Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

eMethods.

Contents

I. Claims-based measures of low-value services

The aim of this section is to describe the low-value service measures employed in our study. Our processes for selecting low-value services for measure construction, developing operational definitions of the measures, and constructing algorithms to detect the services have been described in greater detail elsewhere.[1]

A. Service selection

Services were screened for measure appropriateness from the sources listed in the paper using the following criteria: (1) the service must apply to the general Medicare population; (2) high-value use of the service must be plausibly distinguishable from low-value use using information available in Medicare claims and enrollment files; (3) the published evidence establishing the low-value of the service must have existed prior to 2009. Fulfillment of the second criteria was assessed by the physicians on our research team. The incompleteness of claims information regarding patients' symptoms led to the exclusion of many candidate services.

For some services (e.g., imaging for pulmonary embolism without moderate or high pre-test probability), there was an obvious lack of clinical information in claims necessary to define the low-value scenario (e.g., pre-test probability of pulmonary embolism depends in part on heart rate and physical exam findings not recorded in claims). For other services, we inspected a small random sample of claims detected by preliminary measure algorithms to determine if cases of potentially appropriate use could be systematically excluded. For example, to identify cardiac stress tests for low-risk, asymptomatic patients would require excluding cases with a wide range of symptoms, including non-specific symptoms (e.g., nausea and diaphoresis), as well as cases

with risk factors present that may not be captured in claims (e.g., smoking status, family history, dyslipidemia). In contrast, symptoms of carotid artery disease are more circumscribed as they relate directly to transient ischemic attacks and strokes; thus, we could more confidently exclude appropriate use in developing a measure of screening for asymptomatic carotid artery disease.

B. Service detection

We detected target services on the basis of *Current Procedural Terminology (CPT)* codes appearing in Medicare Carrier and Outpatient Research Identifiable Files. These files include claims for services across all relevant clinical settings. Claims submitted by providers in non-hospital outpatient settings appear in the Carrier file, as do services performed by physicians during inpatient hospital stays. Services delivered in hospital outpatient departments and safety net settings may appear only in the Outpatient file or in both the Carrier and Outpatient files.

Following detection of these target services, restriction criteria were applied using patient demographic data as well as diagnostic and clinical details present in the service claim or other claims. Demographic information like sex and age were drawn from the Beneficiary Summary Files. Patient diagnoses were assessed on the basis of *International Classification of Diseases, Ninth Revision (ICD-9)* codes present in the Carrier and Outpatient files as well as chronic conditions present in the Chronic Conditions Data Warehouse (CCW). The CCW draws from Medicare diagnosis codes collected since 1999, allowing assessment of beneficiaries' accumulated chronic condition burden from initial dates of diagnosis. These fields allow us to assess whether a chronic condition had been diagnosed prior to a service date of interest.

Some operational definitions of low-value service occurrence depend on site of care or timing of the service delivery. For example, preoperative testing measures require an assessment

of whether the testing was followed by a surgical procedure; several other measures employ exclusion restrictions for services received during or shortly following an inpatient stay. Specific services preceding or following a target service were detected in the Carrier or Outpatient files on the basis of CPT codes or Berenson Eggers Type of Service (BETOS) codes. The timing of inpatient stays was identified using admissions and discharge dates present in the Medicare Provider and Analysis Review (MedPAR) files. Emergency department visits were detected on the basis of emergency department evaluation and management CPT codes in the Carrier or Outpatient files, revenue center codes in the Outpatient file, admissions source and type designations in the MedPAR file, and MedPAR emergency department charges. The measure of pulmonary artery catheterization in an intensive care unit (ICU), which required identification of an ICU stay during a non-surgical hospital admission, relied upon a MedPAR indicator for ICU use and Medicare Severity Diagnosis Related Groups (MS-DRGs) indicating medical admissions, based on a prior study.[2] In order to ensure a sufficiently long temporal window of claims preceding a target service that occurred in a given study year, the restriction criteria incorporate claims from the prior calendar year in addition to the study year. For example, when assessing whether a stress test from early January of 2010 met our operational definition of stress testing for stable coronary disease, we checked whether the patient receiving that test had visited an emergency department in December 2009. Similarly, when assessing whether a 2011 use of cervical cancer screening met the operational definition of our low-value cervical cancer screening measure, we used claims data from 2010 to check for relevant diagnoses (human papillomavirus positivity, dysplasia, etc.) for the woman who received the screening.

All codes used for service detection (CPT, ICD-9, BETOS, MS-DRG, and CCW indications) are listed for each service in column 2 of eTable 1. Because the codes for classifying services and

diagnoses change slightly over time, our detection algorithms included some codes that were added or deleted over the course of the study period.

C. Prices

Constructing standardized prices for each service allowed us to categorize services by price (higher-priced vs lower-priced) and to assess spending on low-value services using a price-standardized measure that did not vary as a consequence of setting or geography. In particular, services are reimbursed generally at higher rates in Medicare when provided in hospital outpatient departments rather than in the office setting, and prior research suggests potential shifts from higher priced hospital outpatient settings to lower priced office settings in response to Pioneer ACO contracts.[3] For each measure, a standardized price was calculated as the median of total allowed charges (to Medicare, beneficiaries, and other payers) for relevant services. Prices were calculated based on charges for services detected in the first year of our study period.

For 25 of 31 measures, relevant services consisted of the detected service and other specific services delivered on the same day. For example, venipuncture is included as a relevant service for PSA screening. For the remaining six measures, which detected procedural/surgical services, it was not possible to comprehensively specify the many CPT codes that could be relevant to the service. As described in prior methods,[1] we employed two alternate pricing methods for these measures based on total daily charges and/or inpatient prospective payments. First, for services often performed in the outpatient setting (vertebroplasty, renal artery angioplasty, arthroscopic knee surgery, and spinal injections), we isolated encounters appearing in both the Carrier and Outpatient files and estimated price based on the sum of Carrier and Outpatient allowed charges during the day of the procedure. Second, for surgical procedures

occurring near-exclusively in the inpatient setting (carotid endarterectomy and PCI), price was estimated based on the sum of allowed Carrier charges during the procedure date and the spending allowed by the MS-DRG in the MedPAR file. To limit the inclusion of spending on unrelated services, we restricted the pricing sample to instances where the detected service was the only procedure listed in the MedPAR stay or where the assigned DRG for the admission corresponded to the detected service. CPT and MS-DRG codes for relevant services are included in column 3 of eTable 1.

In order to ensure that prices were consistent across measures, prices for identical services included in multiple different measures (e.g. head imaging for syncope and head imaging for headache) were based on a pooled set of care episodes detected by both measures. For measures that include multiple services with substantial variation in price, we calculated a standardized price for each service. For example, separate prices were calculated for stress testing involving only exercise treadmill testing and for tests including advanced imaging.

The 16 measures with the highest standardized prices were designated as high-price and the remaining 15 were designated as low-price. Each beneficiary's annual spending on detected services was calculated by multiplying his or her annual count of each service by its standardized price.

D. Qualifying indicators

Many beneficiaries do not fit the demographic or clinical characteristics needed to qualify for potential receipt of services we measured. Failure to account for differential changes in the qualifying characteristics of beneficiaries in the ACO vs non-ACO groups could introduce bias into our difference-in-difference estimations. As a result, we include binary indicators of

measure qualification as covariates in our models. These qualification criteria are included in column 4 of eTable 1. We avoided qualification criteria based on symptoms (i.e. back pain or headache) since whether a beneficiary meets such criteria could be influenced by changes in provider practice patterns. We constructed fifteen binary indicators for measure qualification, some applying to multiple measures, for each beneficiary in each year of our study sample.

We conducted a sensitivity test in which qualifying indicators were omitted from regressions estimating differential changes in the count of low-value services and associated spending. Results were extremely close to those presented in Table 2. In these analyses, the start of Pioneer contracts was associated with a differential reduction of 0.8 low value services per 100 beneficiaries in the ACO group ($P<0.001$) and a differential reduction in spending on these services of $455 per 100 beneficiaries ($P=0.005$). These corresponded to reductions of 2.0% and 4.4%, respectively.

II. Beneficiary attribution to ACOs

This section briefly describes our method for attributing beneficiaries to ACOs using Medicare claims data. See prior work for additional details.[3]

A. Defining ACOs

CMS uses claims data to assign a patient population to each Pioneer ACO. In order to determine whether a beneficiary received care at an ACO, CMS relies on a set of National Provider Identifier (NPI) and taxpayer identification number (TIN) combinations that identifies claims submitted by each ACO's set of providers contracting with Medicare. Although the NPI-TIN combinations are not publicly released, ACOs are required to post lists of participating

physicians, practices, and facilities on their website. Because Pioneer ACOs are permitted to select a subset of individual physicians within a practice for inclusion in contracts, we defined ACOs as collections of NPIs for our analysis. For each of the 32 Pioneer ACOs, we matched the listed names of participating physicians, practices, and facilities to an NPI or TIN.[4,5] TINs were converted to the NPIs that billed primarily under that TIN.[3,6] We confirmed that 96% of the NPIs in our ACO definitions appeared in the source files maintained by CMS that list providers participating in the Pioneer program (the Master Data Management MDD Provider Extract files), and 99.9% of these NPIs were attributed to the same ACO by our method and the CMS source files.

By defining each ACO as a collection of NPIs, we held the physicians within each ACO constant over the study period. Holding constant the composition of physicians in each ACO has the advantage of avoiding bias caused by ACOs altering the composition of physicians (i.e. selecting more efficient physicians) after the start of contracts. However, if physicians changed practice affiliations during the study, it could result in misattribution of beneficiaries. This misattribution could introduce error into our measures of ACO performance if physicians' practice patterns changed as they changed practice settings. However, we doubt that this was a major source of bias in our analyses because, despite any changes in organizational affiliations among the NPIs within an ACO, trends in the use of low-value services were similar in the ACO and control groups during the pre-contract period.

B. Attribution of beneficiaries

We adapted the MSSP attribution rules to assign each beneficiary in each year to the ACO or non-ACO TIN that accounted for the most allowed charges for primary care services

received by the beneficiary.[7] Beneficiaries were attributed based on outpatient primary care services (defined by the MSSP rules as CPT codes 99201-99215, G0402, G0438, and G0439). We did not attribute beneficiaries based on physician services provided in nursing facilities or other settings (99304-99318, 99324-99340, and 99341-99350), which are also included in the definition of primary care services in the MSSP rules. We excluded these services to be consistent with prior research,[3] and because nursing facilities and nursing facility-based physicians are underrepresented in Pioneer ACO contracts. Thus, including these services would have caused the ACO group to be systematically different from the control group. We supplemented the above primary care service codes with outpatient specialty consultation codes (CPT codes 99241-99245) in order to maintain a consistent set of services used for attribution throughout the study period. This latter set of codes was eliminated from the Medicare Physician Fee Schedule in 2010, after which physicians used alternate office visit codes in the 99201-99215 range to bill for consultations. Including the eliminated codes prevented any abrupt increase from 2009 to 2010 in the number of patients attributed to ACOs who received primary care services only from specialists.

We attributed beneficiaries in each study year based on their use of outpatient primary care services in that year (retrospective attribution), as in the MSSP. The Pioneer program attributes beneficiaries to ACOs prospectively based on their utilization in the three-year pre-contract period. We chose retrospective attribution because prospective attribution may produce regression-to-the-mean effects that would have biased our findings. For example, note that prospective attribution requires use of primary care services in the pre-contract period, but not in the post-contract period. As a result, some beneficiaries prospectively attributed to an ACO based on use of primary care services in the pre-contract period will not use any care in the post-

contract period. This implies a reduction in measured health care utilization for these beneficiaries at the start of the contract period. If the proportion of patients with no primary care services differs between populations served by ACOs and non-ACO providers, the regression-to-the-mean effect would differ between comparison groups, thereby biasing estimates of differential changes in utilization.

III. Baseline outcomes and mean reversion

Two measures were constructed to assess organizations' baseline rate of low-value service delivery in 2008. The first was a measure of rates of low-value service use in ACO service areas. The measure is based on the risk-adjusted rate of low-value service in each ACO's geographic service area among beneficiaries in the non-ACO group. This estimate is calculated by performing linear regression of per-beneficiary counts of low-value services in 2008 for the control group on a set of HRR indicators as well as the demographic and clinical controls appearing in our main analyses. Then, for each ACO, we calculate an average of the HRR coefficients that is weighted by number of the ACO's beneficiaries in each HRR. ACOs are then categorized as serving areas with high or low levels of low-value services according to whether the weighted average falls above or below that of the median service area. The second measure assesses an ACO's baseline performance relative to its geographic service area. This measure is calculated using the full ACO and non-ACO sample by regressing low-value service counts in 2008 on beneficiary covariates, HRR indicators and ACO indicators. ACOs are classified as above or below the HRR average based on whether their fixed effects coefficients are greater than zero or less than zero.

These measures, based on 2008 data, are predictive of ACO characteristics in the 2009-2011 pre-contract period. In the 2009-2011 ACO group, the adjusted utilization of low-value services relative to the local mean was 5.5 services per 100 beneficiaries higher for ACOs with levels greater than the local mean in 2008 that that of ACOs with levels lower than the local mean in 2008 ($P<0.001$). Also, in 2009-2011, the adjusted count of low-value services in ACO service areas was 12.2 services per 100 beneficiaries higher for ACOs classified as high-use services areas in 2008 than for those classified as low-use service areas ($P<0.001$).

In assessing these baseline characteristics, we used data from 2008, before the start of the study period, to minimize the possibility of bias from regression to the mean. Bias from regression to the mean may occur whenever analyzing whether high or low baseline levels of an outcome to predict future changes in that outcome. Using 2008 data to categorize ACOs at baseline, we observed no evidence of regression to the mean during the pre-contract period. Indeed, ACOs with high baseline utilization levels relative to their service area saw adjusted low-value service utilization grow somewhat faster by 0.5 services per year during 2009-2011 ($P=.06$), a temporal trend in the opposite direction as would be predicted by regression to the mean.

IV. Analyses adjusting for pre-contract trends

We repeated our main analyses with models that test and adjust for the presence of non-parallel trends in outcomes between the ACO and non-ACO groups during the pre-contract period. These models were of the following form:

$$E(Y_{i,t,k,h}) = \beta_0 + \beta_1 ACO\_indicators_k + \beta_2 HRR\_indicators_h \times Year_t + \beta_3 ACO\_contract_{kt} + \beta_4 ACO\_Group_k \times Year\_Continuous_t + \beta_5 Covariates_{it}$$

where "Year_Continuous" is the year of study observation, specified continuously (2009-2012). This model differs from those described in the body of the manuscript because of the inclusion of the "ACO_Group×Year_Continuous" term, whose β_4 term adjusts for the difference in linear annual trend between the ACO and non-ACO group in the pre-contract period. The magnitude and statistical significance of this coefficient serve as our test for non-parallel trends in the pre-contract period. There was no statistically significant evidence of non-parallel trends for any of the outcomes reported in Table 3. For example, during the pre-contract period, the adjusted annual count of low-value services in the ACO group changed at a rate of 0.1 services per 100 beneficiaries per year faster than the non-ACO group (P=0.74), and adjusted spending on low-value services in the ACO group changed at a rate of $20 per 100 beneficiaries per year slower (P=0.88).

β_3 remains the coefficient representing the estimated effect of Pioneer contracts in 2012. However, this estimate now reflects the assumption that, in the absence of the Pioneer contract, outcomes in the ACO group would undergo a shift equal any shift experienced by non-ACO beneficiaries in the region, and would have continued according to the estimated prior linear trend for the ACO group, which may not have been parallel to that of non-ACO beneficiaries in

the region. This assumption may not be reasonable, especially if a pre-contract divergence in trends is random. Such divergence in pre-contract trend would tend to be followed by convergence in the post-contract period rather than continued divergence, due to regression to the mean. Importantly, introducing the trend term into this model increases the confidence intervals on the β_3 coefficient because the estimates now incorporate the additional uncertainty with which these extrapolated trends were estimated. Still, we believe that these models serve a useful purpose as a robustness test even though no statistically significant divergent trends were found in the pre-contract period, since non-significant differences in trend may reflect systematic factors and could have a meaningful impact on estimates. Estimates of trend-adjusted differential changes in low-value service frequency were very similar to those presented in Table 3. Following trend-adjustment, the magnitude of the differential reduction in the count of low-value services was largely unchanged, moving from 1.9% to 2.1%, as was the magnitude of the differential decrease in spending on low-value services, moving from 4.5% to 4.1%.

In order to adjust our analyses of organizational subgroups for pre-contract trends, we introduced interactions between the organizational characteristics of interest and the β_3 and β_4 terms. Results from these analyses are presented in eFigure 1. Following trend adjustment, the estimated effects of Pioneer contracts were still greater for ACOs with higher baseline levels of low-value services than their service area (-1.8 services per 100 beneficiaries) than for ACOs with lower baseline rates (-0.1 services per 100 beneficiaries, P=0.002 for difference), and there were still no statistically significant associations between ACO performance and low-value service use in ACO service areas at baseline.

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eTable 1. Codes for Measures of Low-Value Services

Measure	Codes for detection and restriction criteria	Additional codes for pricing	Beneficiaries qualifying for potential use of service
Cancer screening for patients with chronic kidney disease (CKD) receiving dialysis	**BETOS:** P9A P9B (dialysis) **CPT:** 77057 G0202 (breast screening), G0104-G0106 G0120 - G0122 G0328 45330-45345 45378-45392 82270 (colorectal screening), G0102 G0103 84152-84154 (prostate screening), G0101 G0123 G0124 G0141 G0143 G0144 G0145 G0147 G0148 P3000 P3001 Q0091 (cervical screening)	**CPT:** 36415 (venepuncture), 77051-77059 (mammography add-on codes), 00810 (endoscopy sedation), 87620-87622 (HPV tests)	Patients with CKD[a] receiving dialysis[b]
Cervical cancer screening for women over age 65	**CPT:** G0123 G0124 G0141 G0143 G0144 G0145 G0147 G0148 P3000 P3001 Q0091 (cervical screening) **ICD-9:**180 184x 2190 2331 2332 2333x 6221 (cervical and other relevant cancers, dysplasias) 7950x-7951x (abnormal Papanicolaou finding, human papillomavirus positivity) V1040 V1041 V1322 V1589 (history of cervical cancer, other relevant cancers, dysplasia)	**CPT:** 87620-87622 (HPV tests)	Women over 65
Colorectal cancer screening for adults older than age 85 years	**CCW:** Colorectal cancer first indication date **ICD-9:** V7651 (colon cancer screening) **CPT:** G0104-G0106 G0120-G0122 G0328 45330-45345 45378-45392 82270 (sigmoidoscopy, colonoscopy, barium enema or blood occult test)	**CPT:** 00810 (sedation)	Patients over 75
Prostate-specific antigen (PSA)	**CCW:** Prostate cancer first indication date	**CPT:** 36415 (venepuncture)	Men over 75

testing for men over age 75	**CPT:** G0103 84152-84154 (PSA testing)		
Bone mineral density testing at frequent intervals	**CCW:** Osteoporosis first indication date **CPT:** 76070 76071 76075 76076 76078 76977 77078-77081 77083 78350 78351 (bone density testing)	None	Patients with osteoporosis[a]
Homocysteine testing for cardiovascular disease	**CPT:** 83090 (homocysteine chemistry) 82746 82747 82607 (folate or B12 testing) **ICD-9:** 2662 2704 2810-2812 2859 (folate or B12 disorders)	**CPT:** 36415 (venepuncture)	All patients
Hypercoagulability testing for patients with deep vein thrombosis	**CPT:** 81240 81241 83090 85300 85303 85306 85613 86147 (hypercoagulability chemistries) **ICD-9:** 4151 (pulmonary embolism) 4510 45111 45119 4512 45181 4519 4534 4535 (phlebitis, thrombophlebitis and venous embolism of lower extremity vessels) V1251 V1255 (history of venous thrombosis and embolism, pulmonary embolism)	**CPT:** 83890-83914 (nucleic acid molecular diagnostics)	Patients with deep vein thrombosis[b]
Parathyroid hormone (PTH) measurement for patients with stage 1-3 CKD	**BETOS:** P9A P9B (dialysis) **CCW:** Chronic kidney disease first indication date **CPT:** 83970 (parathyroid hormone chemistry)	**CPT:** 36415 (venepuncture)	Patients with CKD[a] not receiving dialysis[b]
Total or free T3 level testing for patients with hypothyroidism	**CPT:** 84480 84481 (total or free T3) **CCW**: Hypothyroidism first indication date	None	Patients with hypothyroidism[b]
1,25-dihydroxyvitamin	**CPT:**82652 (1, 25 dihydroxyvitamin D3)	None	All patients

D testing in the absence of hypercalcemia or decreased kidney function	**CCW:** Chronic kidney disease first indication date **ICD-9:** 27542 (hypercalcemia) 58881 (secondary hyperparathyroidism of renal origin) 135x 01x 173x 174x 175x 1890 1891 188x 1830 200x-208x (sarcoidosis, TB, select neoplasms)		
Preoperative chest radiography	**BETOS:** P1x P3D P4A P4B P4C P5C P5D P8A P8G (selected surgeries) **ICD-9** V7281 V7282 V7283 V7284 (preoperative examination **CPT:** 71010 71015 71020-71023 71030 71034 71035 (chest x-ray), 19120 19125 47562 47563 49560 58558 (relevant surgical codes not included in BETOS categories)	None	Patients undergoing selected surgeries[b]
Preoperative echocardiography	**BETOS:** P1x P3D P4A P4B P4C P5C P5D P8A P8G (selected surgeries) **CPT:** 93303 93304 93306-93308 93312 93315 93318 (echocardiogram) 19120 19125 47562 47563 49560 58558 (relevant surgical codes not included in BETOS categories)	**CPT:** 93303-93352 (echocardio-graphy)	Patients undergoing selected surgeries[b]
Preoperative pulmonary function testing (PFT)	**BETOS:** P1x P2x P3D P4A P4B P4C P5C P5D P8A P8G (selected surgeries) **CPT:** 94010 (spirometry)	**CPT:** 94010-94799 (pulmonary non-ventilatory services), 93720-93722 (plethysmography)	Patients undergoing selected surgeries[b]
Preoperative stress testing	**BETOS:** P1x P3D P4A P4B P4C P5C P5D P8A P8G (selected surgeries)	**CPT:** 93000-93042 (ECG), 93303-93352 (echocardiography), 78414-78499 (cardiovascular nuclear diagnostic	Patients undergoing selected surgeries[b]

	CPT: 75552-75564 75574 78451-78454 78460 78461 78464 78465 78472 78473 78481 78483 78491 78492 93015-93018 93350 93351 0146T 0147T 0148T 0149T (stress testing, cardiac MRI, CT angiography) 19120 19125 47562 47563 49560 58558 (relevant surgical codes not included in BETOS categories)	services), 75552-75564 (cardiac MRI), 75571-75574 (cardiac CT), A9500-A9700 (contrast), J0150 J0152 J0280 J1245 J1250 J2785 (pharmacologic stress test injection)	
Computed tomography (CT) of the sinuses for uncomplicated acute rhinosinusitis	**CPT:** 70486-70488 (CT of maxillofacial area) **ICD-9:** 461x 473x (sinusitis), 2770x 042 07953 279xx (immune disorders), 471x (nasal polyp) 373xx 37600 (eyelid/orbit inflammation), 800xx-804xx 850xx-854xx 870xx-873xx 9590x 910xx 920xx-921xx (head or face trauma)	None	All patients
Head imaging in the evaluation of syncope	**CPT:** 70450 70460 70470 70551-70553 (CT or MRI of head or brain) **ICD-9:** 7802 9921 (syncope), 345xx 7803x (epilepsy or convulsions), 43xx (cerebrovascular diseases, including stroke/TIA and subarachnoid hemorrhage), 800xx-804xx 850xx-854xx 870xx-873xx 9590x 910xx 920xx-921xx (head or face trauma), 78097 781xx 7820 7845x (altered mental status, nervous and musculoskeletal system symptoms, including gait abnormality, meningismus, disturbed skin sensation, speech deficits), V1254 V10xx (personal history of stroke/TIA)	None	Patients with syncope diagnosis[b]

Head imaging for uncomplicated headache	**CPT:** 70450 70460 70470 70551-70553 (CT or MRI of head or brain) **ICD-9:** 30781 339xx 346x 7840 (headache or migraine), 33920-33922 33943 (post-traumatic or thunderclap headache), 14xx–208xx 230xx-239xx (cancer), 3463x 3466x (migraine with hemiplegia or infarction), 4465 (giant cell arteritis), 345xx 7803x (epilepsy or convulsions), 43xx (cerebrovascular diseases, including stroke/TIA and subarachnoid hemorrhage), 800xx-804xx 850xx-854xx 870xx-873xx 9590x 910xx 920xx-921xx (head or face trauma), 78097 781xx 7820 7845x 79953 (altered mental status, nervous and musculoskeletal system symptoms, including gait abnormality, meningismus, disturbed skin sensation, speech deficits), V1254 V10xx (personal history of stroke/TIA or cancer)	None	All patients
Electro-encephalogram for headaches	**CPT:** 95812 95813 95816 95819 95822 95827 95830 95957 (electroencephalogram) **ICD-9:** 30781 339x 346x 7840 (headaches) 345xx 7803x 7810 (epilepsy or convulsions)	None	All patients
Back imaging for patients with non-specific low back pain	**CPT:** 72010 72020 72052 72100 72110 72114 72120 72200 72202 72220 72131-72133 72141 72142 72146-72149 72156 72157 72158 (radiologic, CT, and MRI imaging of spine)	None	All patients

	ICD-9: 7213 72190 72210 72252 7226 72293 72402 7242-7246 72470 72471 72479 7385 7393 7394 846x 8472 (back pain, various causes), 14xx–208xx 230xx-239xx (cancer), 800x-839xx 850xx-854xx 86xxx 905xx-909xx 92611 92612 929, 952xx 958xx-959xx (trauma), 3040x-3042x 3044x 3054x-3057x (IV drug abuse), 34460 7292x (neurologic impairment), 4210 4211 4219 (endocarditis), 038xx (septicemia), 01xxx (tuberculosis), 730xx (osteomyelitis), 7806x 7830x 7832x 78079 7808x 2859x (fever, weight loss, malaise, night sweats, anemia not due to blood loss) 72142 72191 72270 72273 7244 (myelopathy, neuritis and radiculopathy)		
Screening for carotid artery disease in asymptomatic adults	**CPT:** 70498 70547-70549 93880 93882 3100F (carotid imaging) **CCW:** Stroke/TIA first indication date **ICD-9:** 430 431 43301 43311 43321 43331 43381 43391 43400 43401 43410 43411 43490 43491 4350 4351 4353 4358 4359 436 99702 V1254 (stroke/TIA), 3623 36284 (retinal vascular occlusion/ischemia), 7802 781xx 7820 78451 78452 78459 9921 (nervous and musculoskeletal symptoms)	None	All patients
Screening for carotid artery disease for syncope	**CPT:** 70498 70547-70549 93880 93882 3100F (carotid imaging) **CCW:** Stroke/TIA first indication date	None	Patients with syncope diagnosis[b]

	ICD-9: 7802 9921 (syncope), 430 431 43301 43311 43321 43331 43381 43391 43400 43401 43410 43411 43490 43491 4350 4351 4353 4358 4359 436 99702 V1254 (stroke/TIA), 3623 36284 (retinal vascular occlusion/ischemia), 781xx 7820 7845x 78459 (nervous and musculoskeletal symptoms)		
Imaging for diagnosis of plantar fasciitis/heel pain	**CPT:**73620 73630 73650 (foot radiograph) 73718 73719 73720 (foot MRI) 76880 76881 76882 (extremity ultrasound) **ICD-9:**72871 7294 (plantar fasciitis)	None	Patients with fasciitis diagnosis[b]
Stress testing for stable coronary disease	**CPT:** 75552-75564 75574 78451-78454 78460 78461 78464 78465 78472 78473 78481 78483 78491 78492 93015-93018 93350 93351 0146T 0147T 0148T 0149T (stress testing, cardiac MRI, CT angiography) **CCW:** Ischemic heart disease first indication date, AMI first indication date	**CPT:** 93000-93042 (ECG), 93303-93352 (echocardiography), 78414-78499 (cardiovascular nuclear diagnostic services), 75552-75564 (cardiac MRI), 75571-75574 (cardiac CT), A9500-A9700 (contrast), J0150 J0152 J0280 J1245 J1250 J2785 (pharmacologic stress test injection)	IHD patients[a]
Percutaneous coronary intervention with balloon angioplasty or stent placement for stable coronary disease	**CPT:** 92980 92982 (coronary stent placement or balloon angiography) **CCW:** Ischemic heart disease first indication date, AMI first indication date	**DRG:** 246-251[c] (percutaneous cardiovascular procedure)	IHD patients[a]
Renal artery angioplasty or	**CPT:** 35471 35450 37205 37207 75960 75966 (renal artery	None[d]	Patients with hypertension

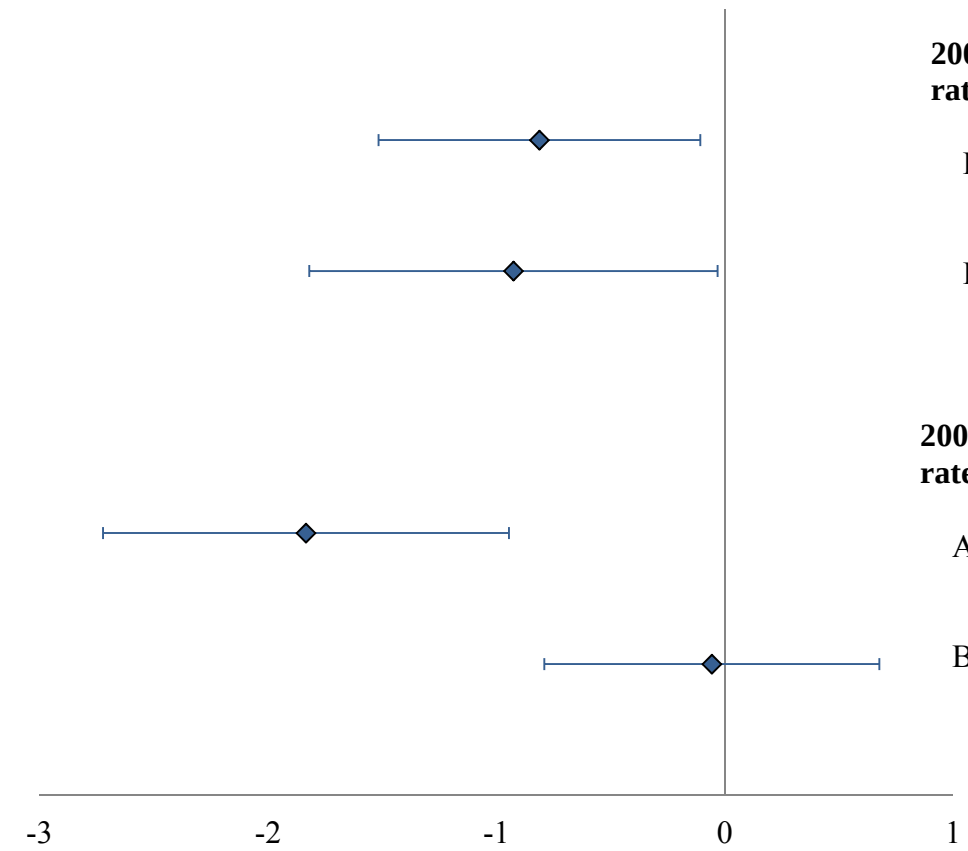
stenting	angioplasty or stenting) **ICD-9:** 4401 40501 40511 40591 (atherosclerosis of renal artery, renovascular hypertension)		(ICD-9: 36221 40xxx 4372)[b]
Carotid endarterectomy in asymptomatic patients	**CPT:** 35301 (carotid endarterectomy) **CCW:** Stroke/TIA first indication date **ICD-9:** 430 431 43301 43311 43321 43331 43381 43391 43400 43401 43410 43411 43490 43491 4350 4351 4353 4358 4359 436 99702 V1254 (stroke/TIA), 3623 36284 (retinal vascular occlusion/ischemia), 781xx 7820 7845x (nervous and musculoskeletal symptoms)	**ICD-9 Procedure**: 3812 0040-0042[e] (carotid endarterectomy)	All patients
Inferior vena cava filters for the prevention of pulmonary embolism	**CPT:** 37191 37192 (IVC placement, repositioning) 75940 (radiological supervision of inferior vena cava filter placement)	**CPT:** 36010 37620 75825 76937 (catheter insertion, IVC interruption, venography, ultrasound guidance)	All patients
Pulmonary Artery Catheterization in the ICU	**CPT**: 93503 (Swan-Ganz placement) **ICD-9:** 4233 (cardiac tamponade) 4160 4161 4162 4168 4169 (pulmonary hypertension) **MS-DRGs (2008-2012):** 001-003 005-008 010 020-033 037-042 113-117 129-139 163-168 215-245 252-264 326-358 405-425 453-517 820-830 853-858 876 901-909 927-929 939-941 955-959 969-970 981-989	None	Patients who were hospitalized with a non-surgical MS-DRG[f]
Vertebroplasty or kyphoplasty for	**CPT:** 22520 22521 22523 22524 (vertebroplasty, kyphoplasty)	None[d]	Patients with osteoporosis[a]

osteoporotic vertebral fractures	**ICD-9:** 73313 8052 8054 (vertebral fracture) , 1702 1985 20973 20300-20302 2132 22809 2380 2386 2392 (primary or secondary neoplasm of vertebral column, multiple myeloma, hemangioma)		
Arthroscopic surgery for knee osteoarthritis	**CPT:** 29877 29879 29880 29881 G0289 (knee arthroscopy with chondroplasty) **ICD-9:** 7177 73392 71500 71509 71510 71516 71526 71536 71596 (chondromalacia, osteoarthritis), 8360-8362 7170 71741 (meniscal tear)	None[d]	All patients
Spinal injection for low-back pain	**CPT:** 62311 64483 (epidural injections) 20552 20553 (trigger point injections) 64493 64475 (facet injections) J1438 (etanercept injection) **ICD-9:** 72142 72191 72270 72273 7243 7244 (back pain with radiculopathy) 7213 72190 72210 7222 72252 7226 72280 72283 72293 72400 72402 72403 7242 7245 7246 72470 72471 72479 7384 7385 7393 7384 7385 7393 7394 75612 8460-8463 8468 8469 8472 (other back pain)	None[d]	All patients

a	Defined by the presence of CCW first indication date prior to December 31st of the year
b	Defined by presence of relevant diagnosis or procedure codes during the year.
c	The pricing sample was restricted to detected hospital admissions with these DRG codes. All professional charges for expenses incurred on the same day of service were included in pricing estimates along with the DRG allowed charges.
d	The pricing sample was restricted to detected episodes that appeared in both the Carrier and Outpatient files. All institutional and professional charges for expenses incurred on the same day of service were included in pricing estimates.
e	The pricing sample was restricted to detected hospital admissions with no procedures besides those listed here. All professional charges for expenses incurred on the same day of service were included in pricing estimates.

f	Non-medical DRGs were defined according to methods presented in a prior study.[2]

eFigure. Trend-Adjusted Differential Changes in Use of Low-Value Services in ACO vs Control Group, by Baseline Use



2008 mean low-value service rate in ACO service area	P-value for test of difference between ACO subgroups
Higher (16)	0.84
Lower (16)	
2008 mean low-value service rate in ACO	
Above local mean (14)	0.002
Below local mean (18)	