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Failure to administer recommended chemotherapy: acceptable variation or cancer care quality blind spot?

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Abstract

Background—Chemotherapy quality measures consider hospitals compliant when chemotherapy is recommended, even if it is not received. This may mask shortcomings in cancer care delivery. Objectives of this study were to (1) identify patient factors associated with failure to receive recommended chemotherapy without a documented contraindication and (2) assess hospital variation in failure to administer recommended chemotherapy.

Methods—Patients from 2005 to 2015 with breast, colon and lung cancers who failed to receive recommended chemotherapy were identified using the National Cancer Database. Hospital-level rates of failure to administer recommended chemotherapy were calculated, and patient and hospital factors associated with failure to receive recommended chemotherapy were identified by multivariable logistic regression.

Results—A total of 183 148 patients at 1281 hospitals were analysed. Overall, 3.5% of patients with breast, 6.6% with colon and 10.7% with lung cancers failed to receive recommended

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chemotherapy. Patients were less likely to receive recommended chemotherapy in all cancers if uninsured or on Medicaid ($p<0.05$), as were non-Hispanic black patients with both breast and colon cancer ($p<0.001$). Significant hospital variation was observed, with hospital-level rates of failure to administer recommended chemotherapy as high as 21.8% in breast, 40.2% in colon and 40.0% in lung cancers.

Conclusions and relevance—Though overall rates are low, failure to receive recommended chemotherapy is associated with sociodemographic factors. Hospital variation in failure to administer recommended chemotherapy is masked by current quality measure definitions and may define a significant and unmeasured difference in hospital quality.

INTRODUCTION

While death rates for many cancers have decreased significantly, there are still an estimated 600 000 cancer-related deaths each year in the USA.¹ Breast, colon and lung cancers are among the three most common malignancies diagnosed in the USA and have well-defined treatment pathways with known benefits to chemotherapy in select subsets of patients.^{2–4} The National Quality Forum (NQF) has endorsed several metrics related to the appropriate administration of chemotherapy. Oversight and accreditation organisations, including the Centers for Medicaid and Medicare Services and American College of Surgeons Commission on Cancer (CoC), use these measures to evaluate hospital cancer care quality.⁵ Thresholds for compliance are defined by the CoC, and cut-offs are defined for subset of measures for formal evaluation of hospital quality. For example, hospitals are considered compliant with the CoC Quality Improvement measure for non-small cell lung cancer if more than 85% of patients receive systemic chemotherapy within 4 months before or 6 months after surgery when pathologically appropriate.⁶

The CoC quality metrics regarding appropriate use of adjuvant therapy in patients with breast, colon and lung cancers are structurally similar. Patients treated at CoC hospitals who meet strict inclusion criteria are expected to receive chemotherapy unless alternative documentation is provided.^{6–8} Patients deemed too frail or systemically ill to tolerate chemotherapy are not counted against the hospital in quality calculations.^{9,10} Similar exemptions exist for patients who die prior to administration of planned chemotherapy and for those patients that received a chemotherapy recommendation but did not undergo treatment. The goal of these exceptions is to ensure that hospitals are not penalised for situations in which chemotherapy is at least recommended, even if a patient subsequently refuses administration or is lost to follow-up.

However, given significant evidence regarding disparities in cancer care,^{11–14} there is a concern that current definitions may mask a true gap in quality. One example would include a vulnerable patient with low health literacy ‘slipping through the cracks’ and never receiving chemotherapy despite a recommendation by a physician, which is considered compliant with current quality measure definitions. Hospitals then artificially appear to be high performers on what is most important: the timely receipt of recommended chemotherapy to patients with cancer. The objectives of this study were (1) to identify patient factors associated with failure to receive recommended chemotherapy and (2) to

assess hospital variation in failure to administer recommended chemotherapy in the absence of documented contraindications.

METHODS

Data source and study population

The 2005–2015 National Cancer Database (NCDB) was the primary dataset for this retrospective cohort study. The NCDB is sponsored by the CoC of the American College of Surgeons and the American Cancer Society. Approximately 30% of USA hospitals participate in the NCDB, which captures approximately 70% of newly diagnosed cancers nationally each year.^{15,16} Data are abstracted by trained registrars and periodically audited.¹⁷ The NCDB is the primary dataset used for quality evaluation by the CoC. The NCDB collects clinical and pathological data based on the American Joint Committee on Cancer (AJCC) guidelines.¹⁸ These staging data, paired with disease-specific inclusion and exclusion criteria, are used to identify patients to be included in hospital-level quality measure calculations.

The three most common cancer sites in the USA with chemotherapy-based quality measures were selected for study: breast, colon and lung cancer. The quality metrics were reconstructed using the CoC definitions for the three quality measures that are publicly available. Briefly, eligible cases receiving treatment at the reporting facility for each of the three cancer sites were identified using Facility Oncology Registry Data Standards definitions.^{6–8} Measure inclusion criteria included diagnosis, histology codes and patient record completeness as laid out by the CoC. Measures are designed to capture patient populations with robust evidence underlying the potential benefit of chemotherapeutics (eg, elderly women with breast cancer are excluded from the quality measure). The breast cancer measure includes receipt of adjuvant chemotherapy in patients with T1N0M0 and stage IB–III hormone receptor negative cancer; the colon cancer measure includes receipt of adjuvant chemotherapy in patients with stage III colon cancer; the lung cancer measure includes either adjuvant or neoadjuvant therapy in patients with pN1 or pN2 NSCLC without evidence of metastatic disease. Clinical exclusion criteria were applied per CoC guidelines. Eligible cases were considered the denominator for each quality measure. Cases were included beginning in the calendar year of the initial release of the CoC quality measure (2006 for breast cancer, 2005 for colon cancer, and 2014 for lung cancer).

Outcome variable: failure to administer recommended chemotherapy

Adherence to appropriate use of chemotherapy was calculated in two ways. First, cases were considered compliant with the measure using the previously defined, NQF endorsed definitions. For this definition, cases are considered ‘compliant’ if chemotherapy is not administered due to patient comorbidities, death, and if chemotherapy is recommended but not administered due to patient refusal or lost to follow-up. All other eligible cases are considered failures towards the measure. An alternative definition was also calculated excluding cases where chemotherapy was recommended but not administered from the quality measure numerator. The difference in hospital-level compliance using the two

definitions above yielded the hospital-level percentage of patients failing to receive recommended chemotherapy.

Covariates: patient sociodemographic and clinical characteristics

Patient-level variables of interest included year of treatment, patient age, sex, race/ethnicity, Charlson-Deyo Score (a composite measure of preexisting medical comorbidities) and socioeconomic variables.¹⁹ Disease-specific variables of interest included T and N staging. Pathological staging was performed using AJCC staging criteria when appropriate, with stages included for study defined by the NQF defined quality measure.²⁰ Hospital-level variables included hospital type (academic vs non-academic), hospital census region and patient travel distance to the hospital.

Hospital-level analysis

Hospital-level rates of failure to administer recommended chemotherapy were calculated based on the difference between the existing CoC compliance definition and the hospital compliance rate when patients failing to receive recommended chemotherapy were excluded from the numerator. All hospitals with at least 10 cases meeting the inclusion criteria were included in the hospital-level analysis.

Statistical analysis

Basic descriptive statistics were performed separately for each cancer site. Significant associations between failure to receive recommended chemotherapy and patient-level variables for each individual cancer site were assessed by multivariable logistic regression models with robust SEs adjusted for patient clustering within hospitals. Hospital-level odds of failing to receive recommended chemotherapy was assessed using both adjusted and unadjusted hierarchical multivariable logistic regression models. Adjusted models included all relevant patient-level variables as fixed effects. Hospitals were considered outliers if the hospital-level ORs and CIs were significantly different than 1.0 in hierarchical models. Tests of significance were two sided with p values considered significant at the 0.05 level. Statistical analyses were performed using Stata V.15.1 (StataCorp).

RESULTS

Cohort development and descriptive statistics

Overall, 183 148 patients met inclusion criteria for administration of chemotherapy (82 598 patients with breast cancer, 92 077 patients with colon cancer and 8473 patients with lung cancer; online supplementary appendix figure 1). The smaller number of lung cancer patients was due predominantly to the recency of the measure and the relative infrequency of surgical management in patients with N2 disease. Consistent with CoC definitions, all patients in the breast cancer cohort were female under the age of 70. Patient characteristics of the final cohort for each cancer site are shown in table 1.

Factors associated with failure to receive recommended chemotherapy

The overall rate of failure to receive recommended chemotherapy was 3.5% in patients with breast cancer. Patients were more likely to fail to receive recommended chemotherapy if over the age of 55 (4.5% vs 2.5% if <55, adjusted OR (aOR) 1.90, 95% CI 1.76 to 2.04), non-Hispanic black (4.1% vs 3.4% in non-Hispanic white patients, aOR 1.26, 95% CI 1.14 to 1.40), from a low-income area (4.3% vs 3.1% in highest income areas, aOR 1.36, 95% CI 1.15 to 1.61), uninsured or on Medicaid (4.0% vs 3.4% if insured, aOR 1.30, 95% CI 1.16 to 1.45) or treated at a non-academic hospital (3.8% vs 3.0% if non-academic, aOR 1.26, 95% CI 1.13 to 1.41). Regional associations were also noted, with patients managed in East North Central, Mountain and Pacific regions more likely to fail to receive recommended chemotherapy (all $p < 0.05$; table 2). There was a stepwise increase in failure to receive recommended chemotherapy with decreasing N-stage, with N0 patients (4.2%, aOR 2.60, 95% CI 2.23 to 3.04 vs N2/3) and N1 patients (2.5%, aOR 1.42, 95% CI 1.20 to 1.68 vs N2/3) significantly more likely to fail to receive chemotherapy than patients with N2 or N3 disease (1.9%).

In patients with colon cancer, the overall rate of failure to receive physician recommended chemotherapy was 6.6%. Patients with colon cancer were more likely to fail to receive recommended chemotherapy if over the age of 70 (10.5% vs 3.4% if <55, aOR 3.56, 95% CI 3.23 to 3.92), non-Hispanic black (8.1% vs 6.3% in non-Hispanic white patients, aOR 1.38, 95% CI 1.26 to 1.51), from a low-income area (7.8% vs 5.5% in highest income areas, aOR 1.30, 95% CI 1.16 to 1.46), uninsured or on Medicaid (7.7% vs 6.4% in insured, aOR 1.62, 95% CI 1.46 to 1.79) or with a high Charlson comorbidity score (9.2% vs 6.1% with a low Charlson comorbidity score, aOR 1.26, (95%CI 1.13 to 1.41). Regional associations were also noted, with several regions demonstrating higher rates of failure (all $p < 0.05$; table 2). Patients with N1 disease were significantly more likely to fail to receive recommended chemotherapy than patients with N2 disease (7.1% vs 5.6%, aOR 1.27, 95% CI 1.19 to 1.34).

Among patients with lung cancer, 10.7% failed to receive recommended chemotherapy. Patients with lung cancer were more likely to fail to receive recommended chemotherapy if over the age of 70 (14.1% vs 7.4% if <55, aOR 2.26, 95% CI 1.75 to 2.93), uninsured or on Medicaid (11.6% vs 10.6% in insured patients, aOR 1.40, 95% CI 1.08 to 1.82) or with N1 disease (12.5% vs 8.4% for N2, aOR 1.56, 95% CI 1.33 to 1.83).

Hospital variation in failure to administer recommended chemotherapy by cancer type

Hospital-level analyses included 1226 hospitals for the breast cancer measure, 1275 hospitals for the colon cancer measure and 302 hospitals for the lung cancer measure. The median hospital-level rates of failure to administer recommended chemotherapy were 3.2% for breast cancer (IQR 0%–5.5%), 6.2% for colon cancer (IQR 3.6%–9.1%) and 9.1% for lung cancer (IQR 4.9%–15.4%; table 3). Rates of hospital-level failure to administer physician recommended chemotherapy were as high as 21.8% in breast cancer, 40.2% in colon cancer and 40.0% in lung cancer. A 0% rate of failure to administer recommended chemotherapy was observed in 309 hospitals (25.2%) in breast cancer, 111 (8.7%) in colon cancer and 62 (20.5%) in lung cancer. Overall variation in hospital-level compliance is

illustrated in figure 1, both including and excluding those patients that failed to receive recommended chemotherapy.

Hierarchical logistic regression modelling was then performed for each cancer type to identify hospital-level odds of failure to receive recommended chemotherapy. In completely unadjusted models, there were 95 high outliers (poor performers, 7.8%) in breast cancer, 184 (14.4%) in colon cancer and 18 (6.0%) in lung cancer. In models adjusting for patient characteristics and sociodemographics, there were 86 high outliers in breast cancer (7.0%), 169 in colon cancer (13.3%) and 17 in lung cancer (5.6%; figure 2). Across all cancer types, adjustment for sociodemographics recategorised 44 hospitals that would have been identified as high outliers in unadjusted models. Notably, only 29 hospitals were high outliers in more than one cancer type. Similar patterns were observed in examining low outliers (high performers).

DISCUSSION

In this study, failure to receive recommended chemotherapy was shown to be associated with demographic, socioeconomic and disease-related variables across multiple cancer types. Hospital variation was notable, with many hospitals achieving very low rates of failure to administer recommended chemotherapy and others identified as low performers. Though overall rates are low, several hospitals had extremely high failure rates that are masked by the current quality measure definitions. Hospital variation in failure to administer recommended chemotherapy may define a significant and unmeasured difference in hospital quality.

Both racial minorities and socioeconomically disadvantaged populations have been shown to have worse outcomes across many studies and cancer types.^{12–14,21–24} The variation in cancer care delivery demonstrated in this study is simultaneously in line with previously identified disparities and substantially more nuanced, as hospitals are actually given credit on quality measures for those patients who fail to receive recommended chemotherapy.^{6–8} Moreover, this study may even underestimate this disparity, as those patients that are early lost to follow-up are excluded from the quality measure. While the goal of this policy is to not punish a hospital for a patient that is non-compliant or is lost to follow-up, the striking variation in hospital-level rates of failure to administer recommended chemotherapy implies that there are significant differences in the effectiveness of local efforts in mitigating these demographic and socioeconomic factors at some facilities. Some of this variation is likely due to unmeasured local factors such as health literacy, language barriers and comorbid substance abuse or psychiatric illness. There are also local efforts that may reduce lost to follow-up or reduce financial and social impediments to receiving care, such as social workers, financial counsellors and patient navigators. Future research should explore additional explanatory variables and how it may pertain to patients failing to receive recommended care.

Beyond the apparent disparity identified, this analysis brings up two notable questions about measurement of hospital quality: risk adjustment for process measures and socioeconomic risk adjustment. Process measures have traditionally not undergone risk adjustment, as they

are by definition measures that that should be taken for all patients who meet inclusion criteria (eg, chemotherapy for disseminated cancer). Rather, patients are removed from process measure calculations based on exclusion criteria (eg, patient comorbidities). However, the conclusions from the NQF regarding the role of socioeconomic status in quality measurement have made this policy more fluid.²⁵ Briefly, the NQF concluded that socioeconomic factors could be used for risk adjustment in both outcome and some process measures when there is a logical connexion between the socioeconomic factor and the quality measure (eg, insurance status and expensive chemotherapeutics) and empirical evidence exists that the connexion may be affecting outcomes. Presentation of such data may take the form of clinically adjusted models stratified by sociodemographic groups. Application of these principles to measures such as those studied in this manuscript has far-reaching implications as care moves towards a more bundled, value-based model.²⁶

There are a few potential solutions to the identified shortcoming in existing quality measures. One method would be to include socioeconomic variables as risk adjusters to ensure that hospitals taking care of more disadvantaged populations are not inadvertently penalised. While our adjusted analyses indicate that some hospitals may have a different assessment based on adjusted models, this may be inappropriate in this setting per NQF guidelines, as this study also suggests that very low rates of failure to administer recommended chemotherapy can be achieved. Alternatively, caveats for failure to administer recommended chemotherapy could be removed entirely from process measure calculations. This approach could disproportionately punish critical access and safety net hospitals, which may treat high proportions of patients that may refuse chemotherapy or be lost to follow-up.^{27,28} A third potential solution would be a simple cap on the proportion of patients at a facility that are included in the numerator of the quality measure when coded as failing to receive recommended chemotherapy. This straightforward solution would not change the quality measure denominator, minimise hospitals being penalised for patient non-compliance and incentivise hospitals with high rates of failure to administer recommended therapy to improve in that area. As hospitals improved, the benchmark 'cap' could be adjusted as necessary to continue to motivate improvement.

Another notable result of this study was the high rate of failure to receive recommended chemotherapy with lower nodal burden of disease observed across all cancer types. Because chemotherapy was recommended by the physician, this is unlikely to represent guideline non-adherence or a physician-level knowledge issue. Rather, we postulate that physicians may be less likely to emphatically recommend chemotherapy in patients with less perceived benefit from chemotherapy. Further study of this association is warranted.

This study has limitations. First, the quality measures for the three cancers studied have been in place for variable lengths of time which coincides with increasing awareness of surgical quality. This limitation was mitigated by analysing each cancer separately and adjusting for year of diagnosis in all models. Second, we do not know the nature of the conversations taking place at the individual level between physicians and patients, and any steps taken to attempt to improve overall administration of chemotherapy must be cognizant of patient autonomy. Third, the nature of the CoC quality measures excludes many patients with an indication for chemotherapy (eg, patients with distant metastatic disease) and thus may not

accurately capture more global cancer care inequalities. However, we believe this is the appropriate population frame for this study, as we are focused on exploring existing quality measures, rather than cancer care inequalities more generally. Finally, the differential staging and inclusion criteria for the three disease may make interpretation of aggregate analysis challenging. However, the similar patient-level trends across all cancer types indicate that overall hospital-level analysis of failure to administer recommended chemotherapy is valid.

CONCLUSION

Socioeconomic and disease-related factors are associated with failure to administer recommended chemotherapy, and significant hospital variation exists in the proportion of patients that fail to receive recommended chemotherapy. These findings reveal a significant blind spot in the current quality measure definitions. While socioeconomic and cultural factors can be challenging to overcome while maintaining patient autonomy, the presence of many facilities with near-perfect administration of recommended chemotherapy indicates optimisation could occur. Modification of existing quality measures to limit a hospital's ability to get credit for cases where chemotherapy was recommended but not administered or development of a separate cancer measure assessing chemotherapy failures should be considered to address these shortcomings.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Hospital-level compliance rates with and without failure to administer recommended chemotherapy considered in metric. Hospital-level compliance rates with appropriate chemotherapy for breast cancer (n=1226; A), colon cancer (n=1275; B) and lung cancer (n=302; C). The line is hospital-level compliance when including failure to administer recommended chemotherapy. Triangles represent hospital-level compliance when failure to administer recommended chemotherapy is not considered compliant. The distance from each triangle to the line is the rate of failure to administer recommended chemotherapy at a given

hospital. Note: these analyses exclude 566 patients at 100 hospitals for breast cancer, 317 patients at 58 hospitals for colon cancer and 2708 patients at 685 hospitals for lung cancer.

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Figure 2.

Unadjusted and adjusted hospital-level odds of failure to administer recommended chemotherapy. Hospital-level ORs for failure to receive recommended chemotherapy for breast (A; n=1277), colon (B, n=1279) and lung cancer (C, n=973) adjusting for both patient sociodemographic and disease characteristics. Adjusted analyses identified 77 high outliers (poor performers; 6.0%) and 21 low outliers (high performers, 1.6%) in breast cancer; 171 high outliers (13.4%) and 108 low outliers (8.4%) in colon cancer; and 13 high outliers (1.3%) and 3 low outliers (0.3%) in lung cancer. Each black dot represents a hospital-level

OR of failure to receive recommended chemotherapy, and whiskers represent standard measurement error. Horizontal line marks a hospital OR of 1.0. Note: these analyses exclude 566 patients at 100 hospitals for breast cancer, 317 patients at 58 hospitals for colon cancer and 2708 patients at 685 hospitals for lung cancer.

Table 1

Patient cohort characteristics

	Breast cancer	Colon cancer	Lung cancer
	n (%)	n (%)	n (%)
Overall, n	82 598	92 077	8473
General characteristics			
Sex			
Male	---	46 701 (50.7)	4303 (50.8)
Female	82 598 (100)	45 376 (49.3)	4170 (49.2)
Age			
<55 years	40 439 (49.0)	21 361 (23.2)	1041 (12.3)
55–69 years	42 159 (51.0)	41 984 (45.6)	4193 (49.5)
70+ years	---	28 732 (31.2)	3239 (38.2)
Race/ethnicity			
Non-Hispanic white	55 395 (67.1)	68 440 (74.3)	7012 (82.8)
Non-Hispanic black	17 609 (21.3)	13 429 (14.6)	790 (9.3)
Hispanic	5394 (6.5)	5447 (5.9)	265 (3.1)
Asian	2713 (3.3)	3237 (3.5)	268 (3.2)
Other	1487 (1.8)	1524 (1.7)	138 (1.6)
Median household income			
US\$63 000+	26 993 (32.7)	28 080 (30.5)	2560 (30.2)
US\$48 000–US\$62 999	21 749 (26.3)	24 368 (26.5)	2314 (27.3)
US\$38 000–US\$47 999	17 980 (21.8)	21 138 (23.0)	2060 (24.3)
<US\$38 000	15 320 (18.6)	17 661 (19.2)	1528 (18.0)
Unknown	556 (0.7)	830 (0.9)	11 (0.1)
Median educational attainment			
<7%	19 682 (23.8)	20 183 (21.9)	1841 (21.7)
7%–13%	25 633 (31.0)	28 885 (31.4)	2838 (33.5)
13%–21%	21 453 (26.0)	24 546 (26.7)	2346 (27.7)
21% and up	15 302 (18.5)	17 680 (19.2)	1440 (17.0)
Unknown	528 (0.6)	783 (0.9)	8 (0.1)

	Breast cancer		Colon cancer		Lung cancer	
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Insurance status						
Uninsured/Medicaid	11 468 (13.9)	9160 (10.0)	743 (8.8)			
Insured/Medicare	68 974 (83.5)	80 603 (87.5)	7430 (87.7)			
Other/unknown	2156 (2.6)	2314 (2.5)	300 (3.5)			
Charlson-Deyo Comorbidity Index						
0	69 373 (84.0)	65 351 (71.0)	4451 (52.5)			
1	11 390 (13.8)	21 972 (23.9)	3099 (26.6)			
2+	1835 (2.2)	4754 (5.2)	923 (10.9)			
Year of treatment						
2005–2008	19 732 (23.9)	34 069 (37.0)	---			
2009–2011	25 840 (31.3)	24 737 (26.9)	---			
2012–2013	18 712 (22.7)	16 180 (17.6)	---			
2014–2015	18 314 (22.2)	17 091 (18.6)	8473 (100)			
Hospital characteristics						
Hospital type						
Academic	27 084 (32.8)	24 556 (26.7)	3464 (40.9)			
Non-academic	55 514 (67.2)	67 521 (73.3)	5009 (59.1)			
Hospital region						
New England	3910 (4.7)	4558 (5.0)	498 (5.9)			
Middle Atlantic	11 817 (14.3)	13 187 (14.3)	1376 (16.2)			
South Atlantic	20 267 (24.5)	20 823 (22.6)	1836 (21.7)			
East North Central	14 676 (17.8)	16 626 (18.1)	1533 (18.1)			
East South Central	6048 (7.3)	7327 (8.0)	763 (9.0)			
West North Central	5841 (7.1)	6645 (7.2)	574 (6.7)			
West South Central	7791 (9.4)	9163 (10.0)	703 (8.3)			
Mountain	3490 (4.2)	9772 (4.1)	299 (3.5)			
Pacific	8758 (10.6)	9976 (10.8)	891 (10.5)			
Hospital distance from patient						
<5 miles	23 410 (28.3)	31 019 (33.7)	1988 (23.5)			
5–9.9 miles	20 197 (24.5)	22 046 (23.9)	1669 (19.7)			

	Breast cancer	Colon cancer	Lung cancer
	n (%)	n (%)	n (%)
10–19.9 miles	18 930 (22.9)	18 773 (20.4)	1763 (20.8)
20+ miles	19 404 (23.5)	19 416 (21.1)	3035 (35.8)
Unknown	657 (0.8)	823 (0.9)	18 (0.2)
Tumour characteristics			
Pathological T-Stage			
T0/T1	42 094 (51.0)	3540 (3.8)	2438 (28.8)
T2	31 960 (38.7)	7482 (8.1)	3802 (44.8)
T3/T4	7063 (8.6)	70 520 (76.6)	1806 (21.3)
Tx	114 (0.1)	10 535 (11.4)	427 (5.0)
Pathological N-stage			
N0	51 594 (62.5)	---	---
N1	20 615 (65.0)	59 737 (64.9)	4647 (54.8)
N2 (+N3 for breast only)	10 389 (12.6)	32 299 (35.1)	3090 (36.5)
Other N+	---	41 (0.0)	736 (8.7)

Table 2

Factors associated with failure to receive recommended chemotherapy by disease site

	Breast cancer				Colon cancer				Lung cancer			
	Rate, %	OR (95% CI)	P value	Rate, %	OR (95% CI)	P value	Rate, %	OR (95% CI)	P value	Rate, %	OR (95% CI)	P value
Overall	3.5			6.6			10.7					
General characteristics												
Sex												
Male	---	---	---	6.5	1.0	Ref	11.0	1.0	Ref			
Female	---	---	---	6.6	0.98 (0.93 to 1.03)	0.450	10.3	0.98 (0.85 to 1.12)	0.732			
Age												
<55 years	2.5	1.0	Ref	3.4	1.0	Ref	7.4	1.0	Ref			
55–69 years	4.5	1.90 (1.76 to 2.04)	<0.001	5.5	1.66 (1.53 to 1.81)	<0.001	8.8	1.27 (0.98 to 1.64)	0.071			
70+ years	---	---	---	10.5	3.56 (3.23 to 3.92)	<0.001	14.1	2.26 (1.75 to 2.93)	<0.001			
Race/ethnicity												
Non-Hispanic white	3.4	1.0	Ref	6.3	1.0	Ref	10.6	1.0	Ref			
Non-Hispanic black	4.1	1.26 (1.14 to 1.40)	<0.001	8.1	1.38 (1.26 to 1.51)	<0.001	10.3	1.04 (0.81 to 1.34)	0.740			
Hispanic	2.7	0.80 (0.66 to 0.98)	0.027	4.8	0.72 (0.62 to 0.84)	<0.001	11.3	1.07 (0.64 to 1.81)	0.794			
Asian	3.1	0.92 (0.73 to 1.15)	0.439	7.3	1.12 (0.94 to 1.32)	0.204	13.1	1.43 (0.97 to 2.12)	0.075			
Other	5.7	1.68 (1.30 to 2.18)	<0.001	7.1	1.15 (0.93 to 1.42)	0.206	10.1	1.02 (0.59 to 1.77)	0.930			
Median household Income												
\$63 000+	3.1	1.0	Ref	5.5	1.0	Ref	9.9	1.0	Ref			
\$48 000–\$62 999	3.4	1.07 (0.95 to 1.21)	0.234	6.5	1.11 (1.02 to 1.20)	0.019	10.7	1.01 (0.80 to 1.28)	0.917			
\$38 000–\$47 999	3.7	1.17 (1.02 to 1.35)	0.028	7.0	1.21 (1.10 to 1.34)	<0.001	11.0	1.04 (0.81 to 1.34)	0.760			
<\$38 000	4.3	1.36 (1.15 to 1.61)	<0.001	7.8	1.30 (1.16 to 1.46)	<0.001	11.3	1.10 (0.81 to 1.50)	0.551			
Local high school diploma												
<7%	3.1	1.0	Ref	5.6	1.0	Ref	10.2	1.0	Ref			
7%–13%	3.5	1.05 (0.93 to 1.18)	0.451	6.5	1.07 (0.99 to 1.16)	0.107	10.3	1.05 (0.85 to 1.3)	0.662			
13%–21%	3.6	0.98 (0.84 to 1.14)	0.818	6.8	1.06 (0.96 to 1.18)	0.273	11.1	1.09 (0.85 to 1.4)	0.509			
21% and up	3.9	0.98 (0.81 to 1.18)	0.831	7.4	1.13 (1.00 to 1.28)	0.059	11.3	1.09 (0.8 to 1.48)	0.598			
Insurance status												
Insured/Medicare	4.0	1.0	Ref	7.7	1.0	Ref	11.6	1.0	Ref			

	Breast cancer				Colon cancer				Lung cancer			
	Rate, %	OR (95% CI)	P value	Rate, %	OR (95% CI)	P value	Rate, %	OR (95% CI)	Rate, %	OR (95% CI)	P value	P value
Uninsured/Medicaid	3.4	1.30 (1.16 to 1.45)	<0.001	6.4	1.62 (1.46 to 1.79)	<0.001	10.6	1.40 (1.08 to 1.82)	10.6	1.40 (1.08 to 1.82)	0.012	0.012
Other/unknown	3.9	1.21 (0.94 to 1.55)	0.131	7.6	1.41 (1.07 to 1.86)	0.015	9.0	0.87 (0.45 to 1.69)	9.0	0.87 (0.45 to 1.69)	0.679	0.679
Charlson-Deyo Score												
0	3.4	1.0	Ref	6.1	1.0	Ref	10.4	1.0	10.4	1.0	Ref	Ref
1	3.8	0.97 (0.88 to 1.08)	0.631	7.4	1.06 (0.99 to 1.12)	0.090	11.0	1.01 (0.87 to 1.18)	11.0	1.01 (0.87 to 1.18)	0.851	0.851
2+	5.2	1.25 (1.00 to 1.56)	0.051	9.2	1.26 (1.13 to 1.41)	<0.001	10.6	0.92 (0.72 to 1.16)	10.6	0.92 (0.72 to 1.16)	0.472	0.472
Year of treatment												
2006–2008	4.1	1.62 (1.41 to 1.85)	<0.001	5.5	0.74 (0.66 to 0.82)	<0.001	---	---	---	---	---	---
2009–2011	3.4	1.26 (1.12 to 1.42)	<0.001	7.0	0.94 (0.85 to 1.04)	0.214	---	---	---	---	---	---
2012–2013	3.6	1.28 (1.12 to 1.45)	<0.001	6.9	0.89 (0.80 to 0.98)	0.024	---	---	---	---	---	---
2014–2015	2.9	1.0	Ref	7.6	1.0	Ref	---	---	---	---	---	---
Hospital characteristics												
Hospital type												
Academic	3.0	1.0	Ref	6.4	1.0	Ref	10.1	1.0	10.1	1.0	Ref	Ref
Non-academic	3.8	1.26 (1.13 to 1.41)	<0.001	6.6	1.05 (0.93 to 1.18)	0.463	11.1	1.06 (0.89 to 1.26)	11.1	1.06 (0.89 to 1.26)	0.519	0.519
Hospital region												
New England	3.3	1.13 (0.88 to 1.46)	0.328	6.2	1.22 (1.01 to 1.47)	0.038	10.8	0.98 (0.71 to 1.36)	10.8	0.98 (0.71 to 1.36)	0.907	0.907
Middle Atlantic	3.3	1.12 (0.93 to 1.35)	0.236	6.4	1.19 (1.01 to 1.40)	0.039	8.0	0.67 (0.49 to 0.91)	8.0	0.67 (0.49 to 0.91)	0.012	0.012
South Atlantic	3.4	1.0	Ref	5.8	1.0	Ref	11.6	1.0	11.6	1.0	Ref	Ref
East North Central	3.7	1.18 (1.02 to 1.36)	0.026	7.4	1.32 (1.17 to 1.50)	<0.001	10.2	0.91 (0.71 to 1.18)	10.2	0.91 (0.71 to 1.18)	0.495	0.495
East South Central	3.8	1.09 (0.89 to 1.33)	0.397	6.4	1.04 (0.84 to 1.30)	0.695	9.6	0.79 (0.60 to 1.04)	9.6	0.79 (0.60 to 1.04)	0.097	0.097
West North Central	3.0	0.93 (0.77 to 1.13)	0.474	7.1%	1.30 (1.11 to 1.52)	0.001	13.6	1.20 (0.89 to 1.63)	13.6	1.20 (0.89 to 1.63)	0.234	0.234
West South Central	3.2	0.98 (0.82 to 1.17)	0.807	5.5	0.96 (0.81 to 1.15)	0.684	12.0	1.06 (0.75 to 1.50)	12.0	1.06 (0.75 to 1.50)	0.741	0.741
Mountain	4.2	1.37 (1.09 to 1.73)	0.007	7.9	1.56 (1.27 to 1.91)	<0.001	12.7	1.15 (0.82 to 1.62)	12.7	1.15 (0.82 to 1.62)	0.427	0.427
Pacific	4.1	1.37 (1.16 to 1.63)	<0.001	7.4	1.47 (1.29 to 1.67)	<0.001	10.9	0.89 (0.66 to 1.21)	10.9	0.89 (0.66 to 1.21)	0.461	0.461
Patient travel												
<5 miles	3.6	1.0	Ref	6.8	1.0	Ref	9.8	1.0	9.8	1.0	Ref	Ref
5–9.9 miles	3.5	1.02 (0.91 to 1.14)	0.759	6.3	0.99 (0.91 to 1.06)	0.698	9.9	1.04 (0.83 to 1.30)	9.9	1.04 (0.83 to 1.30)	0.753	0.753
10–19.9 miles	3.4	1.04 (0.92 to 1.17)	0.535	6.2	1.05 (0.97 to 1.14)	0.228	11.1	1.20 (0.97 to 1.49)	11.1	1.20 (0.97 to 1.49)	0.096	0.096

	Breast cancer			Colon cancer			Lung cancer		
	Rate, %	OR (95% CI)	P value	Rate, %	OR (95% CI)	P value	Rate, %	OR (95% CI)	P value
20+ miles	3.6	1.07 (0.96 to 1.20)	0.234	6.8	1.04 (0.96 to 1.14)	0.344	11.4	1.18 (0.97 to 1.44)	0.097
Tumour characteristics									
Pathologic T-stage									
Tis/T1	3.4	1.0	Ref	5.9	1.0	Ref	9.9	1.0	Ref
T2	3.9	1.02 (0.91 to 1.14)	0.759	7.0	1.14 (0.96 to 1.36)	0.121	11.9	1.17 (0.98 to 1.38)	0.077
T3/T4	3.4	1.04 (0.92 to 1.17)	0.535	6.9	1.13 (0.98 to 1.32)	0.101	9.9	0.96 (0.78 to 1.19)	0.736
Tx	0.4			4.3	0.80 (0.67 to 0.95)	0.012	6.8	0.66 (0.39 to 1.09)	0.106
Pathological N-stage									
N0	4.2	2.60 (2.23 to 3.04)	<0.001	---	---	---	---	---	---
N1	2.5	1.42 (1.20 to 1.68)	<0.001	7.1	1.27 (1.19 to 1.34)	<0.001	12.5	1.56 (1.33 to 1.83)	<0.001
N2+	1.9	1.0	Ref	5.6	1.0	Ref	8.4	1.0	Ref
Other N+	---	---	---	---	---	---	8.7	1.31 (0.91 to 1.87)	0.142

Table 3

Hospital-Level rates of failure to administer recommended chemotherapy by disease site

Cancer site	Median, %	IQR, %	Minimum, %	Maximum, %
Breast cancer	3.2	0.0–5.5	0.0	21.8
Colon cancer	6.2	3.6–9.1	0.0	40.2
Lung cancer	9.1	4.9–15.4	0.0	40.0