medicare patients and industry management initiatives with respect to imaging use have both been credited as significant contributors to the reduction in utilization growth[6]. Other factors cited as facilitating the slowdown in imaging include technological saturation of imaging technology, increased promotion of clinical practice

Correspondence to: Timothy Copeland, Radiology and Biomedical Imaging, Box 0946, 185 Berry Street B North, Room 350, San Francisco, California 94143 U.S.A. E-mail: Timothy.Copeland@ucsf.edu ■ **DOI:** https://doi.org/10.3747/co.24.3216

guidelines, and implementation of utilization management tools[7].

Although the overall growth of high-cost imaging has diminished substantially, specific changes in oncologic imaging practices have remained unexplored. Understanding imaging trends within the staging, monitoring, and end-of-life treatment phases could provide valuable clinical context for the formulation of imaging guidelines. Recent findings indicate that a relatively modest 2% annual growth in U.S. cancer care costs during the staging and end-of-life treatment phases would lead to a 39% increase from 2010 to 2020, totaling approximately US$173 billion[8]. End-of-life cancer care in particular has proved to be an area of interest in the ongoing discussion of associations between cancer treatment intensity and quality-of-care outcomes[9–11].

The purpose of the present study was to retrospectively evaluate the use of high-cost tomographic imaging by the treatment phases of cancer care, with a focus on trends by imaging modality during 2005–2014.

METHODS

This retrospective study was compliant with the U.S. Health Insurance Portability and Accountability Act and was approved by our institutional review board.

A database of all imaging studies from the radiology department's information systems was queried for brain and body CT, brain and body MR imaging, and body PET, with each record's inclusion based on an indication of malignant neoplasm. For the purposes of the present study, "PET" refers to either PET or PET-CT. "Body imaging" was defined as any tomographic imaging of chest, abdomen, or pelvis.

The resulting records were matched with the institution's cancer registry to establish each patient's date of death and primary tumour site. Patients with a date of death between 1 January 2000 and 31 December 2014 were selected for inclusion, resulting in 12,059 patients with a total of 77,729 imaging studies. The radiology information system records provided date of birth, sex, race, date of imaging study, and ICD-9 (*International Classification of Diseases,* 9th revision) code, but did not discern between inpatient and outpatient imaging. The cancer registry provided date of diagnosis, date of death, primary tumour site, and information about cancer recurrence. To focus our study's analysis on the timing of imaging, the cancer registry's active therapy and staging information were not included. Death records from the State of California were matched with radiology data to provide a date of death for cancer patients not included in the cancer registry. Adult patients were classified into three age ranges: 18–39 years, 40–64 years, and 65 years and older.

Cancer type groups were organized based on the primary site given in the cancer registry using the ranges of the *International Classification of Diseases for Oncology,* revision 3. When that classification was missing or ambiguous, the ICD-9 codes in the radiology information system records were used if the code corresponded with a diagnosis of malignant neoplasm.

Diagnostic Phases and Year of Death Range

Trends in mean imaging intensity by imaging modality and physical region were assessed by using date of death to group patients into three 5-year time periods: 2000–2004, 2005–2009, and 2010–2014. Because the data were drawn from an academic cancer centre, there was heterogeneity in patient care; patients were treated either in part at the cancer centre from the date of initial diagnosis, fully at the cancer centre from the date of initial diagnosis, or for a recurrence of cancer, as specified in the cancer registry. The 5-year grouping method was selected to provide clarity in utilization assessment and comparison, reducing the stochastic variation more likely to arise within smaller time periods. The choice to break the two later time periods between 2009 and 2010 was intended to reflect the shift in attitudes and policies that had happened in the period leading up to the breakpoint.

Imaging studies were defined as belonging to one of three diagnostic phases: staging, including all images within 1 year after diagnosis; monitoring, including all images from 18 months to 6 months before death; and end of life, including all images from 6 months before death to death. Thus, the end-of-life phase was defined based relative proximity to death, rather than in a clinical sense, in which "end of life" references an advanced, progressive, and incurable disease state.

All patients were imaged at least once in the staging phase or at least once between the monitoring and the end-of-life phases. Imaging studies from the staging phase were not permitted to overlap into the monitoring or end-of-life phases; imaging that fell into both the staging and the end-of-life phases was included in the imaging count only for staging phase. Patients who entered treatment at the cancer centre for recurrence of cancer after completion of initial therapy were omitted from the staging phase, because they were staged elsewhere.

For our analysis, the imaging intensity unit of measure was exams per patient–phase, referring to the mean number of imaging studies per patient within a given oncologic phase. Our study excluded patients who survived cancer; accordingly, imaging intensity as reported in this study is not generalizable to patients who survive their cancer.

Aggregate tomographic imaging intensity during the staging, monitoring, and end-of-life phases was analyzed separately using 3-month periods within each treatment phase. Those shorter time scales were intended to provide additional clarity with respect to the timing of imaging during staging and the relationship between imaging intensity and temporal proximity to death during the monitoring and end-of-life phases. Mean imaging intensities for the 6-month end-of-life and 3-month end-of-life phases were both calculated as the mean imaging intensity for the 5625 patients (46.6% of the study sample) who underwent at least 1 imaging study in their final 18 months of life.

Analyses of imaging intensity by modality and region (Table I, Figure 1) were limited to patients who were diagnosed more than 18 months before death. Patients staged near the end of life, defined as a diagnosis within 18 months of death, were included only in analyses of aggregate imaging during staging (Figure 2) and of aggregate imaging during the final 18 months of life (Figure 3). Aggregate

TABLE I Imaging intensity statistics by modality, phase of cancer treatment, and year-of-death period

Region and modality	Treatment phase	2000–2004				2005–2009				2010–2014			
		(*n*)	Mean	Percentile		(*n*)	Mean	Percentile		(*n*)	Mean	Percentile	
				75th	90th			75th	90th			75th	90th
Brain													
	Computed tomography												
	Staging	188	0.80±1.28	1	2	339	0.79±1.49	1	2	454	0.85±1.20	1	2
	Monitoring[a]	147	0.44±0.67	1	1	288	0.51±1.04	1	1	259	0.38±0.81	1	1
	End-of-life	302	0.89±1.11	1	2	567	1.05±1.26	1	3	670	1.05±1.22	1	2
	Magnetic resonance imaging												
	Staging	658	1.91±2.15	3	5	1,090	1.96±2.33	2	6	1,767	2.18±2.47	3	6
	Monitoring	662	1.21±1.58	2	3	1,228	1.49±2.03	2	5	1,691	1.51±2.15	2	5
	End-of-life	530	1.00±1.07	2	3	942	1.20±1.30	2	3	1,251	1.28±1.29	2	3
Body													
	Computed tomography												
	Staging	1,507	2.44±2.12	3	5	3,655	3.08±2.99	4	7	5,436	3.22±3.03	5	7
	Monitoring[a]	1,423	1.60±1.89	2	4	3,384	2.19±3.15	3	7	4,283	1.95±2.94	3	6
	End-of-life	1,177	1.45±1.54	2	3	2,592	2.13±2.32	3	5	3,446	2.03±2.24	3	5
	Magnetic resonance imaging												
	Staging	499	1.25±1.26	2	3	1,061	1.41±1.30	2	3	1,378	1.35±1.29	2	3
	Monitoring[b]	490	0.92±1.41	1	2	798	0.82±1.44	1	3	767	0.61±1.13	1	2
	End-of-life	373	0.78±1.22	1	2	579	0.75±1.11	1	2	617	0.66±1.02	1	2
	Positron-emission tomography												
	Staging[b]	160	0.95±0.83	1	2	475	1.08±1.06	1	2	1,056	1.31±1.09	2	3
	Monitoring	115	0.52±0.64	1	1	523	0.92±1.26	1	3	1,126	1.04±1.45	1	3
	End-of-life[c]	59	0.33±0.61	1	1	268	0.56±0.77	1	2	654	0.71±0.87	1	2
Aggregate imaging intensity													
	Staging	3,012	3.72±2.92	5	8	6,620	4.36±3.92	6	9	10,091	4.43±3.78	6	9
	Monitoring	2,837	2.81±2.76	4	6	6,221	4.16±4.45	6	10	8,126	4.09±3.85	6	10
	End-of-life	2,441	2.1±2.39	3	5	4,948	2.96±3.27	4	7	6,638	2.93±3.08	4	7

[a] $p < 0.05$.
[b] $p < 0.001$.
[c] $p < 0.01$.

per-patient imaging was calculated in 3-month periods for both the staging phase (Figure 2) and the final 18 months before death (Figure 3).

Statistical Analysis

The data were analyzed in the Stata software application (StataSE 13.1: StataCorp, College Station, TX, U.S.A.) using Wilcoxon rank-sum tests. The changes in mean imaging intensity from the 2005–2009 to the 2010–2014 year-of-death ranges were tested for the various imaging modalities. To focus the analysis on trends in the most recent periods, the 2000–2004 period was not included in tests of variation.

RESULTS

Sample Characteristics

Of the 12,059 identified patients, 890 (7%) were 18–39 years of age; 5593 (46%) were 40–64 years of age; and 5576 (46%) were 65 years of age or older. Gastrointestinal cancers—a classification that included all digestive, liver, and pancreatic cancers—were the most common in the sample (26%). The distribution of cancer types and case complexities at our academic cancer centre was not expected to be representative of either regional or national cancer incidence rates. Table II summarizes the distributions of age, sex, race, cancer recurrence, and cancer type by year-of-death period.

Body CT accounted for more than half of the 77,729 imaging studies in the cohort (53%), followed by brain MR imaging (18%), body MR imaging (13%), body PET (8%), and brain CT (8%). Table III summarizes the distribution of imaging studies by modality and year-of-death period.

Most patients who were diagnosed near the end of life were diagnosed with a gastrointestinal cancer (32%), a respiratory cancer (18%), or an endocrine or neuroendocrine cancer (18%); very few breast cancers (2%), male reproductive cancers (1%), or brain cancers (1%) were diagnosed near the end of life.

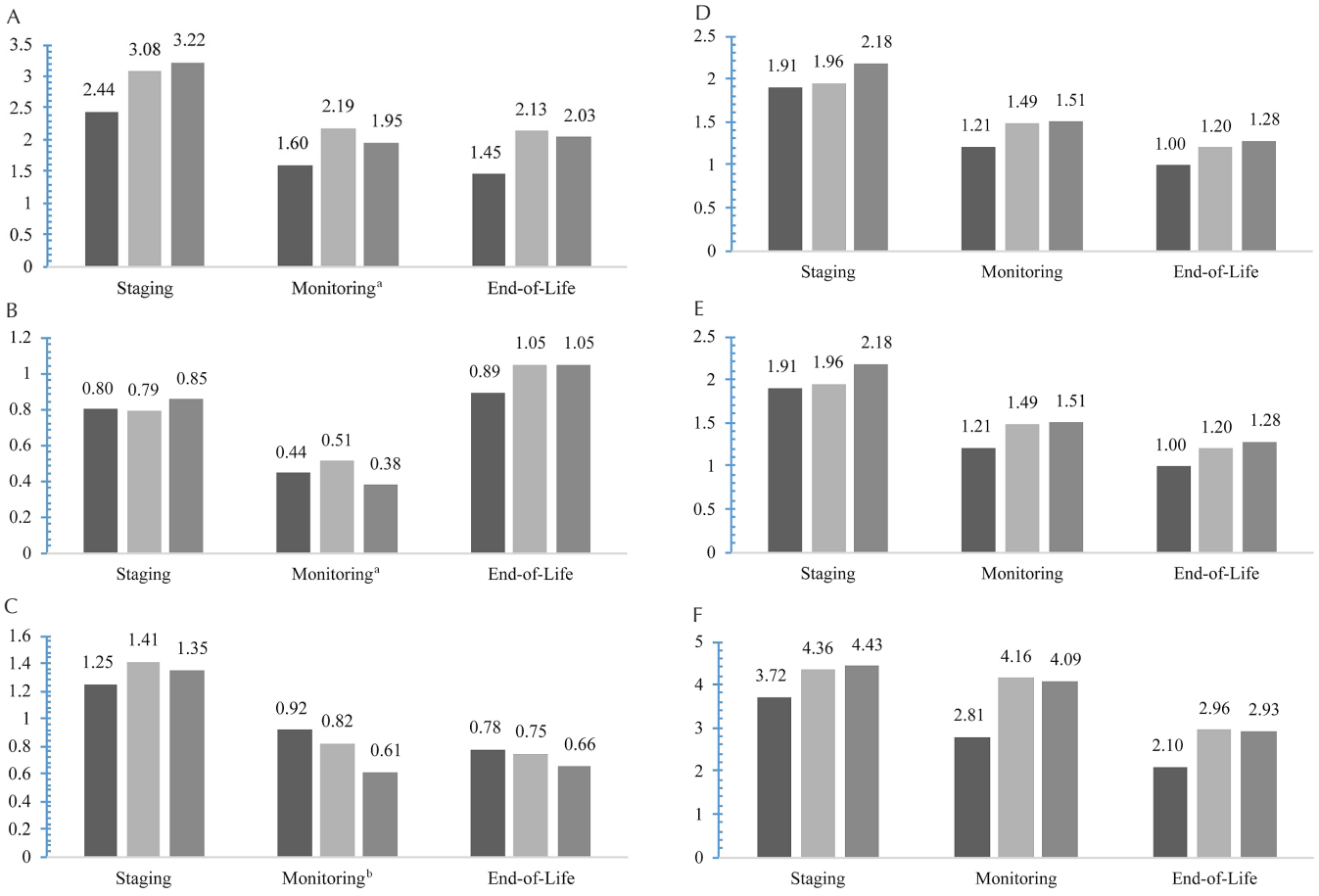

FIGURE 1 Mean imaging intensity by treatment phase and year-of-death period (left to right: 2000–2004, 2005–2009, 2010–2014). (A) Body computed tomography. (B) Brain computed tomography. (C) Body magnetic resonance imaging. (D) Brain magnetic resonance imaging. (E) Body positron-emission tomography. (F) Mean tomographic imaging intensity. [a]$p < 0.05$; [b]$p < 0.001$.

Imaging Intensity Across All Modalities and Phases

Comparing the 2005–2009 and 2010–2014 periods, we observed no statistically significant changes in aggregate patient tomographic imaging intensity at any imaging phase for patients diagnosed at least 18 months before death. Variations ranged from –2% to 2%.

Imaging Utilization Trends by Modality and Region

Comparing the 2005–2009 and 2010–2014 periods, mean imaging intensity for body PET during staging increased significantly [Figure 1(E)]. Mean PET imaging intensity increased by 21% (to 1.31 from 1.08 exams per patient–phase, $p = 0.0000$); CT and MR imaging intensity during staging did not vary significantly.

For patients undergoing body CT studies, mean imaging intensity decreased by 11% during the monitoring phase between 18 and 6 months before death [to 1.95 from 2.19 exams per patient–phase, $p = 0.0118$; Figure 1(A)]. Mean imaging intensity decreased by 26% among patients undergoing body MR imaging during the monitoring phase between 18 and 6 months before death [to 0.61 from 0.82 exams per patient–phase, $p = 0.0008$; Figure 1(C)]. For patients undergoing brain CT, mean imaging intensity decreased by 26% during monitoring from 18 to 6 months before death [to 0.38 from 0.51 exams per patient–phase, $p = 0.002$; Figure 1(B)].

Comparing the 2005–2009 and 2010–2014 end-of-life phases, mean body PET imaging intensity increased by 27% (to 0.71 from 0.56 exams per patient–phase, $p = 0.0019$). For CT and MR imaging, changes in mean end-of-life imaging intensity during the 5-year periods were not statistically significant.

Table I presents descriptive statistics with Wilcoxon rank-sum significance levels by imaging modality and year-of-death period.

Staging, Monitoring, and End-of-Life Aggregate Imaging Intensities

Aggregate per-patient imaging intensity during staging was assessed in 3-month treatment periods (Figure 2). In that analysis, imaging was observed to be concentrated during the first 3 months after diagnosis not only for patients diagnosed more than 18 months before death, but also for patients diagnosed near the end of life, although patients diagnosed near death received more imaging (2.87 vs. 1.87 exams, $p = 0.0000$). However, the mean imaging intensity during staging was lower for patients diagnosed near the end of life both at 6–9 months after diagnosis (0.71 vs. 0.75

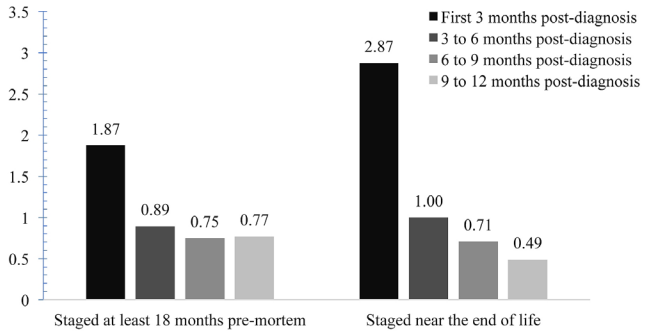

FIGURE 2 Mean tomographic imaging intensity during staging by duration of patient survival.

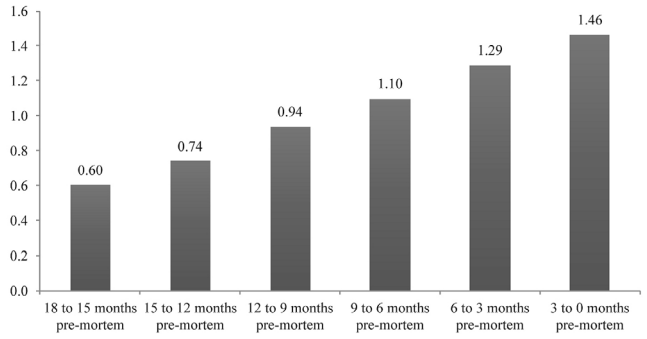

FIGURE 3 Mean tomographic imaging intensity in the final 18 months of life.

exams, $p = 0.0000$) and at 9–12 months after diagnosis (0.49 vs. 0.77 exams, $p = 0.0000$).

In patients diagnosed at least 18 months before death, aggregate imaging intensity consistently increased as temporal proximity to death decreased, from a mean of 0.60 exams per patient at 18 months before death to a mean of 1.46 exams per patient in the final 3 months of life (Figure 3). As with aggregate imaging for the 1-year staging, 1-year monitoring, and 6-month end-of-life phases, the mean imaging intensity in each 3-month phase from 18 months before death to death did not change significantly from the 2005–2009 period to the 2010–2014 period.

DISCUSSION

The per-patient tomographic imaging intensity trends from this single-institution study at an academic cancer centre parallel the recent growth plateau in high-cost tomographic imaging within the United States. However, modality-specific results reveal greater complexity in the directionality of oncologic imaging trends. Analysis of modality-specific trends in the 2005–2009 and 2010–2014 periods revealed a strong positive trend in mean body PET imaging intensity during the staging phase (to 1.31 from 1.08 exams, $p = 0.0000$) and the end-of-life phase (to 0.71 from 0.56 exams, $p = 0.0019$)—increases of 21% and 27% respectively. However, the mean imaging intensity for other modalities varied significantly only during the monitoring phase of treatment, showing a 26% decrease in brain CT imaging intensity (to 0.38 from 0.51 exams, $p = 0.0133$), an 11% decrease in body CT imaging intensity (to 1.95 from 2.19 exams, $p = 0.0118$), and a 26% decrease in body MR imaging intensity (to 0.61 from 0.82 exams, $p = 0.0008$).

In the face of significant increases in PET studies and no change in aggregate per-patient imaging intensity, the statistically insignificant changes in CT and MR imaging during the staging and end-of-life phases might be indicative of modality preference shifts as knowledge about technology and practices spread, with brain MR imaging providing the greatest clinical utility in metastatic disease detection in the brain, and CT and PET providing the greatest clinical utility in disease detection in the body.

The findings with respect to aggregate imaging by stage show that, compared with patients staged outside their end-of-life phase, those staged near the end of life undergo an average of 1 additional imaging study in the 3 months after diagnosis (2.87 vs. 1.87 exams, $p = 0.0000$). In parallel, compared with patients diagnosed at least 18 months before death, those diagnosed near the end of life undergo 1 additional imaging study in their final 3 months of life (2.47 vs. 1.46 exams, $p = 0.0000$). The disparity in aggregate imaging intensity associated with staging near the end of life necessitates further study of high-cost imaging intensity, with a focus on cancer type and TNM classification at diagnosis. An extension of the present analysis using insurance provider data from a community setting is planned, with the intent of facilitating an evaluation of outcomes related to imaging intensity throughout the phases of cancer treatment.

The clarification of imaging intensity trends during the monitoring and end-of-life phases, in 3-month periods beginning 18 months before death, demonstrated an inverse relationship of decreasing temporal proximity to death with increasing aggregate imaging intensity (Figure 3). When annualized, the 6-month end-of-life imaging intensities were comparable to staging imaging intensities for all modalities (Table I). Both findings about end-of-life imaging are counterintuitive, given an apparent lack of clinical utility in tomographic imaging for low-prognosis patients. We do not expect oncologists to have accurately predicted survival duration for their patients, but we assume that education and clinical experience would give the oncologists some ability to estimate long-term survival likelihood and duration. Despite the conflict between provider knowledge and ordering behaviours, our findings about imaging intensity in the final months of life are congruent with research indicating a tendency toward patients receiving "all care possible" at end of life[12].

The 21% increase in PET use in the end-of-life phase ($p = 0.0019$) parallels the 27% increase in PET use during staging ($p = 0.0000$), probably reflecting the continuing incorporation of PET into diagnostic practice. The increase also underscores the importance of understanding the role of PET during the formulation of practice guidelines as growth in PET utilization continues. Further study to explore provider level variations in PET utilization is planned. The 11% decrease in the mean imaging intensity for body CT during the monitoring phase is notable because body CT imaging accounted for 54.4% of the imaging for patients with a date of death during the 2005–2014 period.

Our estimates of imaging utilization could be conservative given the strong likelihood that many patients in our study population are missing imaging records from other imaging facilities. The study focused on a single major academic cancer centre and did not include all imaging or treatment records for most patients in the 15-year sample. Given that the study population was drawn from a major academic cancer centre, our approach could have led to the inclusion of a greater number of complex cases than might be expected in most hospital oncology departments, potentially acting in counterpoint to the effects of partial patient imaging records—a situation that was especially

TABLE II Distribution of the study population by year-of-death period

Variable	Year-of-death period							
	2000–2004		2005–2009		2010–2014		TOTAL	
	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)
Patients	2,809	23	4,024	33	5,226	43	12,059	100
Age at death								
18–39 Years	236	8	303	8	351	7	890	7
40–64 Years	1,326	47	1,895	47	2,372	45	5,593	46
≥65 Years	1,247	44	1,826	45	2,503	48	5,576	46
Sex								
Men	1,495	53	2,108	52	2,783	53	6,386	53
Women	1,314	47	1,916	48	2,443	47	5,673	47
Race								
White	2,133	76	3,000	75	3,910	75	9,043	75
Black	185	7	268	7	352	7	805	7
Asian	336	12	496	12	659	13	1,491	12
Pacific Islander	70	2	101	3	147	3	318	3
Other/unknown	85	3	159	4	158	3	402	3
Cancer type								
Head, neck, throat	142	5	205	5	241	5	588	5
Gastrointestinal	656	23	996	25	1,425	27	3,077	26
Respiratory	452	16	597	15	642	12	1,691	14
Bone, skin, connective tissue	343	12	510	13	673	13	1,526	13
Breast	214	8	262	7	335	6	811	7
Male reproductive	103	4	139	3	240	5	482	4
Female reproductive	135	5	315	8	376	7	826	7
Kidney, bladder	152	5	231	6	315	6	698	6
Endocrine, neuroendocrine	497	18	626	16	775	15	1,898	16
Brain, central nervous system	32	1	50	1	76	1	158	1
Blood, lymphatic	83	3	93	2	128	2	304	3

TABLE III Distribution of imaging by modality and year-of-death period

Imaging modality	Year-of-death period							
	2000–2004		2005–2009		2010–2014		TOTAL	
	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)
Computed tomography, body	6,947	49	15,243	56	19,278	54	41,468	53
Computed tomography, brain	1,336	9	2,237	8	2,369	7	5,942	8
Magnetic resonance imaging, body	2,510	18	3,537	13	3,777	11	9,824	13
Magnetic resonance imaging, brain	2,961	21	4,617	17	6,542	18	14,120	18
Positron-emission tomography, body	560	4	1,810	7	4,005	11	6,375	8
TOTAL	14,314	100	27,444	100	35,971	100	77,729	100

true of the 75th and 90th percentiles for imaging intensity (Table I). However, the diverse oncologic cases, the data sources, and the sample size support the robustness of the findings.

Variation in the ordering of high-cost imaging studies could be attributable to a complex dynamic involving the oncologic specialties and institutional affiliations of the ordering physicians, as well as heterogeneity and uncertainty with respect to the insurance provider. The imaging intensity trends in the present study might be typical of a major academic cancer centre during the periods studied; non-academic cancer hospitals might experience different rates of imaging intensity because of differences in median case complexity.

CONCLUSIONS

Static aggregate per-patient imaging intensity for a decade and an escalation in utilization of high-cost imaging during the final 18 months of a patient's life demonstrate the need for evidence-based oncologic imaging practices, particularly during end-of-life treatment. Efforts toward that end have been made in recent years. Treatment of low-prognosis patients with "no strong evidence supporting the clinical value of further anticancer treatment" was identified in 2012 by the American Society of Clinical Oncology as one of the primary targets for reduction of practices unsupported by clinical research[13]. Findings in the present study suggest persistence of a bias against promoting alternatives to aggressive treatment and surveillance on the part of providers despite efforts to the contrary. Oncologic imaging guidelines have focused largely on preventing a first unnecessary image, or on limiting imaging to a single imaging study, but imaging intensity according to cancer treatment phase or cancer stage has not been addressed directly[1,14,15]. The lack of such direct studies might be a reflection of a reluctance to identify limits for treatment intensity in cancer care and alternatives to aggressive cancer treatment. The linear increase in imaging over the final 18 months of life, as seen in Figure 3, is another potential consequence of avoiding a larger conversation of about end-of-life cancer care.

The findings related to the differences in aggregate imaging intensity during staging and the final 18 months of life suggest that imaging guidelines should consider imaging intensity within phases of treatment, with a focus on the timing of follow-up imaging for patients diagnosed with advanced cancers. The consistency of aggregate tomographic imaging intensity across treatment phases during 2005–2014 (Table I) also suggests that fluctuations in the preferred modality for oncologic imaging occur based on knowledge about the suitability of the modality rather than on the appropriateness of tomographic imaging utilization in general. The consistent similarities between imaging intensity during staging and during end of life and the consistent increases in imaging intensity during the final 18 months of life both reinforce the notion that provider perspectives about the suitability of imaging modalities within cancer care have changed at the same time that their perspectives on imaging utilization as a whole have not changed.

ACKNOWLEDGMENTS

We thank Ann Griffin and Joseph McGuire of the UCSF Helen Diller Family Comprehensive Cancer Center Cancer Registry, Christopher Jovais of the UCSF Radiology Information Systems, and Dana Ludwig of the UCSF Academic Research Systems.

CONFLICT OF INTEREST DISCLOSURES

We have read and understood *Current Oncology*'s policy on disclosing conflicts of interest, and we declare that we have none.

AUTHOR AFFILIATIONS

*Radiology and Biomedical Imaging and †Clinical and Translational Science Institute, University of California–San Francisco, San Francisco, CA, U.S.A.; ‡Sutter Medical Group, Sacramento, CA, U.S.A.

REFERENCES

1. Smith TJ, Hillner BE. Bending the cost curve in cancer care. *N Engl J Med* 2011;364:2060–5.
2. Sullivan R, Peppercorn J, Sikora K, *et al.* Delivering affordable cancer care in high-income countries. *Lancet Oncol* 2011;12:933–80.
3. Dinan MA, Curtis LH, Hammill BG, *et al.* Changes in the use and costs of diagnostic imaging among Medicare beneficiaries with cancer, 1999–2006. *JAMA* 2010;303:1625–31.
4. Maitino AJ, Levin DC, Parker L, Rao VM, Sunshine JH. Nationwide trends in rates of utilization of noninvasive diagnostic imaging among the Medicare population between 1993 and 1999. *Radiology* 2003;227:113–17.
5. Levin DC, Rao VM, Parker L, Frangos AJ, Sunshine JH. Bending the curve: the recent marked slowdown in growth of noninvasive diagnostic imaging. *AJR Am J Roentgenol* 2011;196:W25–9.
6. Lee DW, Levy F. The sharp slowdown in growth of medical imaging: an early analysis suggests combination of policies was the cause. *Health Aff (Millwood)* 2012;31:1876–84.
7. Harvey L. Neiman Health Policy Institute. *Medical Imaging: Is the Growth Boom Over?* Series: The Neiman Report. Reston, VA: Harvey L. Neiman Health Policy Institute; 2012.
8. Mariotto AB, Yabroff KR, Shao Y, Feuer EJ, Brown ML. Projections of the cost of cancer care in the United States: 2010–2020. *J Natl Cancer Inst* 2011;103:117–28.
9. Mack JW, Cronin A, Keating NL, *et al.* Associations between end-of-life discussion characteristics and care received near death: a prospective cohort study *J Clin Oncol* 2012;30:4387–95.
10. Teno JM, Gozalo PL. Quality and costs of end-of-life care: the need for transparency and accountability. *JAMA* 2014;312:1868–9.
11. Hui D, Kim SH, Roquemore J, Dev R, Chisholm G, Bruera E. Impact of timing and setting of palliative care referral on quality of end-of-life care in cancer patients. *Cancer* 2014;120:1743–9.
12. Narang AK, Wright AA, Nicholas LH. Trends in advance care planning in patients with cancer: results from a National Longitudinal Survey. *JAMA Oncol* 2015;1:601–8.
13. Schnipper LE, Smith TJ, Raghavan D, *et al.* American Society of Clinical Oncology identifies five key opportunities to improve care and reduce costs: the top five list for oncology. *J Clin Oncol* 2012;30:1715–24.
14. Qaseem A, Alguire P, Dallas P, *et al.* Appropriate use of screening and diagnostic tests to foster high-value, cost-conscious care. *Ann Intern Med* 2012;156:147–9.
15. Levin DC, Rao VM. Turf wars in radiology: other causes of overutilization and what can be done about it. *J Am Coll Radiol* 2004;1:317–21.