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Authors
Baxi, Shrujal S
Kale, Minal
Keyhani, Salomeh
et al.

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Overuse of Health Care Services in the Management of Cancer: A Systematic Review

Shrujal S. Baxi, MD, MPH,
Head and Neck Oncology Service, Department of Medicine, Memorial Sloan Kettering Cancer Center, 300 East 66th Street, Rm 1459, New York, NY 10065, (646) 888-8236 (phone), (646) 888-8269 (fax)

Minal Kale, MD,
Department of Medicine, Mount Sinai Hospital, One Gustave Levy Place Box 1087, New York, NY 10029, USA, 212-824-7492 (phone), 212-824-2317 (fax)

Salomeh Keyhani, MD, MPH,
Department of Medicine, University of California San Francisco, 4150 Clement Street, San Francisco, CA 94121, USA, Phone: (415) 221-4810 ext. 25819

Benjamin R Roman, MD,
Department of Surgery, Memorial Sloan Kettering Cancer Center, 1275 York Ave, Rm C-1075, New York, NY 10065, 646-888-7508 (phone), 917-432-2311 (fax)

Annie Yang, BA,
Center for Health Policy and Outcomes, Memorial Sloan Kettering Cancer Center, 485 Lexington Avenue, New York, NY 10017, USA, 646-888-8202 (phone), 646-227-7102 (fax)

Antonio Derosa, MLIS, AHIP, and
Medical Library, Memorial Sloan Kettering Cancer Center, 1275 York Avenue, New York, NY 10065, USA, 646-287-5845 (phone), 646-422-2316 (fax)

Deborah Korenstein, MD
Center for Health Policy and Outcomes, Memorial Sloan Kettering Cancer Center, 485 Lexington Avenue, New York, NY 10017, USA, 646-888-8139 (phone), 929-321-1518 (fax)

Abstract

Background—Overuse, the provision of health services for which harms outweigh the benefits, results in suboptimal patient care and may contribute to the rising costs of cancer care. We performed a systematic review of the evidence on overuse in oncology.

Methods—We searched Medline, EMBASE, the Cochrane Library, Web of Science, SCOPUS databases, and two grey literature sources, for articles published between December 1, 2011 and

Corresponding Author: Shrujal S. Baxi, MD MPH, baxis@mskcc.org, Head and Neck Oncology Service, Department of Medicine, Memorial Sloan Kettering Cancer Center, 300 East 66th Street, Rm 1459, New York, NY 10065, (646) 888-8236 (phone), (646) 888-8269 (fax).

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March 10, 2017. We included publications from December 2011 to evaluate the literature since the inception of the ABIM Foundation's Choosing Wisely initiative in 2012. We included original research articles quantifying overuse of any medical service in patients with a cancer diagnosis when utilizing an acceptable standard to define care appropriateness, **excluding studies of cancer screening**. One of 4 investigator reviewed titles and abstracts and 2 of 4 reviewed each full-text article and extracted data. Methodology used PRISMA Guidelines.

Results—We identified 59 articles measuring overuse of 154 services related to imaging, procedures, and therapeutics in cancer management. The majority of studies addressed adult or geriatric patients (98%) and focused on US populations (76%); the most studied services were diagnostic imaging in low-risk prostate and breast cancer. Few studies evaluated active cancer therapeutics or interventions aimed at reducing overuse. Rates of overuse varied widely among services and among studies of the same service.

Conclusion—Despite recent attention to overuse in cancer, evidence identifying areas of overuse remains limited. Broader investigation, including assessment of active cancer treatment, is critical for identifying improvement targets to optimize value in cancer care.

Keywords

cancer care; health services research; health services; quality of care; utilization

Introduction

Despite a stable cancer incidence, the cost of cancer care is high and is rising more rapidly than costs in other medical sectors; in the US, the estimated total cost of cancer care was $125 billion in 2010 and is projected to increase to $173 billion US by 2020.(1) These escalating costs have led to concerns about the ability of the healthcare system to pay(2) and have led to removal of some drugs from coverage in the UK.(3) In the US, rising costs are also relevant to individual patients who are experiencing rising deductibles, increased cost shifting, and growing premiums.(1, 4) As a result, there is a growing emphasis on improving value in cancer management.(5, 6) One approach to improving value in cancer care is the identification and elimination of overuse.

In health care, overuse can be defined as the provision of medical care that has no benefit or for which harms outweigh potential benefits.(7) In 2012, the Institute of Medicine (IOM) estimated that in the US more than $750 billion a year, or nearly 30% of all medical expenses, resulted from unnecessary or inefficient services, contributing to thousands of unexpected deaths.(8) In response, there has been a call to action by national organizations to identify and eliminate overuse. In 2012, attention to overuse accelerated with the launch of the Choosing Wisely campaign from the ABIM Foundation, in which specialty societies identified services that patients and clinicians should question and reconsider.(9) **The American Society of Clinical Oncology (ASCO) was an early supporter of Choosing Wisely**.(10, 11)

Although there has been increased recognition by ASCO and others of the importance of reducing overuse to improve the value of cancer care, the scope of overuse in oncology has

not been well described. A 2012 systemic review of overuse of all health care services in the United States included papers published from 1978–2011 and found few addressed overuse in cancer.(12) However, it is likely that additional studies have been undertaken in more recent years given the greater attention to overuse and value.(13, 14) To describe the current prevalence of overuse in cancer care and the state of the overuse literature in cancer, we performed a systematic review of published articles reporting rates of overuse of diagnostic tests, therapeutic procedures, and medications in the management of patients diagnosed with cancer. We chose to focus on patients with a cancer diagnosis and not on cancer screening since cancer care itself is particularly costly and since overuse of screening has been well discussed in the literature.(15–19)

Methods

Literature Search

This systematic review was conducted according to PRISMA guidelines.(20) We conducted systematic literature searches in five databases for references **written in all languages** with no specified sex or ages, limited to human-only research, and published from December 1, 2011 to March 10, 2017. We used controlled vocabulary and text words to search (1) MEDLINE (via PubMed), (2) EMBASE, (3) The Cochrane Library, (4) Web of Science, and (5) Scopus. The Web of Science and Scopus databases do not employ controlled vocabularies, so they were searched using only text words. We also conducted comprehensive searches in two grey literature sources: (a) Grey Literature Report provided by the New York Academy of Medicine and (b) Open Grey which is operated by the Institute of Scientific and Technical Information (INIST-CNRS) in Vandoeuvre-les-Nancy, France.

The search strategy included two major components that were linked together with the AND operator: (1) cancer terms including neoplasms, tumors, carcinomas, sarcomas, and malignancies; (2) health services overuse terms including laboratory testing, imaging, secondary screening/testing, overutilization, choosing wisely, overuse, and guideline adherence (see Figure, Supplemental Digital Content, for a complete list of MeSH and keyword terms used). After combining the concepts in all five databases, we added the following publication type filters to the search (where applicable): clinical trial, comparative study, controlled clinical trial, observational study, pragmatic clinical trial, review, systematic review, meta-analysis, technical report, and guidelines. We performed reference tracking by searching the references of all studies included for full-text review.

Study Selection

Each title and abstract was reviewed by one of four investigators (D.K., M.K., S.K., A.Y.) to determine inclusion for full-text review. Each full-text article, including those identified through reference tracking, was reviewed by a pair of investigators (D.K. and B.R., D.K. and M.K., S.B. and D.K., or S.B. and M.K.) to determine inclusion for qualitative synthesis. Disagreements were resolved by group consensus. We determined inter-rater reliability (Cohen κ) for each of the four pairs of full-text reviewers. The flow of article selection is presented in Figure.

Articles were eligible for inclusion if they were original research quantifying overuse of any medical service in patients with a cancer diagnosis and utilizing an acceptable standard that included: 1) a guideline from a governmental organization, 2) a guideline from a professional society, 3) a multidisciplinary panel consensus process (e.g. Rand Appropriateness Method) or 4) a Choosing Wisely recommendation. We excluded studies in patients without cancer including those evaluating cancer screening in the general population, and studies in which overuse rates were not presented or calculable.

Data Extraction

We developed a data extraction tool to collect information from each study in the review. Data extraction was performed by one reviewer (S.B., D.K., M.K., B.R.) and checked by a second reviewer (S.B. or D.K.) for accuracy. The following data were extracted from each study: general information about the publication (first author's name, year of publication), study specifics (e.g. study design, data source, and sample size), cancers addressed, country of study, type of service (e.g. diagnostic vs. therapeutic), and where in the cancer continuum the service was provided. We categorized the cancer care continuum as diagnostic evaluation, active treatment, surveillance after active treatment, or end of life. We recorded specific service(s) evaluated, whether costs were reported with overuse and whether an intervention to reduce overuse was evaluated. We also noted whether overuse was presented as the percent of the population receiving a non-recommended service or as the percent of services provided inappropriately. We documented overuse of each individual service separately. When rates of overuse were not directly presented we calculated rates when possible and contacted study authors for rates of overuse or raw data when we were unable to calculate with information reported.

We assessed the quality of each study by assessing for potential bias in design. In all studies, we evaluated for bias in patient selection (e.g. one physician's panel) and in the determination of the appropriateness of the service (e.g. determinations of appropriateness were subjective and non-reproducible). We categorized studies that used only claims-based data as having potential bias because the lack of detailed clinical information could lead investigators to incorrectly classify the appropriateness of particular services.

Data Analysis

Given the diversity of the literature, we did not believe that quantitative analysis was scientifically justified and conducted only qualitative data analysis. Inter-rater reliability for the decision to include the article in the review (Cohen's kappa, 0.85, 0.66, 0.84, 0.82 for the four investigator pairs) was excellent.

We generated descriptive statistics to analyze studies included in the systematic review. We synthesized information for all services that were evaluated for overuse. We recorded overuse of either an aggregate of multiple services in a specific situation (e.g. any inappropriate surveillance imaging in breast cancer patients) and/or of an individual service (e.g. PET scan for surveillance in breast cancer patients) based on how the data was presented in the original article. We defined an individual service as a distinct test or treatment in a defined population based on the disease, specific test or treatment (e.g. bone

scan versus CT), risk group or cancer stage (e.g. low risk prostate versus intermediate risk prostate), and year (e.g. bone scan in 1998 versus bone scan in 2006). If rates for both individual and aggregate services were available, we recorded both. For interventional studies, we defined overuse as the rate in the pre-intervention phase or control arm. To calculate descriptive statistics of services, we removed duplicates by discounting aggregate services if rates for individual services were also available (e.g. we discounted "any imaging [PET or CT]" if individual rates for PET and CT were available).

Results

Study Characteristics

Our primary search identified 13,064 articles, of which 59 met our inclusion criteria (Figure).(21–79) Characteristics of included studies are summarized in Table 1 and details of all studies are listed in Table 2. **All studies were published in English**, most were retrospective (92%), were completed in the US (76%), and addressed overuse in adult or geriatric cancer patients (98%). The National Cancer Institute's linked Surveillance, Epidemiology, and End Results (SEER)-Medicare was the most commonly analyzed dataset, used in 37% of all studies; 14 studies (24%) were framed around a Choosing Wisely item. In terms of quality, 41 (69%) of studies had some form of bias, mostly due to use of claims-based data. Three studies (5%) evaluated an intervention to address overuse and 9 (15%) addressed financial costs associated with overuse. (Table 2)

Clinical services studied

Because many included studies reported overuse rates for multiple services, the 59 included studies assessed the overuse of 154 distinct services. The most common cancers addressed were breast (49% of services) and prostate (32% of services). (Table 3) In terms of phase of cancer care, studies were predominantly focused on diagnostic evaluation (56%) followed by post-treatment surveillance (23%), active treatment (19%) and end of life (1%). The most commonly evaluated service modality was imaging (71%) with a fair representation of numerous imaging modalities.

Multiple addressed services related to the **overuse** of imaging in early stage breast and prostate cancer. Overuse of imaging in the diagnostic evaluation of early prostate cancer was addressed 43 times with 20 (47%) of these evaluations relying on SEER-Medicare data. Similarly, 34 of the evaluated services related to diagnostic imaging for staging in early stage breast cancer, with 8 (24%) relying on SEER-Medicare data, most commonly assessing overuse of PET (n=7), CT (n=7), bone scan (n=7), or any advanced imaging (n=3). Overuse of radiographic surveillance following treatment for early stage breast cancer was also commonly addressed (n=22 evaluations).

Rates of overuse

The majority of studies (n=53, 90%) reported overuse as a percentage of the population receiving a non-recommended service and many (n=27, 46%) used administrative data to determine the prevalence of overuse. Three studies compared rates of overuse measured from administrative data to measurements for the same service using clinical data.(40, 41,

65) Studies of high-tech imaging at the time of diagnosis in early stage breast cancer found that administrative data over-reported clinically relevant imaging as overuse (prevalence 15% vs. 8% from clinical data).(40) In a second study, rates of overuse of post-treatment imaging for surveillance in early stage breast cancer were higher using administrative data from 8,618 patients compared to chart review from a subset of 110 patients from the larger dataset. The rates differed widely for CT (20% vs. 0.8%) and PET or Bone scan (4.3% vs. 0.8%). Interestingly, rates of overuse of tumor markers were similar from both data sources (28% vs. 28%).(41) The third study reported higher measured rates of overuse of radioactive iodine for low-risk thyroid from administrative (range 47–53%) versus clinical (range 20–32%) data (note that Table 2 reflects rates determined through administrative review).(65)

Rates of overuse varied widely between 0 and 100% across services. (Table 2) The most frequently studied services were bone scan (n=17 evaluations) and CT (n=11 evaluations) for staging of low and/or intermediate risk prostate cancer and tumor markers for surveillance in early stage breast cancer (n=9 evaluations); rates of overuse were 0.09–100%, 5–72%, and 5–77%, respectively across studies. Overuse of cancer-directed pharmacologic agents, including chemotherapy, targeted and hormonal therapies was measured in lung, breast and prostate cancer. Weeks and colleagues found that rates of overuse of chemotherapy were approximately 40% in patients with metastatic lung cancer and a poor performance status, 36% in post-menopausal women with limited metastatic breast cancer, and 55% in pre-menopausal women with limited metastatic breast cancer.(79) In the adjuvant setting, a study in rural Georgia reported 11.5% of women received overtreatment with hormonal therapy.(36) Targeted therapy was addressed in two studies evaluating the appropriate use of trastuzumab, the monoclonal antibody directed at the human epidermal receptor 2 (HER2). Overuse of trastuzumab was reported in 3.9% and 4.7% of patients due to a lack of documentation of HER2 testing.(37, 73) Three studies evaluated the overuse of anti-androgen therapy in low risk prostate cancer where it is not routinely recommended,(67, 72, 77) demonstrating a decline in rates of overuse over time(72) and high levels of geographic variation across the US.(77) Outside the US, a French study reported that approximately 21% of all chemotherapy administered for any cancer at two academic centers was administered against national guideline recommendations.(47)

Interventional studies

We identified three studies evaluating interventions; all aimed to reduce overuse of imaging in patients with newly diagnosed low- and intermediate-risk prostate cancer. In one study, Miller and colleagues evaluated guideline dissemination followed by utilization review and feedback through the Urological Surgery Quality Collaborative. They reported decreased rates of bone scans and CT scans from 31% to 21% and 28% to 13% ($p<.01$), respectively. (54) In a Swedish study, Makarov and colleagues reported decline in inappropriate diagnostic imaging over a 10-year period from 45% to 3% ($p< .001$) in patients with low-risk prostate cancer after national guideline dissemination. This appropriate decline was accompanied by a simultaneous unwanted decline in recommended imaging in high-risk patients from 63% to 47% ($p<.001$).(51) In the more recent MUSIC study, Ross and colleagues reported the results of a state-wide collaboration in Michigan to reduce

diagnostic imaging in patients with low-risk prostate cancer. Rates of overuse of bone scans (3.7%) and CT scans (5.2%) were low at the start of the study and declined to 1.3% (p=.03) and 3.2% (p=.17), respectively.(64)

Discussion

Our review of overuse in cancer care delivery identified 59 articles published over the last 6 years evaluating 154 clinical services. The majority of studies focused on overuse of imaging in early stage breast cancer and low to intermediate risk prostate cancer, and despite concerns about the high cost of active cancer care only 29% of studies addressed services delivered during active treatment.(2) Rates of overuse varied widely among studies and among services addressed. Despite calls to reduce overuse, very few studies evaluated interventions and costs associated with overuse were rarely reported.

Overuse of imaging

There were multiple studies addressing imaging in breast and prostate cancers. However, the prevalence of overuse of these services remains difficult to define with rates of overuse of specific tests varying widely (though overuse of PET was consistently uncommon). Further, even in this well-studied clinical area, estimates of cost associated with overuse were rare. Despite this lack of clarity on the extent of the problem of overuse of diagnostic imaging in early prostate cancer, all three interventional studies in our review addressed methods to reduce it. Those interventions were generally successful, but the clinical and financial implications of that success are not clear and in one study, reductions in overuse were accompanied by unwanted reduction in recommended services.

Overuse of systemic therapy

Data is still lacking on some of the most concerning, and costly, areas of overuse in cancer. While new high-cost, cancer-directed therapies represent a significant driver of rising oncology care costs,(14, 80) **few studies evaluated rates of overuse of cancer treatments, which can lead to financial harm even when used appropriately**. We identified two studies evaluating overuse of newer, high-cost drugs, both of which focused on trastuzumab for patients with HER2-positive breast cancer; both reported relatively low rates of use in the absence of appropriate HER-2 testing.(37, 73) The remaining therapeutic studies evaluated chemotherapies more generically, but did not specifically address high-cost therapeutics.

Methodology of overuse research

Our review highlights important issues related to the research of overuse and informs possible strategies aimed at reducing inappropriate health care utilization in cancer patients. First, overuse can only be measured when a normative practice has been established. By definition, identifying overuse implies that there are established criteria for appropriate use of a service, available as a guideline or other standard. In cancer and many other diseases, there may be lack of consensus on optimal management in many clinical situations, so appropriate use cannot be determined. It may be that we identified numerous studies addressing imaging in early stage prostate and breast cancer because these were the services highlighted by the ASCO Choosing Wisely campaign in 2012. Further, studies of services

for which appropriateness is more nuanced, such as chemotherapy use in patients with metastatic solid tumors and poor performance status, are challenging and therefore less likely to be performed, even if those services may be more important in terms of patient outcomes and cost.

In addition, even when appropriate care can be defined, its measurement can be difficult without detailed clinical information that often requires chart review. So while overuse is measurable in these situations, it is infrequently evaluated because doing so is time consuming and cumbersome. As a result, much of the cancer overuse literature focuses on issues where there are both clear recommendations and the opportunity to measure use through administrative datasets such as SEER-Medicare, mainly evaluating diagnostic imaging in early stage cancers and for post-treatment surveillance. Indeed, many (49%) studies we identified presented data from administrative datasets and over half (64%) of the services studied represented diagnostic and/or surveillance imaging. Over-representation of imaging and over-reliance on claims data for overuse research may bias both the topics of study and estimates of rates of overuse. Despite widespread concern about overuse at the end of life,(81, 82) we found only one study addressing overuse in this setting, likely because of the challenges of assessing appropriateness of this care. In addition, in the three studies we identified that used both clinical and administrative data to assess overuse, overuse rates derived from clinical data were much lower for most services than those identified through administrative data, suggesting that much of the literature may be overestimating the prevalence of overuse of imaging.(40, 41, 65) However, clinically documented indications in support of imaging might represent clinician efforts to secure imaging reimbursement in situations in which the clinician favors routine imaging; thus chart review may underestimate overuse. This phenomenon may be specific to evaluations of imaging, either because it requires insurance authorization or because it is done for a variety of clinical indications.(41) True rates of overuse of non-recommended imaging likely lie between the high rates derived from administrative data and the low rates derived from chart review.

Going forward, it will be critical both to focus inquiry on the areas of greatest clinical and/or financial importance and to generate reliable estimates of overuse informed by detailed clinical data. Priority areas for research will need to be defined, with participation from stakeholders including government, professional societies and patients, focusing on services with the most potential to harm patients or the health system. Choosing Wisely has become somewhat of a focal point since 2012, with 14 (24%) of included studies mentioning it. However, the emphasis in our study sample on relatively few clinical services suggests that we need to go further. Researchers must find creative ways to accurately measure overuse across populations while minimizing bias. Cancer cooperative groups that conduct clinical trials may provide opportunities to use relevant prospectively collected clinical data to measure overuse rates while enabling evaluations of interventions to reduce overuse.

Limitations

Our study has a number of limitations. First, standard MeSH terminology for overuse in MEDLINE was only introduced in 2016, so identifying articles reporting rates of overuse is challenging and we may have missed some. We addressed this by performing extensive

reference tracking and by searching multiple databases, so it is unlikely we missed major publications. We excluded articles without a generally accepted standard for defining overuse. While this approach may have excluded some less rigorous but thematically relevant articles, our study provides an estimate of rates of true overuse to inform our understanding of the literature on overuse in cancer care delivery.

Conclusions

Despite recognition of the need to improve value in cancer care and the importance of avoiding overuse, our systematic review suggests gaps in our understanding of overuse in patients with cancer. While we found many studies evaluating diagnostic or surveillance imaging in breast and prostate cancer, there is a dearth of data on overuse in other clinical scenarios, particularly overuse of cancer therapeutics and at the end of life, and an emphasis on using administrative data. Given the enormity of the cost and potential harm associated with overuse in cancer care, there is a need to identify priority areas for investigation to expand the evidence base and inform future efforts to reduce overuse.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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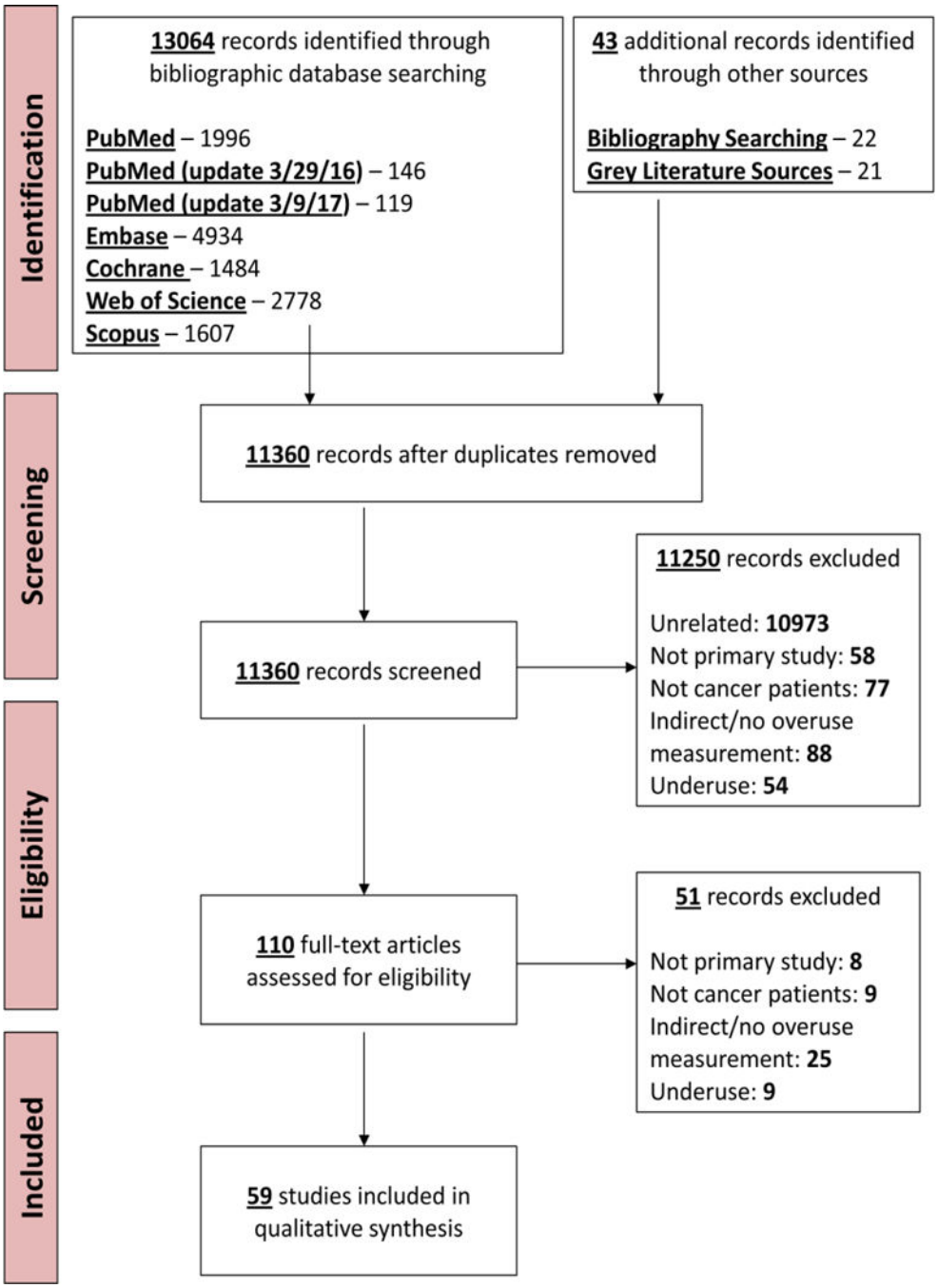

Figure. PRISMA Diagram: flow of articles in the systematic review
Flow of articles in the review

Table 1

Demographic and methodological characteristics of included studies (n=59)

	No. (%)
Publication Year	
2016	4 (7)
2015	22 (37)
2014	9 (15)
2013	6 (10)
2012	11 (19)
2011	7 (12)
Country	
U.S	45 (76)
Non-U.S.	14 (24)
Study Type	
Retrospective	54 (92)
Prospective	5 (8)
Intervention evaluated	3 (5)
SEER-Medicare	22 (37)
Cooperative Group	4 (7)
Choosing Wisely	14 (24)
Bias present	41 (69)
Patient population[a]	
Adult	34 (58)
Pediatric	0 (0)
Adult & Pediatric	1 (2)
Geriatric (≥65)	24 (41)
Cost estimates presented	9 (15)

Abbreviations: U.S=United States; SEER=Surveillance, Epidemiology, and End Results Program

[a]Percentages do not sum to 100 due to rounding

Table 2

Study details from articles included in the review

Author Year Journal[a]	Country, Patient population	Study design	Bias in study design (Reason for bias)	Cancer type	Sample size	Phase of care	Services evaluated	Rate/range of overuse (%)[b]
Akalin 2015	Turkey, Adult	P	Yes (insufficient clinical detail)	Multiple	36	AT	Hospitalization in low-risk patients with fever and neutropenia	53.0
Backhus 2014	USA, Adult	R	Yes (insufficient clinical detail)	Lung	3,808	D	Bone scan if PET was already performed	24.7
Barni 2015	Italy, Adult	R	No	Lung	153	D	Diagnostic exploratory thoracotomy	2.0
Buhrkuhl 2012	New Zealand, Adult & pediatric	R	Yes (subjective determination of overuse)	Not specified	63	AT	Platelet transfusion	28.0[c]
Choi 2011	USA, Geriatric	R	Yes (claims-based)[d]	Prostate	6,444	D	MRI, CT, Ultrasound, or bone scan after low-risk prostate cancer diagnosis	36.2
Cooper 2013	USA, Adult	R	No	Pancreas	101	D	PET, MRI, or CT after an index CT in patients with resectable pancreatic cancer	94.0
Crivello 2013	USA, Geriatric	R	Yes (claims-based)[d]	Breast	67,874	D	PET, MRI, CT, and bone scan in Stage I or II breast cancer	PET: 1.0 MRI: 0.7 CT 9.5 Bone scan: 13.9
Daskivich 2011	USA, Adult	R	No	Prostate	Patients with high comorbidity score: 57 Patients aged >75 years: 44	AT	Radiation, brachytherapy, or radical prostatectomy in low-risk prostate cancer	High comorbidity score: 54.0 Aged> 75 years: 16.0
Ellis 2015	USA, Geriatric	R	Yes (claims-based)[d]	Prostate	12,943	AT	Androgen deprivation therapy in low-risk prostate cancer	18.5
Erb 2016	USA, Geriatric	R	Yes (claims-based)[d]	Lung	9,321	S	PET for surveillance	2.7 – 24.8 (between years of 1998 and 2008)
Falchook 2015	USA, Geriatric	R	Yes (claims-based)[d]	Prostate	41,817	D	MRI, CT, or bone scan in early stage prostate cancer	Pelvic CT/MRI: 38.0 Bone scan: 43.0
Falchook 2014	USA, Geriatric	R	Yes (claims-based, insufficient clinical detail)[d]	Prostate	27,339	D	Bone scan in low-risk prostate cancer	41.1
Feng 2015	Taiwan, Adult	R	Yes (subjective determination of overuse)	CRC, Gastric, H&N, Esophageal	107	AT, EOL	Parenteral nutrition	14.1[c]
Geurts 2012	Netherlands, Adult	R	Yes (insufficient clinical detail)	Breast	144	S	Routine visits during surveillance	31.0 – 76.0 (varies by year after treatment)

Author Year Journal[a]	Country, Patient population	Study design	Bias in study design (Reason for bias)	Cancer type	Sample size	Phase of care	Services evaluated	Rate/range of overuse (%)[b]
Goffredo 2015	USA, Adult	R	No	Thyroid	Papillary: 60,586 Medullary: 6,375 Anaplastic: 3,095	AT	Radioactive iodine after surgery for thyroid cancer	Papillary: 23.3 Medullary: 3.4 Anaplastic: 1.6
Guy 2015	USA, Adult	R	No	Breast	844	AT	Adjuvant hormonal therapy, radiation, and chemotherapy in early stage breast cancer	11.5 - 18.2
Haas 2011	USA, Geriatric	R	No	Breast	638	AT	Trastuzumab in early stage breast cancer	3.9
Haddad 2013	USA, Adult	R	Yes (insufficient clinical detail)	Melanoma	546	D	Preoperative PET, MRI, CT, x-ray, or bone scan	Chest x-ray: 70.0 PET, MRI, or CT: 14.0
Hahn 2016	USA, Adult	R	No	Breast	8,618	S	CT, PET, bone scan and tumor markers for surveillance in early stage breast cancer	CT: 20.0[c] PET/Bone scan: 4.3[c] Tumor markers: 28[c]
Hahn 2015	USA, Adult	R	No	Breast	10,010	D	Pre-treatment PET, CT, or bone scan in early stage breast cancer	15.0
Hahn 2013	USA, Adult	R	No	Breast	258	S	Imaging (abdominal CT, breast MRI, chest CT, chest x-ray, or PET) and lab tests (CA15–3, CA125, CA27–29, or CEA)	Imaging: 55.0 Blood test: 80.0
Han 2012	Canada, Adult	R	No	Breast	231	D	Ultrasound, x-ray, or bone scan in early stage breast cancer	55.0
Lavery 2011	USA, Adult	R	No	Prostate	677	AT	MRI, CT, or bone scan in low-risk prostate cancer	48.0
Linkugel 2015	USA, Adult	R	No	Breast	3,291	D	Pre-treatment PET, CT, or bone scan in early stage breast cancer	27.0
Lipitz-Snyderman 2016	USA, Geriatric	R	Yes (claims-based)[d]	Breast	Imaging-D: 89,006 Imaging-S: 44.216 Radiation: 25,271	D, AT, S	Imaging-D: CT, PET, or bone scan for staging in early stage breast cancer Imaging-S: CT, PET, or bone scan for staging for surveillance in low-risk breast cancer Radiation: IMRT of breast in breast conserving therapy	Imaging-D: 14.0 Imaging-S: 26.0 Radiation: 18.0
				Prostate	Imaging: 32,093 Radiation: 3,464	D, AT	Imaging: CT, PET, or bone scan for staging in early-stage prostate cancer Radiation: Extended fractionation for palliation of bone metastases	Imaging: 41.0 Radiation: 35.0
Livingstone 2015	Germany, Adult	P	Yes (patient selection)	Melanoma	524	S	S100 blood test or lymph node ultrasound in early stage melanoma cancer	22.4
Lochard-Lefrancois 2012	France, Adult	R	No	Multiple	2,062	AT	Non-recommended use of expensive drugs	21.4[c]
Makarov 2016	US, Adult	R	No	Prostate	30,029	D	PET, CT, MRI, or bone scan at diagnosis in low-risk prostate cancer	40.8

Author Year Journal[a]	Country, Patient population	Study design	Bias in study design (Reason for bias)	Cancer type	Sample size	Phase of care	Services evaluated	Rate/range of overuse (%)[b]
Makarov 2015	USA, Geriatric	R	Yes (claims-based)[d]	Breast	30,398	D	PET, CT, or bone scan in low-risk breast cancer	41.8
				Prostate	9,219	D	PET, CT, or bone scan in low-risk prostate cancer	44.4
Makarov 2013	Sweden, Adult	R	Yes (insufficient clinical detail)	Prostate	99,879	D	MRI, CT, or bone scan in low-risk prostate cancer	13.0
Makarov 2012 J Urol	USA, Geriatric	R	Yes (claims-based)[d]	Prostate	18,491	D	MRI, CT, or bone scan in low-risk prostate cancer	45.0
Makarov 2012 Health Aff	USA, Geriatric	R	Yes (claims-based)[d]	Prostate	18,491	D	MRI, CT, or bone scan in low-risk prostate cancer	24.0 – 65.0 (varies across states)
Massarweh 2011	USA, Geriatric	R	Yes (claims-based)[d]	HCC	3,696	D	Diagnostic biopsy, MRI, CT, or ultrasound	Biopsy: 32.4 Imaging: 47.8
Miller 2011	USA, Adult	P	Yes (insufficient clinical detail)	Prostate	375	D	CT and bone scan in early stage prostate cancer	Bone scan: 10.0 CT: 14.0
Palvolgyi 2011	USA, Adult	R	No	Prostate	519	D	Bone scan in low-risk prostate cancer	25.0
Panageas 2012	USA, Geriatric	R	Yes (claims-based)[d]	Breast	25,555	S	PET, MRI, CT, or bone scan in early stage breast cancer	40.0
Parmar 2013	USA, Geriatric	R	Yes (insufficient clinical detail)	Breast	8,598	S	PET, MRI, CT, and bone scan in early stage breast cancer	Chest CT/MRI: 16.5 Head CT/MRI: 21.2 PET or PET/CT: 6.5 Bone scan: 16.4
Paulson 2015	USA, Geriatric	R	Yes (claims-based)[d]	CRC	Colon: 23,990 Rectal: 5,665	S	CT in stage I CRC cancer	26.0
Peeraphatdit 2015	USA, Adult	R	No	HCC	224	D	Unnecessary biopsy	34.0
Porten 2014	USA, Adult	R	Yes (insufficient clinical detail)	Prostate	9,333	D	MRI, CT, and bone scan in early stage prostate cancer	MRI: approximately 0[e] Bone scan: 12.0–15.0[e] CT: 11.0–28.0[e]
Prasad 2012	USA, Geriatric	R	Yes (claims-based)[d]	Prostate	22,606	D	CT or bone scan in low and intermediate-risk prostate cancer	42.0
Ramsey 2015 J Clin Onc	USA, Geriatric	R	Yes (claims-based)[d]	Breast	39,650	S	Tumor markers (CEA, CA 15.3, CA27.29) in non-metastatic breast cancer	42.0
Ramsey 2015 J Onc Prac	USA, Adult	R	Yes (insufficient clinical detail	Breast, Prostate, Lung	Varies by service[f]	D, AT, S	Multiple services[f]	Varies by service[f]

Author Year Journal[a]	Country, Patient population	Study design	Bias in study design (Reason for bias)	Cancer type	Sample size	Phase of care	Services evaluated	Rate/range of overuse (%)[b]
Ross 2015	USA, Adult	R	Yes (patient selection)	Prostate	410	D	CT and bone scan in low-risk prostate cancer	CT: 5.2 Bone scan: 3.7
Sacks 2015	USA, Adult	R	Yes (insufficient clinical detail)	Thyroid	Local study: 444 NCDB: 18,000 – 20,000	AT	Radioactive iodine in low-risk thyroid cancer	Local study: 27.7 NCDB: 50.3
Salloum 2012	USA, Adult	R	Yes (insufficient clinical detail)	Breast	6,205	S	Unnecessary metastatic evaluation after treatment for breast cancer	65.0
				CRC	2,297	S	Unnecessary metastatic evaluation after treatment for CRC cancer	73.0
Sammon 2015	USA, Geriatric	R	Yes (claims-based)[d]	Prostate	46,376	AT	Androgen deprivation therapy in localized prostate cancer	30.0
Sawazaki 2014	Japan, Adult	R	No	Prostate	144	D	Bone scan and CT in low-risk prostate cancer	Bone scan: 100 CT: 72.0
Schroeck 2014 J Urol	USA, Geriatric	R	Yes (claims-based)[d]	Prostate	9,014	D	Bone scan in low-risk prostate cancer	34.1
Schroeck 2014 Urology	USA, Geriatric	R	Yes (claims-based)[d]	Prostate	31,321	D	Bone scan in low-risk prostate cancer	30.0
Segal 2014	USA, Geriatric	R	Yes (claims-based)	Breast	1,451,142	S	Tumor markers in women with history of breast cancer	73.2
				Prostate		D	PET, CT, or bone scan in low-risk prostate cancer	20.7
Shahinian 2015	USA, Geriatric	R	Yes (claims-based)[d]	Prostate	27,169	AT	Androgen deprivation therapy	31.1 – 46.6
Shih 2014	USA, Geriatric	R	Yes (claims-based)[d]	Breast	2,984	AT	Trastuzumab without documentation of HER-2 status	4.7[c]
Simonato 2012	Italy, Adult	P	No	Prostate	1,063	D	Preoperative CT, MRI, and bone scan in early stage prostate cancer	CT: 48.4 MRI 2.4 Bone scan: 71.2
Simos 2015 CMAJ	Canada, Adult	R	Yes (insufficient clinical detail)	Breast	26,547	D	PET, MRI, CT, ultrasound, or x-ray in early stage breast cancer	79.6
Simos 2015 J Onc Prac	Canada, Adult	R	Yes (insufficient clinical detail)	Breast	200	D	CT, ultrasound, x-ray, or bone scan for distant metastases in early stage breast cancer	82.6
Swisher-McClure 2012	USA, Geriatric	R	Yes (claims-based)[d]	Prostate	2,184	AT	Androgen deprivation therapy in low-risk prostate cancer when undergoing external beam radiation therapy	32.2
Vazin 2015	Iran, Adult	P	No	Various hematologic cancers	116	AT	Antifungal use in bone marrow transplant patients with neutropenia	19.0[c]

Author Year Journal[a]	Country, Patient population	Study design	Bias in study design (Reason for bias)	Cancer type	Sample size	Phase of care	Services evaluated	Rate/range of overuse (%)[b]
Weeks 2014	USA, Adult	R	Yes (insufficient clinical detail)	Breast, Lung, NHL	Varies by service[g]	D, AT, S	Multiple services[g]	Varies by service[g]

Abbreviations: AT=Active treatment; CT=Computerized tomography; CEA=carcinoembryonic antigen; CRC=colorectal; D=Diagnostic; EOL=end of life; H&N=head and neck; HCC=Hepatocellular carcinoma; IMRT=intensity-modulated radiation therapy; MRI=Magnetic resonance imaging; NCDB=National Cancer Database; NHL= Non-Hodgkin's Lymphoma; P=Prospective; PET=Positron emission tomography; R=Retrospective; S=Surveillance; USA=United States

[a]Journal is reported for studies with the same first author and year

[b]Reported as percentage of the population receiving the unnecessary service, unless otherwise noted

[c]Reported as percentage of services being used inappropriately

[d]used SEER-Medicare database

[e]Data extracted from published graph; numbers not presented

[f]Ramsey (JOP, 2015): PET/CT/bone scan in prostate staging: 10% (n=518); PET/CT/bone scan in breast staging: 22% (n=1,798); Tumor markers OR imaging in breast surveillance: 47% (n=629); white blood cell stimulating factors in low-risk patients: 30% (n=672)

[g]Weeks (Ann Intern Med, 2014): Liver function test in breast surveillance: 62% (n=564); MRI in breast surveillance: 12% (n=928); chest x-ray in breast surveillance: 25% (n=928); chest CT in breast surveillance: 8% (n=928); PET in breast surveillance: 1% (n=928); hormonal therapy in breast: 74% (n=375); chemotherapy, post-menopausal breast patients: 36% (n=346); chemotherapy, pre-menopausal breast: 55% (n=266); diagnostic PET in stage III breast: 17% (n=598); diagnostic PET in stage I-II breast: 4% (n=6,827); diagnostic brain imaging in breast: 2% (n=6,827); radiation in breast: 4% (n=965); diagnostic brain imaging in lung: 37% (n=1,437); systemic therapy in lung: 40% (n=147); growth factors in Non-Hodgkin's lymphoma: 23% (n=232)

Table 3

Classification of evaluated overused services by disease and service type (n=154)

	No. (%)
Disease	
Breast	76 (49)
Prostate	50 (32)
Lung	5 (3)
Non-CRC GI	4 (3)
Colorectal	2 (1)
Other[a]	17 (11)
Phase	
Diagnostic	87 (56)
Surveillance	36 (23)
Active treatment	30 (19)
Treatment and end of life	1 (1)
Service	
Imaging	109 (71)[b]
CT	24 (16)
Bone Scan	27 (18)
PET	13 (8)
MRI	9 (6)
X-ray	7 (5)
Ultrasound	6 (4)
Multiple imaging modalities[c]	23 (15)
Radiation	11 (7)
Lab	10 (6)
Hormonal therapy	7 (5)
Chemotherapy	5 (3)
Targeted therapy	2 (1)
Other[d]	10 (6)

Abbreviations: CRC=colorectal; GI=gastrointestinal; CT=computed tomography; PET=positron emission tomography; MRI = magnetic resonance imaging

[a] Includes services that were associated with another disease, multiple diseases, or an unspecified disease.

[b] Percentages of imaging sub-services do not sum to imaging total due to rounding

[c] Refers to services that evaluated more than one imaging modality

[d] Includes: hospitalization, white-cell stimulating factors, antifungal use, thoracotomy, parenteral nutrition, routine visits during surveillance, prophylactic transfusion, biopsy