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Telemedicine Adoption and Low-Value Care Use and Spending Among Fee-for-Service Medicare Beneficiaries

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IMPORTANCE Low-value care is a persistent problem with direct and cascading harms. Telemedicine is now commonly used and may reduce low-value testing by introducing barriers to completing tests at a given visit or expand opportunities for low-value testing by contributing to higher visit volumes.

OBJECTIVE To quantify the association between telemedicine adoption and low-value testing among fee-for-service Medicare beneficiaries.

DESIGN, SETTING, AND PARTICIPANTS In this cohort study using 100% fee-for-service Medicare claims data, US health systems were divided into quartiles based on 2020 telemedicine adoption. Beneficiary-level linear regression in difference-in-differences (DiD) analyses was used to compare beneficiaries who were continuously enrolled from 2019 through 2022 and were attributed before telemedicine adoption (2019) to high telemedicine–adopting (top quartile) vs low telemedicine–adopting (bottom quartile) health systems on low-value test and visit outcomes in 2022 vs 2019. Data were analyzed from October 2023 to December 2024.

EXPOSURE Health system telemedicine adoption.

MAIN OUTCOMES AND MEASURES Receipt of, and spending on, 20 low-value screening, preoperative, chronic condition management, and acute diagnostic tests, as well as total visits (in person and virtual).

RESULTS The sample included 1 382 033 beneficiaries who were attributed to high-telemedicine systems (mean [SD] age, 71.6 [10.5] years; 58.8% female) and 999 051 beneficiaries who were attributed to low-telemedicine systems (mean [SD] age, 71.8 [10.0] years; 57.0% female). From 2019 to 2022, those in high-telemedicine systems had a small differential rise in visits (DiD visits per beneficiary, 0.12; 95% CI, 0.03 to 0.21) and differential decreases in use of 7 of 20 low-value tests: cervical cancer screening (DiD, −0.45 percentage points [pp]; 95% CI, −0.72 to −0.17 pp), screening electrocardiograms (DiD, −1.30 pp; 95% CI, −1.96 to −0.65 pp), screening metabolic panels (DiD, −1.84 pp; 95% CI, −2.87 to −0.80 pp), preoperative complete blood cell counts (DiD, −0.64 pp; 95% CI, −1.06 to −0.22 pp), preoperative metabolic panels (DiD, −1.35 pp; −1.91 to −0.80 pp), total or free T3 (triiodothyronine) level testing for hypothyroidism (DiD, −0.90 pp; 95% CI, −1.38 to −0.41 pp), and imaging for uncomplicated low back pain (DiD, −1.66 pp; 95% CI, −2.35 to −0.98 pp). There were no statistically significant differences in other tests. Those in high-telemedicine systems saw statistically significant differential decreases in spending on visits per beneficiary (−$47.87; 95% CI, −$86.85 to −$8.88) and on 2 of 20 low-value tests, but no differences in low-value spending overall.

CONCLUSIONS AND RELEVANCE In this cohort study, telemedicine adoption was associated with modestly lower use of 7 of 20 examined low-value tests (most point-of-care) and no changes in use of other low-value tests, despite a small rise in total visits that might offer more testing opportunities. Results suggest possible benefits of telemedicine and mitigate concerns about telemedicine contributing to increased spending.

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Multimedia

Supplemental content

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Low-value care—medical tests and other services that offer minimal benefit yet have potential for direct and cascading harms[1-5]—represents a common and persistent problem that worsens patient outcomes, contributes to excess medical spending, and diverts resources from high-value care.[6-9] Low-value care occurs in many contexts, including annual checkups, preoperative visits, and symptom-based visits.[5,7,10] Low-value care use declined early in the COVID-19 pandemic,[11,12] but it is unclear if this decline persisted or whether telemedicine played a role in deterring such care.

Understanding how telemedicine influences low-value care has gained new importance as telemedicine becomes a more established delivery modality with an uncertain policy future. Since March 2020, when the pandemic compelled rapid telemedicine adoption and the Centers for Medicare & Medicaid Services (CMS) broadened telemedicine coverage for fee-for-service (FFS) Medicare beneficiaries in response, telemedicine has persisted as a complement to in-person care.[13-15] In theory, telemedicine may reduce low-value care use by introducing barriers to completing these services at a given visit (eg, when patients are not in the office, clinicians may be less likely to order low-value tests or patients may be less likely to complete them).[16-19] This may be especially true for tests usually completed at point of care (ie, in the examination room or at an on-site laboratory), with examples including blood and urine tests, cervical cancer screening, and electrocardiograms. Conversely, clinical uncertainty stemming from the lack of physical examination in virtual (vs in-person) visits may lead clinicians to use more low-value diagnostic tests in virtual visits. Or, if telemedicine contributes to higher total visit volumes, low-value test use and spending may increase in aggregate across these visits.[20] Through such mechanisms, telemedicine may also narrow or exacerbate existing socioeconomic disparities in low-value care use and spending.[20-24]

To date, evidence on telemedicine and low-value care is limited and mixed. Prepandemic studies comparing direct-to-consumer telemedicine visits to office- or emergency department-based in-person visits found that direct-to-consumer telemedicine clinicians were equally likely[25,26] or more likely[17,27,28] to prescribe inappropriate antibiotics for upper respiratory infections and equally likely to order low-value back imaging.[27] In a Pennsylvania health system, patients seen via telemedicine had lower risk of low-value back imaging than those seen in the office.[29] A recent study of FFS Medicare beneficiaries in Michigan primary care practices found that telehealth was associated with lower rates of low-value cervical cancer screening and thyroid testing.[30]

Yet, national evidence on the relationship between telemedicine and low-value care is needed to inform policy decisions on telemedicine reimbursement and regulation. This is particularly important for FFS Medicare beneficiaries who are at high risk of low-value care[8,31,32] and for whom there is active debate about whether and how telemedicine reimbursement should continue (eg, whether reimbursements should remain equal for virtual and in-person visits), in part due to concerns about care quality and spending.[14,33] Therefore, we used FFS Medicare claims data to estimate the association between telemedicine adoption and use of and spending on a broad range of low-value tests, for the population overall and among those in racial minority groups or with Medicaid dual eligibility. We focused on tests since they comprise the majority of defined low-value services and are likely sensitive to visit modality.[34] The difference-in-differences (DiD) study design leveraged variation in telemedicine adoption across health systems (ie, the integrated health care delivery systems from which a large, growing share of Medicare beneficiaries receive care).[31,35]

Key Points

Question What is the relationship between telemedicine adoption and low-value care use among fee-for-service Medicare beneficiaries?

Findings In this difference-in-differences cohort study of 2 381 084 Medicare beneficiaries receiving care in 286 US health systems, those in high telemedicine–adopting systems vs low telemedicine–adopting systems had slightly higher total visit rates, modestly lower use of 7 of 20 observed low-value tests, and modestly lower spending on total visits and on 2 of 20 tests following telemedicine adoption.

Meaning Telemedicine adoption was associated with modestly lower use of, and spending on, some low-value tests, despite a small rise in total visits that might offer more testing opportunities.

Methods

Study Design and Data Sources

We used 2019 to 2022 100% FFS Medicare claims data and DiD analysis to compare beneficiaries who were continuously enrolled in Medicare Parts A and B through December 31, 2022, or until death, and attributed prepandemic (2019) to systems in the top vs bottom quartile of telemedicine adoption during the pandemic (2020). This quasi-experimental approach accounted for baseline quality differences in health systems and minimized selection bias since patients attributed to systems in 2019 could not have chosen these systems based on their future adoption of telemedicine. We used administrative and claims data from the beneficiary summary, Parts A and B, home health agency, skilled nursing facility, and Chronic Condition Data Warehouse files accessed through the CMS Virtual Research Data Center as well as the American Community Survey. When identifying diagnoses to construct patient cohorts, we used a lookback period starting in 2015.

This study was approved by Mass General Brigham's institutional review board. Patient informed consent was not required owing to use of deidentified data. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

Health System Definition and Attribution

We identified health systems using the Health Systems and Provider Database (HSPD),[35] which links data from the CMS Provider of Services File; American Hospital Association annual survey data; CMS Provider Enrollment, Chain, and Ownership System; IQVIA's physician and hospital database; and Medicare and commercial claims data. The database defines health systems as jointly owned or managed groups of provider organizations with 1 or more acute care hospitals, 10 or more primary care physicians, and 50 or more total physicians, and identifies mutually exclusive provider networks for each system.

Then, we identified all beneficiaries with 1 or more primary care visits in 2019 (Healthcare Common Procedure Coding System [HCPCS] codes 99201-15, G0402, or G0438-9, with provider specialty codes 01, 08, 11, or 38). Consistent with CMS Medicare Shared Savings Program methodology,[31] we attributed each of these beneficiaries to the physician practice (defined in the HSPD[35]) where they received the plurality of their primary care visits in 2019. We broke ties in visit number by using plurality of 2019 primary care spending. We then attributed each beneficiary to the health system affiliated with their practice. To ensure adequate sample to define the exposure, we excluded health systems with fewer than 100 attributed beneficiaries.

Exposure Definition

For each health system, we calculated the fraction of total ambulatory visits that was delivered via telemedicine among all attributed Medicare beneficiaries in 2020 (peak year for telemedicine adoption), then used this variable to group systems into quartiles of telemedicine adoption.[36] Total visits included in-person office and outpatient visits (Berenson-Eggers Type of Service 2.0 codes[37] beginning with EV or EB without telemedicine indicators) and telemedicine visits (HCPCS codes 99441-99443, 98966-98968, 99446-99452, 99453-99454, 99421-99423, 99457, 95250, 95251, 99091, G2061-G2063, G0425-G0427, G0459, G0406-G0408, G0508, G0509, 0188T, G0071, or G2025, or Berenson-Eggers Type of Service 2.0 codes beginning with EV or EB and Place of Service Code 02 or Modifier GT, GQ, 95, or G0).

Measures

Outcomes

The primary outcomes were low-value care use and spending. We calculated total visits per beneficiary in each calendar year. We then examined 20 low-value tests (based on the ABIM Foundation's Choosing Wisely campaign[34,38] and the US Preventive Services Task Force[39]) that are usually ordered in the context of a physician's visit, are usually provided either at point of care or scheduled at a later date, and have been associated with high direct or downstream cascade spending.[5,21,31,34,40,41] These included screening tests (cervical cancer screening,[42] colorectal cancer screening, prostate cancer screening,[42,43] carotid artery imaging in asymptomatic adults, screening electrocardiogram,[5,42] screening complete blood cell count with or without differential, screening metabolic panel, thyroid screening, and screening urinalysis[5]), preoperative tests (complete blood cell count with or without differential, metabolic panel, prothrombin time test with international normalized ratio, and partial thromboplastin time), chronic condition management tests (total or free T3 [triiodothyronine] testing in hypothyroidism and stress testing for stable coronary artery disease), and acute diagnostic tests (imaging for uncomplicated low back pain, carotid imaging for syncope, head imaging for syncope,[31] head imaging for uncomplicated headache,[31] and radiography for plantar fasciitis). For each test, we refined and operationalized established claims-based measures[5,31,35,44] within relevant patient cohorts based on age; sex; *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* diagnoses; and *Current Procedural Terminology*/HCPCS procedure codes (eTable 1 in Supplement 1). For example, we defined low-value cervical cancer screening as screening tests performed in women older than 65 years without history of, or certain risk factors for, cervical cancer. We then determined the proportion of beneficiaries eligible for each service (ie, for whom it would be considered low value) who received the service in a given year. We measured spending (based on allowed charges on relevant claims [2019 US dollars inflation adjusted to 2022 rates[45]]) on each service per service-eligible beneficiary, aggregated spending per service-eligible beneficiary across all low-value tests, and spending per service-eligible beneficiary on total visits.

Characteristics

Using 2019 data, we assessed beneficiary characteristics (age, sex, and race and ethnicity [Research Triangle Institute variable[46]], including American Indian or Alaska Native, Asian, Hispanic, non-Hispanic Black, non-Hispanic White, and other or unknown for those who could not be sorted into the named categories), Medicaid eligibility (proxy for low income), chronic condition count (out of 30 Chronic Condition Data Warehouse conditions[47]), and urban-rural residence (Rural-Urban Commuting Area Codes[48]); area-level characteristics (high school completion and median household income using American Community Survey, US Census region; all based on beneficiaries' zip code of residence); and health system characteristics[35] (share in primary care [percentage of physicians with primary care specialty] and ownership/size status).

Statistical Analysis

We ran descriptive statistics of patients in 2019 and graphed monthly use of each test in the exposure and comparison groups to allow visual assessment of preintervention trends. We used linear models to quantify univariate associations between total visits and use of each low-value service. We then conducted absolute DiD analysis using linear probability models to compare patients attributed to low (first quartile) vs high (fourth quartile) telemedicine-adopting health systems on the previously mentioned outcomes in 2019 vs 2022. We used linear models since interpretation of DiD interaction terms in nonlinear models is not uniquely defined.[49] We excluded 2020 to 2021 due to concerns that differences in COVID-19 prevalence in these years could bias results. Standard errors were clustered by hospital referral region (HRR) to account for unmeasured area-level practice differences and because most health systems are within single HRRs.

We first analyzed the outcome of total visits. Next, we assessed use of each low-value service as an outcome using 3 sets of models: without adjustment, with adjustment for total visits (to determine if accounting for visit volume changed the association between telemedicine and low-value test use), and with adjustment for beneficiary characteristics (age, sex, race and ethnicity, Medicaid eligibility status, chronic condition count, and urban-rural residence). Finally, we analyzed spending outcomes without and with adjustment for patient characteristics and calculated total low-value test spending changes and percentage changes in spending attributable to telemedicine adoption. The primary models were those adjusted for patient characteristics.

Sensitivity Analyses

DiD relies on the assumption that any differences in outcomes between the exposure and comparison groups would have remained constant (ie, parallel trends) over the study period in the absence of telemedicine introduction. While this assumption is, by definition, untestable, parallel preintervention trends lend it credibility. To this end, we used visual assessment of preintervention trends. We did not use significance testing for parallel preintervention trends (the parallel trends test) because these tests do not reliably rule out potentially meaningful violations.[50] Instead, we assessed differences in preintervention trends and ran sensitivity analyses estimating the results if any observed differences in preintervention trends had continued into the postintervention period. The main results, and the results of these trend-adjusted analyses, provide bounds under 2 assumptions: first, that trends remained parallel and, second, that differences in preintervention trends continued into the postintervention period. Then, to compare beneficiaries within the same areas, we repeated the primary models with HRR fixed effects. To examine potential time-varying confounding by Census region, we repeated the primary models with an interaction term between US Census region and year. We performed sensitivity analyses excluding decedents. Finally, to test the robustness of DiD results, we performed a negative control (placebo) test. Specifically, we analyzed an outcome representing a common elective procedure that should not be affected by increased telemedicine use: ocular biometry[1,51] (performed by ophthalmologists before cataract surgery). If we found no statistically significant DiD for this outcome, this would further reassure against major trajectory differences between low- and high-telemedicine systems that might threaten the validity of our approach.

Stratified Analyses

To understand how results varied by beneficiaries' sociodemographic status, we stratified by patient race and ethnicity (non-Hispanic White compared with those in racial or ethnic minority groups), since the social construct of race is associated with differential use of both telemedicine and low-value care.[21-24] We grouped individuals who were not non-Hispanic White into 1 category to allow sufficient sample size for each clinically defined cohort of service-eligible beneficiaries. We also stratified by Medicaid eligibility. We examined estimates within stratified groups for ease of interpretation and since results for individual groups were of primary interest.

We used SAS Enterprise Guide, version 7.15 HF9 (SAS Institute), and Stata, version 18 (StataCorp), for all analyses. P values were 2-sided, with $P < .05$ representing statistical significance. For primary models, we used Holm-Bonferroni correction to correct for multiple comparisons. Data were analyzed from October 2023 to December 2024.

Results

Characteristics

Of 6 520 377 beneficiaries meeting inclusion criteria, 1 382 033 beneficiaries were attributed to 143 high-telemedicine systems (mean [SD] age, 71.6 [10.5] years; 58.8% female) and 999 051 were attributed to 143 low-telemedicine systems (mean [SD] age, 71.8 [10.0] years; 57.0% female) (**Table 1** and eFigure 1 and eTable 2 in Supplement 1). High-telemedicine systems had larger shares of patients from racial and ethnic minority groups, with Medicaid eligibility, and living in urban areas and the Northeast, and they more often included academic medical centers. In 2022, 21% of beneficiaries in low-telemedicine systems and 43% of those in high-telemedicine systems had 1 or more telemedicine visits.

In 2019, beneficiaries in high-telemedicine systems vs low-telemedicine systems had more visits (10.9 vs 9.4), higher rates of some low-value services (eg, cervical and colorectal cancer screening, screening electrocardiograms), and lower rates of others (eg, prostate cancer screening, head imaging) (**Figures 1** and **2** and eTable 3 in Supplement 1). In 2019, monthly trends in visits and tests appeared parallel (eFigure 2 in Supplement 1). Post-telemedicine adoption, there was a small differential rise in total visits among beneficiaries in high-telemedicine systems (DiD visits per beneficiary, 0.12; 95% CI, 0.03 to 0.21) and differential decreases in the use of 7 low-value services: cervical cancer screening (DiD, −0.45 percentage points [pp]; 95% CI, −0.72 to −0.17 pp), screening electrocardiograms (DiD, −1.30 pp; 95% CI, −1.96 to −0.65 pp), screening metabolic panels (DiD, −1.84 pp; 95% CI −2.87 to −0.80 pp), preoperative complete blood cell counts (DiD, −0.64 pp; 95% CI, −1.06 to −0.22 pp), preoperative metabolic panels (DiD, −1.35 pp; 95% CI, −1.91 to −0.80 pp), total or free T3 level testing for hypothyroidism (DiD, −0.90 pp; 95% CI, −1.38 to −0.41 pp), and early back imaging for nonspecific low back pain (DiD, −1.66 pp; 95% CI, −2.35 to −0.98 pp) (Figures 1 and 2 and eTable 3 in Supplement 1).

Total Visits

Univariate associations between total visits and low-value service rates varied by service and were largely positive (eg, for blood tests usually offered at point of care) or of small magnitude (eTable 4 in Supplement 1). Adjusting models for total visits did not meaningfully change low-value test use results (eTable 3 in Supplement 1).

Spending

When examining individual low-value services, there were statistically significant differential decreases in spending per ben-

Table 1. Baseline Characteristics of Health Systems in the Lowest and Highest Quartiles of Telemedicine Adoption and of Attributed Beneficiaries, 2019

Characteristic	Quartiles of telemedicine adoption, No. (%) Low-telemedicine systems	High-telemedicine systems
Beneficiary level		
Total No. of beneficiaries	999 051	1 382 033
≥1 Telemedicine visit in 2020	334 893 (33.5)	960 225 (69.5)
≥1 Telemedicine visit in 2022	214 192 (21.4)	597 441 (43.2)
Age, mean (SD), y	71.8 (10.0)	71.6 (10.5)
Sex		
Female	569 421 (57.0)	812 474 (58.8)
Male	429 630 (43.0)	569 559 (41.2)
Race and ethnicity[a]		
American Indian or Alaska Native	3288 (0.3)	3160 (0.2)
Asian	6931 (0.7)	48 679 (3.5)
Hispanic	14 169 (1.4)	64 093 (4.6)
Non-Hispanic Black	49 865 (5.0)	122 799 (8.9)
Non-Hispanic White	902 395 (90.3)	1 091 530 (79.0)
Other or unknown	25 403 (2.5)	51 772 (3.7)
Medicaid eligibility	80 991 (8.1)	172 785 (12.5)
Total chronic conditions, mean (SD)	6.8 (3.4)	6.9 (3.5)
Urban residence	664 478 (66.5)	1 279 664 (92.6)
Area level[b]		
High school graduation rate, mean (SD), %	91.1 (5.6)	92.0 (6.5)
Household income, median (IQR), $	66 326 (62 575-76 009)	93 950 (67 337-113 204)
Census region		
West	117 807 (11.8)	257 435 (18.6)
Midwest	417 071 (41.8)	220 617 (16.0)
Northeast	36 966 (3.7)	573 583 (41.5)
South	417 071 (41.8)	330 359 (23.9)
Organizational		
Total No. of health systems	143	143
Share in primary care, mean (SD), %[c]	32.5 (8.6)	28.8 (11.5)
System size/ownership status		
Academic	2 (1.4)	53 (37.1)
Large for profit	2 (1.4)	1 (0.7)
Large nonprofit	27 (18.9)	23 (16.1)
Public	38 (26.6)	17 (11.9)
Other private	74 (51.8)	49 (34.3)

[a] Race and ethnicity categories are based on Research Triangle Institute codes, which pull from Social Security Administration data. The other category includes all people whose race could not be sorted into the 5 named categories in Social Security Administration data.

[b] Area-level characteristics refer to characteristics of the attributed beneficiaries' zip code of residence.

[c] Share in primary care is defined as the percentage of all physicians in the health system who have a primary care specialty.

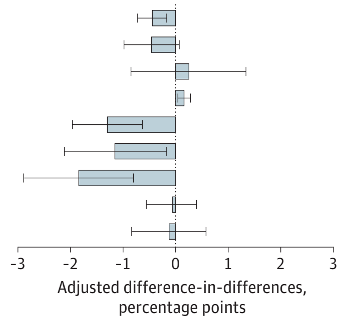
eficiary for 2 of 20 services: cervical cancer screening (−$0.56; 95% CI, −$0.89 to −$0.23; 27% spending reduction) and preoperative blood cell counts (−$0.15; 95% CI, −$0.24 to −$0.06; 7% reduction). Across all beneficiaries eligible for 1 or more low-value services, there was no differential change in total low-value care spending per beneficiary (−$0.15; 95% CI, −$2.62 to $2.33). There was a statistically significant decrease in total visit spending per beneficiary (−$47.87; 95% CI, −$86.85 to −$8.88) (**Table 2**).

Sensitivity Analyses

Preintervention trend differences in visit rates and low-value care use and spending were very small, except those for low-value acute diagnostic services, for which high-telemedicine systems had been increasing use and spending more rapidly than low-telemedicine systems prior to telemedicine adoption (eTable 5 in Supplement 1). In DiD models adjusting for trend differences, the magnitude and statistical significance of the estimates were essentially unchanged, with some exceptions. For low-value care use, there were new statistically significant differential decreases for beneficiaries in high- vs low-telemedicine systems for 2 tests: carotid imaging for syncope (−1.41 pp; 95% CI, −1.95 to −0.87 pp) and head imaging for syncope (−2.15 pp; 95% CI, −3.49 to −0.81 pp) (eTable 3 in Supplement 1). For spending, the differential total visit spending decrease was no longer statistically significant (−$38.62; 95% CI, −$77.45 to $0.22), but there were new statistically significant differential decreases in spending per beneficiary for 6 tests: screening electrocardiograms (−$0.15; 95% CI, −$0.29 to −$0.02), thyroid screening (−$0.09; 95% CI, −$0.22 to −$0.04), stress testing (−$0.61; 95% CI, −$1.22 to −$0.01), carotid imaging for syncope (−$1.12; 95% CI, −$2.15 to −$0.09),

Figure 1. Differential Changes in Use of Low-Value Screening Tests for Medicare Beneficiaries in High- vs Low-Telemedicine Health Systems

	Low-telemedicine systems		High-telemedicine systems	
Screening tests	2019 Use, % of eligible beneficiaries	Adjusted pre-post difference in use	2019 Use, % of eligible beneficiaries	Adjusted pre-post difference in use
Cervical cancer screening[a]	3.68	-1.70	5.04	-2.17
Colorectal cancer screening	4.84	-1.91	5.57	-2.59
Prostate cancer screening	41.97	-6.89	39.66	-6.39
Carotid artery imaging in asymptomatic adults	4.18	-0.07	4.24	0.09
Screening electrocardiogram[a]	13.52	-1.56	17.19	-3.06
Screening CBC with or without differential	67.96	1.33	65.31	0.12
Screening metabolic panel[a]	70.94	-1.09	68.59	-3.06
Thyroid screening	14.77	1.03	17.20	0.95
Screening urinalysis	26.02	-1.77	25.16	-1.96

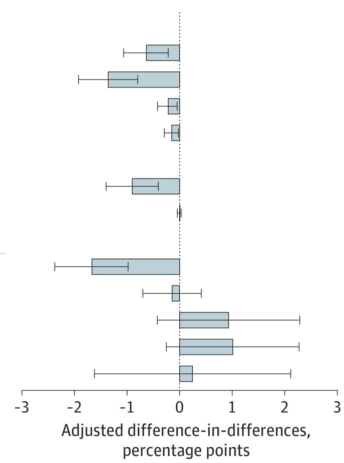


The figure shows difference-in-differences estimates adjusted for beneficiary characteristics. Eligible beneficiaries include those for whom a given test would be considered low value. Error bars represent 95% CIs. CBC indicates complete blood cell count.

[a]Statistically significant after Holm-Bonferroni correction.

Figure 2. Differential Changes in Use of Low-Value Preoperative, Chronic Condition Management, and Acute Diagnostic Tests for Medicare Beneficiaries in High- vs Low-Telemedicine Health Systems

	Low-telemedicine systems		High-telemedicine systems	
Test	2019 Use, % of eligible beneficiaries	Adjusted pre-post difference in use	2019 Use, % of eligible beneficiaries	Adjusted pre-post difference in use
Preoperative				
Complete blood cell count with or without differential[a]	25.39	3.32	24.58	2.65
Metabolic panel[a]	23.72	3.31	24.09	1.95
Prothrombin time test with INR	4.61	-0.13	4.89	-0.36
Partial thromboplastin time	2.20	0.06	2.56	-0.09
Chronic condition management				
Total or free T3 testing in hypothyroidism[a]	5.43	0.36	8.15	-0.52
Stress testing for stable coronary artery disease	1.38	-0.38	1.46	-0.39
Acute diagnostic				
Imaging for uncomplicated low back pain[a]	15.03	6.47	14.85	4.72
Carotid imaging for syncope	4.39	-0.12	3.47	-0.24
Head imaging for syncope	23.53	-0.32	21.32	0.54
Head imaging for uncomplicated headache	22.50	1.46	20.98	2.46
Radiography for plantar fasciitis	17.17	1.85	17.91	2.08



The figure shows difference-in-differences estimates adjusted for beneficiary characteristics. Eligible beneficiaries include those for whom a given test would be considered low value. INR indicates international normalized ratio; T3, triiodothyronine. Error bars represent 95% CIs.

[a]Statistically significant after Holm-Bonferroni correction.

head imaging for syncope (−$10.36; 95% CI, −$13.23 to −$7.49), and head imaging for uncomplicated headache (−$8.31; 95% CI, −$11.32 to −$5.30) (eTable 6 in Supplement 1). Results of sensitivity analyses with HRR fixed effects, time-varying Census region effects, or decedents excluded were very similar (eTable 3 in Supplement 1). In the negative control test, there was no association between telemedicine adoption and ocular biometry (DiD, 0.13; 95% CI, −0.04 to 0.30).

Stratified Results

When examining low-value test receipt stratified by race and ethnicity (eTable 7 in Supplement 1) and Medicaid eligibility (eTable 8 in Supplement 1), there were no substantial qualitative differences between groups.

Discussion

In this national study of FFS Medicare beneficiaries, those receiving care in high-telemedicine health systems saw modest differential decreases in use of 7 of 20 low-value tests and no changes in others, despite a small increase in total visits that might offer more testing opportunities. Spending was lower for 2 low-value tests and for total visits, while there was no differ-

Table 2. Differential Changes in Spending on 20 Low-Value Tests and Visits for Medicare Beneficiaries in High-Telemedicine vs Low-Telemedicine Health Systems

Spending outcome	Spending per beneficiary, mean (SD), $[a]				DiD spending per beneficiary (95% CI), $[b]	Change (95% CI)	
	Preperiod		Postperiod				
	Low telemedicine	High telemedicine	Low telemedicine	High telemedicine		Total spending, $[c]	Spending, %[d]
Total low-value care spending	65.73 (259.50)	55.99 (246.15)	50.06 (220.81)	40.18 (198.67)	−0.15 (−2.62 to 2.33)	−203 982 (−3 562 886 to 3 168 520)	−0.4 (−6.1 to 6.2)
Total visit spending	1255.92 (1138.23)	1627.99 (1671.30)	1207.49 (1144.30)	1531.70 (1617.62)	−47.87 (−86.85 to −8.88)	−65 097 456 (−118 105 578 to −12 075 734)	−3.0 (−5.4 to −0.58)
Low-value screening tests							
Cervical cancer screening	2.33 (14.02)	3.43 (17.62)	1.00 (8.27)	1.54 (10.56)	−0.56 (−0.89 to −0.23)[e]	−408 314 (−648 928 to −167 700)	−26.7 (−36.6 to −13.0)
Colorectal cancer screening	23.62 (190.89)	25.52 (208.04)	15.1 (144.7)	15.73 (154.45)	−1.04 (−4.63 to 2.55)	−68 186 (−303 557 to 167 186)	−6.2 (−22.7 to 19.3)
Prostate cancer screening	24.78 (48.84)	18.32 (37.84)	19.63 (42.54)	13.46 (30.05)	0.40 (−1.00 to 1.80)	139 048 (−347 619 to 625 714)	3.1 (−6.9 to 15.4)
Carotid artery imaging in asymptomatic adults	6.08 (51.59)	5.06 (50.48)	4.84 (44.20)	3.86 (41.00)	0.05 (−0.24 to 0.34)	55 611 (−266 931 to 378 152)	1.3 (−5.9 to 9.7)
Screening electrocardiogram	1.30 (11.82)	1.15 (10.57)	1.10 (10.57)	0.85 (8.85)	−0.11 (−0.24 to 0.03)	−18 737 (−40 880 to 5110)	−11.5 (−22.0 to 3.7)
Screening complete blood cell count with or without differential	10.11 (20.73)	8.56 (16.02)	8.78 (19.30)	6.93 (13.27)	−0.32 (−0.63 to −0.01)	−198 287 (−390 378 to −6196)	−4.4 (−8.3 to −0.14)
Screening metabolic panel	14.02 (29.20)	12.29 (25.99)	11.94 (32.71)	9.51 (22.90)	−0.72 (−1.30 to −0.14)	−122 299 (−220 818 to −23 780)	−7.0 (−12.0 to −1.5)
Thyroid screening	2.85 (9.70)	3.02 (9.23)	2.73 (9.89)	2.80 (8.54)	−0.10 (−0.22 to 0.03)	−42 827 (−94 219 to 12 848)	−3.4 (−7.3 to 1.1)
Screening urinalysis	1.10 (4.09)	1.03 (3.56)	0.88 (3.84)	0.78 (3.26)	−0.04 (−0.10 to 0.03)	−32 754 (−81 884 to 16 377)	−4.9 (−11.4 to 2.6)
Low-value preoperative tests							
Complete blood cell count with or without differential	2.64 (10.15)	2.36 (7.32)	2.48 (9.19)	2.05 (6.27)	−0.15 (−0.24 to −0.06)[e]	−59 214 (−94 743 to −23 686)	−6.8 (−10.5 to −2.8)
Metabolic panel	3.41 (13.07)	3.23 (12.39)	3.21 (13.13)	2.75 (10.75)	−0.30 (−0.50 to −0.09)	−31 545 (−52 575 to −9463)	−9.8 (−15.4 to −3.2)
Prothrombin time with INR	0.25 (3.98)	0.24 (2.89)	0.18 (3.61)	0.14 (1.95)	−0.03 (−0.07 to 0.01)	−18 772 (−43 800 to 6257)	−17.6 (−33.3 to 7.7)
Partial thromboplastin time	0.05 (1.39)	0.04 (0.97)	0.05 (1.52)	0.04 (0.88)	−0.01 (−0.02 to −0.00)	−6257 (−12 514 to 0)	−21.7 (−35.7 to 0.0)
Low-value chronic condition management tests							
Total or free T3 level testing for hypothyroidism	0.41 (5.03)	0.44 (4.49)	0.37 (4.61)	0.33 (3.86)	−0.08 (−0.14 to −0.01)	−34 464 (−60 311 to −4308)	−19.5 (−29.8 to −2.9)
Stress testing for stable coronary artery disease	8.67 (114.33)	7.26 (107.85)	5.64 (89.99)	4.53 (80.55)	0.28 (−0.32 to 0.89)	2 036 698 (−2 327 654 to 6 473 789)	6.6 (−6.6 to 24.5)
Low-value acute diagnostic tests							
Imaging for uncomplicated low back pain	7.18 (68.20)	7.56 (56.68)	7.85 (61.85)	7.76 (52.90)	−0.52 (−1.13 to 0.10)	−62 988 (−136 877 to 12 113)	−6.3 (−12.7 to 1.3)
Carotid imaging for syncope	5.99 (45.63)	5.31 (44.70)	4.96 (36.50)	4.11 (36.80)	−0.17 (−1.20 to 0.86)	−5296 (−37 380 to 26 789)	−4.0 (−22.6 to 26.5)
Head imaging for syncope	25.31 (124.46)	17.28 (92.43)	23.12 (108.55)	15.9 (76.00)	0.75 (−2.11 to 3.62)	20 595 (−57 941 to 99 405)	5.0 (−11.7 to 29.5)
Head imaging for uncomplicated headache	32.99 (148.47)	25.29 (122.18)	29.53 (122.61)	24.35 (112.67)	2.37 (−0.64 to 5.37)	52 924 (−14 292 to 119 917)	10.8 (−2.6 to 28.3)
Radiography for plantar fasciitis	3.95 (26.79)	5.06 (24.53)	5.16 (30.70)	5.26 (25.38)	−1.11 (−2.31 to 0.09)	−7790 (−16 212 to 631)	−17.4 (−30.5 to 1.7)

Abbreviations: DiD, difference-in-differences; INR, international normalized ratio; T3, triiodothyronine.

[a] Per-beneficiary spending estimates for each low-value service (which were calculated for the relevant populations eligible for each service) do not add up to the total per-beneficiary low-value spending estimates (which were calculated among all beneficiaries eligible for at least 1 service) because of the differences in relevant denominators.

[b] Adjusted for patient characteristics, including age, sex, Medicaid eligibility status, chronic condition count, and urban-rural residence.

[c] Total spending changes were calculated by taking the product of the characteristics-adjusted DiD estimates and the number of eligible beneficiaries in the high-telemedicine systems in 2022.

[d] The percentage changes were calculated by dividing the DiD estimates by the difference between 2022 high-telemedicine system spending and the DiD estimate, representing postperiod spending per beneficiary in the high-telemedicine systems had they not adopted telemedicine.

[e] Statistically significant after Holm-Bonferroni correction.

ential change in spending for other tests or across all 20 tests. These results suggest that while virtual options might lower the bar to obtain a physician's visit, as reflected in higher visit rates found here and in prior work,[15,52] telemedicine may also deter certain low-value tests and some of the direct and cascade spending and other harms that can result.[5,53]

Specifically, the present findings support the hypothesis that on the margin, a virtual (vs in-person) visit may be a deterrent for clinicians or patients considering point-of-care low-value tests outside of acute scenarios. We found differential reductions in screening tests usually completed in examination rooms (eg, cervical cancer screenings, electrocardiograms) and some screening, preoperative, and monitoring blood tests usually completed at on-site laboratories. In contrast, there was no statistically significant change for colon cancer screening or stress tests, which are typically scheduled for later dates. These findings are largely consistent with those of the study focused on Medicare beneficiaries in Michigan,[30] which found reductions in low-value cervical cancer screening and thyroid testing and no change for the 6 other low-value services examined (including prostate cancer screening, colorectal cancer screening, head imaging for headache, and back imaging for low back pain.) In contrast to the Michigan study, we found that at a national level there were differential reductions in low-value diagnostic tests for the usually self-limited condition low back pain, which may reflect shifts in care-delivery patterns associated with telemedicine adoption (eg, clinicians may offer follow-up virtual visits for reassurance in lieu of imaging).

To the extent that low-value testing is reduced, it is natural to ask whether there are similar, but unwanted, effects on high-value care. Using similar methodology, members of our group found no differential changes in use of high-value screening tests for breast, colorectal, prostate, or cervical cancer.[15] That study also found slightly lower rates of visits with any imaging or laboratory test, corroborating studies showing fewer overall tests associated with virtual vs in-person visits in primary care,[16,52] otolaryngology,[18] and cardiology.[19] Thus, it is possible that the testing "friction" introduced by the virtual modality differs by the perceived value of a test, which clinicians and health systems could harness to encourage higher-value testing decisions.

The present findings of modest absolute decreases in use of and spending on a subset of examined low-value tests and visit savings require nuanced interpretation. Some low-value test reductions represent large relative decreases (eg, cervical cancer screening use dropped by 13% and spending by 27%). Our estimates reflect the possible impact of a relatively small difference in telemedicine adoption (21% vs 43%); future policy initiatives that increase telemedicine use to a larger extent might influence low-value care use differently. Our estimates are conservative in that when accounting for different trajectories in low-value care use predating telemedicine adoption, telemedicine adoption was associated with decreased use and spending for more tests (9 and 8 out of 20, respectively). Savings may also be underestimated given the high potential[34] of these tests to trigger costly cascades of uncertain clinical benefit.[1,2,5,53] Alongside the estimated $66 million in total savings on visit reimbursements (likely due to virtual visits being billed at lower complexity levels), the present findings provide policymakers some reassurance against telemedicine increasing spending on low-value care and visits. Finally, the lack of substantive differences by patient race and ethnicity and Medicaid eligibility is somewhat reassuring and may reflect variable relationships between these factors and both telemedicine use and low-value care.[20-24]

Limitations

While this is the first study, to our knowledge, to examine telemedicine and low-value care use and spending nationally across a range of services, we note several limitations. Findings may not generalize to those enrolled in Medicare Advantage or other plans. We focus on health systems, where up to half of Medicare beneficiaries receive care[31,35,40]; results may not generalize to those who primarily receive care from other settings. We note well-described limitations of claims (eg, we cannot observe clinicians' intentions nor orders that were placed but not completed; there may be coding practice variation across regions and health systems over time). Finally, while the quasi-experimental DiD design reduces selection bias and allows for a comparison group to account for temporal trends, and sensitivity analyses reinforced the robustness of the main analyses, results may be biased by unobserved system-level confounders to the extent that they produced unanticipated differences in the trajectories of each group (eg, high vs low adopters of telemedicine may have made differential changes in other aspects of care delivery that influence low-value care). Future studies should explore the extent to which these patterns are explained by differences in clinicians ordering tests vs patients completing them and examine low-value prescribing.

Conclusions

In this cohort study, Medicare beneficiaries exposed to greater telemedicine adoption postpandemic had slightly more visits, yet modestly lower use of 7 of 20 examined low-value tests and modestly lower spending on 2 services and total visits. As CMS and private payers evaluate telemedicine reimbursement policies, such as the extension of Medicare's temporary allowance of broad telemedicine coverage beyond 2024,[33] these results suggest potential benefits of telemedicine and mitigate concerns about telemedicine contributing to increased Medicare spending.

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REFERENCES

1. Ganguli I, Lupo C, Mainor AJ, et al. Prevalence and cost of care cascades after low-value preoperative electrocardiogram for cataract surgery in fee-for-service Medicare beneficiaries. *JAMA Intern Med*. 2019;179(9):1211-1219. doi:10.1001/jamainternmed.2019.1739

2. Ganguli I, Simpkin AL, Lupo C, et al. Cascades of care after incidental findings in a US national survey of physicians. *JAMA Netw Open*. 2019;2(10):e1913325. doi:10.1001/jamanetworkopen.2019.13325

3. Ganguli I, Simpkin AL, Colla CH, et al. Why do physicians pursue cascades of care after incidental findings? a national survey. *J Gen Intern Med*. 2020; 35(4):1352-1354. doi:10.1007/s11606-019-05213-1

4. Ganguli I, Cui J, Thakore N, et al. Downstream cascades of care following high-sensitivity troponin test implementation. *J Am Coll Cardiol*. 2021;77(25): 3171-3179. doi:10.1016/j.jacc.2021.04.049

5. Ganguli I, Lupo C, Mainor AJ, et al. Assessment of prevalence and cost of care cascades after routine testing during the Medicare annual wellness visit. *JAMA Netw Open*. 2020;3(12):e2029891. doi:10.1001/jamanetworkopen.2020.29891

6. Shrank WH, Rogstad TL, Parekh N. Waste in the US health care system: estimated costs and potential for savings. *JAMA*. 2019;322(15):1501-1509. doi:10.1001/jama.2019.13978

7. Ganguli I, Souza J, McWilliams JM, Mehrotra A. Association of Medicare's annual wellness visit with cancer screening, referrals, utilization, and spending. *Health Aff (Millwood)*. 2019;38(11):1927-1935. doi:10.1377/hlthaff.2019.00304

8. Mafi JN, Reid RO, Baseman LH, et al. Trends in low-value health service use and spending in the US Medicare fee-for-service program, 2014-2018. *JAMA Netw Open*. 2021;4(2):e2037328. doi:10.1001/jamanetworkopen.2020.37328

9. Park S, Jung J, Burke RE, Larson EB. Trends in use of low-value care in traditional fee-for-service Medicare and Medicare Advantage. *JAMA Netw Open*. 2021;4(3):e211762. doi:10.1001/jamanetworkopen.2021.1762

10. Gerend MA, Bradbury R, Harman JS, Rust G. Characteristics associated with low-value cancer screening among office-based physician visits by older adults in the USA. *J Gen Intern Med*. 2022;37 (10):2475-2481. doi:10.1007/s11606-021-07072-1

11. Levine DM, Samal L, Neville BA, et al. The association of the first surge of the COVID-19 pandemic with the high- and low-value outpatient care delivered to adults in the USA. *J Gen Intern Med*. 2022;37(15):3979-3988. doi:10.1007/s11606-022-07757-1

12. Chalmers K, Brownlee S, Gopinath V, Saini V. Overuse in US Medicare during the COVID-19 pandemic: 2020 versus 2019. *medRxiv*. Preprint posted online August 5, 2022. doi:10.1101/2022.05.25.22275006

13. Bartelt K, Piff A, Allen S, Barkley E. Telehealth utilization higher than pre-pandemic levels, but down from pandemic highs. Epic Research. November 21, 2023. Accessed August 9, 2024. https://www.epicresearch.org/articles/telehealth-utilization-higher-than-pre-pandemic-levels-but-down-from-pandemic-highs

14. Medicare's coverage of telehealth: considerations from the Congressional Budget Office. Congressional Budget Office. July 1, 2024. Accessed January 21, 2025. https://www.cbo.gov/system/files/2024-06/60458-Telehealth.pdf

15. Nakamoto CH, Cutler DM, Beaulieu ND, Uscher-Pines L, Mehrotra A. The impact of telemedicine on Medicare utilization, spending, and quality, 2019–22. *Health Aff (Millwood)*. 2024;43 (5):691-700. doi:10.1377/hlthaff.2023.01142

16. Norden JG, Wang JX, Desai SA, Cheung L. Utilizing a novel unified healthcare model to compare practice patterns between telemedicine and in-person visits. *Digit Health*. 2020;6: 2055207620958528. doi:10.1177/2055207620958528

17. Uscher-Pines L, Mulcahy A, Cowling D, Hunter G, Burns R, Mehrotra A. Antibiotic prescribing for acute respiratory infections in direct-to-consumer telemedicine visits. *JAMA Intern Med*. 2015;175 (7):1234-1235. doi:10.1001/jamainternmed.2015.2024

18. Shehan JN, Agarwal P, Danis DO III, et al. Effects of COVID-19 on telemedicine practice patterns in outpatient otolaryngology. *Am J Otolaryngol*. 2021; 42(6):103044. doi:10.1016/j.amjoto.2021.103044

19. Yuan N, Pevnick JM, Botting PG, et al. Patient use and clinical practice patterns of remote cardiology clinic visits in the era of COVID-19. *JAMA Netw Open*. 2021;4(4):e214157. doi:10.1001/jamanetworkopen.2021.4157

20. Schpero WL, Morden NE, Sequist TD, Rosenthal MB, Gottlieb DJ, Colla CH. Datawatch: for selected services, blacks and Hispanics more likely to receive low-value care than whites. *Health Aff (Millwood)*. 2017;36(6):1065-1069. doi:10.1377/hlthaff.2016.1416

21. Ganguli I, Mackwood MB, Yang CWW, et al. Racial differences in low value care among older adult Medicare patients in US health systems: retrospective cohort study. *BMJ*. 2023;383:e074908. doi:10.1136/bmj-2023-074908

22. Marcondes FO, Normand ST, Le Cook B, et al. Racial and ethnic differences in telemedicine use. *JAMA Health Forum*. 2024;5(3):e240131. doi:10.1001/jamahealthforum.2024.0131

23. Reed ME, Huang J, Graetz I, et al. Patient characteristics associated with choosing a telemedicine visit vs office visit with the same primary care clinicians. *JAMA Netw Open*. 2020;3 (6):e205873. doi:10.1001/jamanetworkopen.2020.5873

24. White-Williams C, Liu X, Shang D, Santiago J. Use of telehealth among racial and ethnic minority groups in the United States before and during the COVID-19 pandemic. *Public Health Rep*. 2023;138 (1):149-156. doi:10.1177/00333549221123575

25. Yao P, Clark S, Gogia K, Hafeez B, Hsu H, Greenwald P. Antibiotic prescribing practices: is there a difference between patients seen by telemedicine versus those seen in-person? *Telemed J E Health*. 2020;26(1):107-109. doi:10.1089/tmj.2018.0250

26. Shi Z, Mehrotra A, Gidengil CA, Poon SJ, Uscher-Pines L, Ray KN. Quality of care for acute respiratory infections during direct-to-consumer telemedicine visits for adults. *Health Aff (Millwood)*. 2018;37(12):2014-2023. doi:10.1377/hlthaff.2018.05091

27. Uscher-Pines L, Mulcahy A, Cowling D, Hunter G, Burns R, Mehrotra A. Access and quality of care in direct-to-consumer telemedicine. *Telemed J E Health*. 2016;22(4):282-287. doi:10.1089/tmj.2015.0079

28. Ray KN, Shi Z, Gidengil CA, Poon SJ, Uscher-Pines L, Mehrotra A. Antibiotic prescribing during pediatric direct-to-consumer telemedicine visits. *Pediatrics*. 2019;143(5):e20182491. doi:10.1542/peds.2018-2491

29. Baughman D, Ptasinski A, Baughman K, Buckwalter N, Jabbarpour Y, Waheed A. Comparable quality performance of acute low-back pain care in telemedicine and office-based cohorts. *Telemed J E Health*. 2022;28(11). doi:10.1089/tmj.2021.0535

30. Liu T, Zhu Z, Thompson MP, et al. Primary care practice telehealth use and low-value care services. *JAMA Netw Open*. 2024;7(11):e2445436. doi:10.1001/jamanetworkopen.2024.45436

31. Ganguli I, Morden NE, Yang CWW, Crawford M, Colla CH. Low-value care at the actionable level of individual health systems. *JAMA Intern Med*. 2021; 181(11):1490-1500. doi:10.1001/jamainternmed.2021.5531

32. Boudreau E, Schwartz R, Schwartz AL, et al. Comparison of low-value services among Medicare Advantage and traditional Medicare beneficiaries. *JAMA Health Forum*. 2022;3(9):e222935. doi:10.1001/jamahealthforum.2022.2935

33. Calendar year (CY) 2025 Medicare Physician Fee Schedule proposed rule. Centers for Medicare & Medicaid Services. July 10, 2024. Accessed August 8, 2024. https://www.cms.gov/newsroom/fact-sheets/calendar-year-cy-2025-medicare-physician-fee-schedule-proposed-rule

34. Ganguli I, Thakore N, Rosenthal MB, Korenstein D. Longitudinal content analysis of the characteristics and expected impact of low-value services identified in US Choosing Wisely recommendations. *JAMA Intern Med*. 2022;182(2):127-133. doi:10.1001/jamainternmed.2021.6911

35. Beaulieu ND, Chernew ME, McWilliams JM, et al. Organization and performance of US health systems. *JAMA*. 2023;329(4):325-335. doi:10.1001/jama.2022.24032

36. Patel SY, Mehrotra A, Huskamp HA, Uscher-Pines L, Ganguli I, Barnett ML. Variation in telemedicine use and outpatient care during the COVID-19 pandemic in the United States. *Health Aff (Millwood)*. 2021;40(2):349-358. doi:10.1377/hlthaff.2020.01786

37. Restructured BETOS Classification System. Centers for Medicare & Medicaid Services. Accessed September 20, 2023. https://data.cms.gov/provider-summary-by-type-of-service/provider-service-classifications/restructured-betos-classification-system

38. Bhatia RS, Levinson W, Shortt S, et al. Measuring the effect of Choosing Wisely: an integrated framework to assess campaign impact on low-value care. *BMJ Qual Saf*. 2015;24(8):523-531. doi:10.1136/bmjqs-2015-004070

39. US Preventive Services Task Force website. Accessed October 21, 2024. https://www.uspreventiveservicestaskforce.org/uspstf/

40. Ganguli I, Crawford ML, Usadi B, et al. Who's accountable? low-value care received by Medicare beneficiaries outside of their attributed health systems. *Health Aff (Millwood)*. 2023;42(8):1128-1139. doi:10.1377/hlthaff.2022.01319

41. Chant ED, Crawford M, Yang CWW, Fisher ES, Morden NE, Ganguli I. Sources of low-value care received by Medicare beneficiaries and associated spending within US health systems. *JAMA Netw Open*. 2023;6(9):e2333505. doi:10.1001/jamanetworkopen.2023.33505

42. Mafi JN, Russell K, Bortz BA, Dachary M, Hazel WA Jr, Fendrick AM. Low-cost, high-volume health services contribute the most to unnecessary health spending. *Health Aff (Millwood)*. 2017;36(10):1701-1704. doi:10.1377/hlthaff.2017.0385

43. Ma X, Wang R, Long JB, et al. The cost implications of prostate cancer screening in the Medicare population. *Cancer*. 2014;120(1):96-102. doi:10.1002/cncr.28373

44. Schwartz AL, Landon BE, Elshaug AG, Chernew ME, McWilliams JM. Measuring low-value care in Medicare. *JAMA Intern Med*. 2014;174(7):1067-1076. doi:10.1001/jamainternmed.2014.1541

45. Gross domestic product: implicit price deflator. Federal Reserve Bank of St. Louis. July 25, 2024. Accessed August 14, 2024. https://fred.stlouisfed.org/series/GDPDEF

46. Jarrín OF, Nyandege AN, Grafova IB, Dong X, Lin H. Validity of race and ethnicity codes in Medicare administrative data compared with gold-standard self-reported race collected during routine home health care visits. *Med Care*. 2020;58(1):e1-e8. doi:10.1097/MLR.0000000000001216

47. Condition categories. Chronic Conditions Data Warehouse. Accessed January 20, 2020. https://www2.ccwdata.org/web/guest/condition-categories

48. Rural-Urban Commuting Area (RUCA) codes. WWAMI Rural Health Research Center. Accessed September 26, 2022. https://familymedicine.uw.edu/rhrc/ruca/

49. Ai C, Norton EC. Interaction terms in logit and probit models. *Econ Lett*. 2003;80(1):123-129. doi:10.1016/S0165-1765(03)00032-6

50. Bilinski A, Hatfield LA. Nothing to see here? non-inferiority approaches to parallel trends and other model assumptions. *arXiv*. Preprint posted online May 8, 2018. https://arxiv.org/abs/1805.03273

51. Chen CL, Lin GA, Bardach NS, et al. Preoperative medical testing in Medicare patients undergoing cataract surgery. *N Engl J Med*. 2015;372(16):1530-1538. doi:10.1056/NEJMsa1410846

52. Zeltzer D, Einav L, Rashba J, Balicer RD. The impact of increased access to telemedicine. *J Eur Econ Assoc*. 2024;22(2):712-750. doi:10.1093/jeea/jvad035

53. Ganguli I, Ying W, Shakley T, Colbert JA, Mulligan KL, Friedberg MW. Cascade services and spending following low-value imaging for uncomplicated low back pain among commercially insured adults. *J Gen Intern Med*. 2023;38(4):1102-1105. doi:10.1007/s11606-022-07829-2