# The Impact of the Choosing Wisely Campaign Recommendations on Supplemental Oxygen Management

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**Abstract**

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Passive dissemination of information is commonly used to influence clinical practice. Our objective was to assess whether passive dissemination of the Choosing Wisely Campaign recommendations to reassess hypoxemia before renewing post-discharge supplemental oxygen impacted receipt of oxygen reassessment or oxygen appropriateness. We conducted a cohort study of all patients with inpatient COPD exacerbation at a VA facility between October 2010 and September 2019 and primary care visits within 90 days. The primary outcome was oxygen reassessment within 90 days of hospital discharge, defined as measurement of either partial pressure of oxygen by blood gas analysis (PaO2) or oxygen saturation by pulse oximeter (SpO2). Our secondary outcome was home oxygen appropriateness at 90 days post-discharge, defined as continuation of supplemental oxygen for those with hypoxemia (PaO2≤55 mmHg or SpO2≤88%) at rest or with exertion. We used the CWC publication month of October 2013 as the time of intervention to conduct an interrupted time series analysis using multivariable logistic regression to estimate pre-CWC trends, immediate change at the time of intervention, and post-CWC trends. We adjusted for age, gender, ethnicity, race, Elixhauser comorbidity score, rural residence, and primary care facility complexity. We identified 21,429 patients who met our inclusion criteria. Pre-CWC, 65.8% (4,600/6,992) received oxygen reassessment within 90 days of discharge, 17.4% (799/4,600) of whom met oxygen appropriateness criteria. There was no significant change in oxygen reassessment or oxygen appropriateness over time pre-CWC, no immediate change in at the time of intervention, and no change in trend post-CWC. The Choosing Wisely Campaign's recommendation for post-discharge oxygen management was not associated with a change in home oxygen reassessment or prescription practices. Our findings support existing research showing that passive dissemination of recommendations alone is a weak intervention for behavior change. Health systems should consider active knowledge translation strategies for implementation of evidence-based care.

## Background

Passive dissemination of information, through the publication of manuscripts, reports, and presentations, is a commonly used approach to influence clinical practice.[1,2] Disseminating key research findings in the form of guidelines or recommendations, while generally tailored to a more targeted audience, are passive forms of information dissemination within the "intervention ladder" framework.[1] Overall, it is considered an ineffective approach to knowledge translation.[3–5] Conversely, active dissemination of healthcare research, such as using clinical decision support systems, involves targeted communication of information to specific audiences at the point of care.[6–8] Active approaches may more effectively guide clinician behaviors to achieve high quality care delivery, but tend to be resource-intensive.[9]

Long-term oxygen therapy confers benefit for adults with COPD who have chronic severe room air hypoxemia.[10,11] These benefits have been extrapolated to short-term oxygen use for patients experiencing hypoxemia during acute hospitalizations for COPD exacerbations. However, many patients normalize their oxygen saturations within 2-3 months of discharge.[12,13] Despite recommendations for short-interval oxygen saturation reassessment for patients using supplemental oxygen,[14] implementation has been inconsistent.[12,15] Inappropriate home oxygen therapy exposes patients to unnecessary risk[16] and is costly to the healthcare system.[17] In October 2013, the American Thoracic Society (ATS) and the American College of Chest Physicians (ACCP) advised against renewing post-discharge supplemental oxygen prescriptions without first demonstrating ongoing hypoxemia as part of the American Board of Internal Medicine's (ABIM) Choosing Wisely Campaign (CWC).[18,19] The CWC is a national initiative to reinforce evidence-based clinical practice and to reduce low-value care.[19] Although the CWC is widely recognized and cited, evaluation of its impact on real-world clinical practice in pulmonary medicine is limited.[20–23] The CWC represents a relatively passive form of dissemination. However, partnership with the ATS and ACCP may have improved targeted messaging to those most likely to use the recommendations. Evaluating its impact is critical in guiding health system efforts to optimize high-value care.

We used an interrupted time series approach[24] to investigate whether passive dissemination of the ATS/ACCP recommendations impacted oxygen reassessment and potential appropriateness of oxygen prescription. Preliminary results were previously published as an abstract.[25]

## METHODS

### Study Design, Data, and Cohort Selection

We conducted a cohort study of US Veterans who experienced a COPD hospitalization within the Veterans Health Administration (VA) between October 2010 and September 2019, were discharged on supplemental oxygen, and had subsequent primary care follow up. COPD hospitalization was defined by International Classification of Diseases (ICD) codes for either: 1) a primary discharge diagnosis code for COPD or 2) a primary discharge diagnosis code for acute respiratory failure with a secondary diagnosis code of COPD.[26] We used the VA Corporate Data Warehouse which contains extensive patient information including patient-level demographics, vital signs, diagnostics, and medications. Supplemental oxygen prescriptions were identified in the CDW using Common Procedure Coding system (HCPCS) codes (e-Table1), which is further detailed in the Supplemental Material (e-Appendix 1). This study was approved by the VA Puget Sound Health Care System Institutional Review Board (#1587947) and the University of Washington Institutional Review Board (STUDY00013255).

### Exposure

The primary intervention of interest was the publication of the CWC recommendations in October 2013, with the running variable of time as the exposure, modeled in calendar months elapsed relative to the date of intervention. The two time periods in this analysis were prepublication (October 2010 to September 2013) and post-publication (October 2013 to September 2019) of the Choosing Wisely Campaign recommendations.

**Outcomes**

Our primary outcome was outpatient oxygen reassessment within 90 days of the index hospitalization discharge date. We defined oxygen reassessment as the measurement of oxygen saturation by pulse oximetry (SpO2) or arterial partial pressure of oxygen by arterial blood gas (PaO2). These values were extracted from the electronic health record from three primary sources: 1) structured vital sign data; 2) structured lab data for PaO2; and 3) notes from pulmonary diagnostic testing (e.g., pulmonary function testing or 6-minute walk tests) (e-Appendix 1). Those who did not have documented receipt of the above within 90 days were considered to have had no oxygen reassessment. Our secondary outcome was oxygen appropriateness among those who had an oxygen reassessment. We defined appropriate oxygen prescriptions by 1) continuation of supplemental oxygen for those with documented hypoxemia (SpO2 ≤ 88% or PaO2 ≤ 55 mmHg) at rest or with exertion, while on room air or on supplemental oxygen; 2) discontinuation in the absence of documented hypoxemia at rest or with exertion, while on room air or on supplemental oxygen; and 3) either continuation or discontinuation if there was documented hypoxemia with exertion alone (i.e., no documented hypoxemia at rest) on room air or on supplemental oxygen (e-Table 2). These definitions were aligned with international society recommendations and the Medicare National Coverage Determination for home use of oxygen.[12,14,27] Further detail is outlined in the Supplement Material (e-Appendix 1).

**Covariates**

To account for differences in baseline characteristics over time, we assessed key patient-level characteristics. We included patient-level characteristics that were *a priori* hypothesized to be confounders, including: demographics (age, sex, race, ethnicity, rural residence); pertinent comorbidity (smoking status, Elixhauser comorbidity index); and healthcare factors (primary care facility complexity). Facility complexity is a measure of clinical complexity of a VAMC, with scores ranging from most (1) to least (3) complex, determined by the patient population served, complexity of clinical services available, as well as education and research.[28] Facility complexity has previously been associated with oxygen reassessment, and was focused at the primary care clinic, where the majority of COPD care is provided nationally.[29] Rural residence was included as a confounder as a marker of geographic access to care that may impact receipt of recommended care.[30] Residence was categorized using Rural Urban Commuting Area codes, consistent with VA health system classification of rurality.[31] Smoking status was included to reflect the complexity of home oxygen therapy management among those who smoke and recommendations for smoking cessation education among those who use home oxygen.[12,32]

**Statistical Analyses**

We used an interrupted time-series analysis to examine the probability of patients receiving oxygen reassessment and appropriate oxygen management over time. We used logistic regression to model the association between time (relative to CWC publication) and the outcomes of interest. We estimated the 1) trend in log-odds of reassessment pre-CWC (i.e., October 2010 to September 2013); 2) the level change (i.e. change in intercept) in log-odds at the time of CWC publication, representing the immediate effect of CWC; and 3) the change in the log-odds trend (i.e., the change in the log-odds slope in the post-CWC period [October 2013-September 2019] compared to the pre-CWC period) of the outcomes following CWC publication.[33] To account for differences in baseline characteristics among the population in the pre-CWC period and post-CWC period, we adjusted for potential confounders. In a sensitivity analysis, we conducted an interrupted time series analysis excluding those who were on supplemental oxygen prior to hospitalization to evaluate whether the impact of the CWC differed between patients with prevalent versus new use of supplemental oxygen.

## Results

*Baseline characteristics*

We identified 21,429 patients who met our inclusion criteria (Table 1). Among the patients discharged on supplemental oxygen and had a visit with a VA PCP within 90 days of index hospital discharge, the mean age was 70.3 years (standard deviation 8.8), and the majority were White (84.5%) men (96.5%). Most had an urban residence (83.2%) and 35.6% received care at a facility with a high VA complexity score.

*Primary outcome*

Prior to the publication of CWC (October 2013), most patients had oxygen reassessment within 90 days (65.8%, N = 4,600/6,992), but few of those with a reassessment had appropriate management of their supplemental oxygen (17.4%, N = 799/4,600). After the publication of CWC a higher proportion of patients received oxygen reassessment within 90 days (73.7%, N = 10,641/14,437), but a lower proportion of these patients received appropriate management of their supplemental oxygen (15.1%, N = 1,602/10,641). The adjusted log-odds of oxygen reassessment increased over time in the pre-CWC period (slope of log-odds 0.007 [95% CI: -0.001, 0.014)]), and there was no immediate change at the time of CWC (slope of log-odds 0.128 [95% CI: <0.001, 0.256]) or sustained change in log-odds trend post-CWC (change in slope of log-odds <0.001 [95% CI: -0.005, 0.006]) (Table 2).

*Secondary outcome*

Among patients who received oxygen reassessment within 90 days of index hospitalization, the log-odds of appropriate oxygen management did not change over time pre-CWC (slope of log-odds 0.004 [95% CI: -0.004, 0.012)]), immediately at the time of CWC (slope of log-odds -0.148 [95% CI: -0.338, 0.042]), and post-CWC (change in slope of log-odds -0.008 [95% CI: -0.016, <0.001]) (Table 3).

*Sensitivity Analysis*

We conducted a sensitivity analysis where we excluded the 16,029 individuals who were on oxygen prior to index date. In analyses limited to the remaining 5,400 individuals, we found similar results, indicating no immediate or sustained change in the slope of the log-odds of oxygen reassessment or appropriate oxygen management within 90 days of the index discharge (e-Table 3, e-Table 4).

**Discussion**

The CWC has been an important influence in raising clinician attention to low-value care and highlighting the direct role clinicians can play in improving value-based care. Despite widespread attention and endorsement of the Choosing Wisely Campaign, we failed to identify an impact of the CWC recommendations on oxygen reassessment or appropriate oxygen prescriptions among patients discharged on oxygen following COPD hospitalization. These results call attention to the ineffectiveness of passive dissemination of information and the need for more active, targeted interventions to influence care quality.

Our findings are consistent with existing literature demonstrating the limited impact of the CWC. A retrospective analysis using claims data from commercial health plans evaluated seven recommendations of the CWC and found that only two of seven low-value interventions showed improvement, two low-value interventions had interval worsening and three had no change.[20] In another study of academic medical centers, the CWC was credited with reduced low-value testing for acute myocardial infarction throughout the study period, though there was wide variation across institutions.[34] Implementation of the CWC was associated with a limited reduction in low-value services in pediatric hospitalizations.[20] These studies are in keeping with the broader literature, suggesting that passive dissemination of recommendations is an ineffective approach to improving clinical care.[3–5] Our work adds to this literature by demonstrating the limited impact of the CWC in a high-risk, national population of patients with COPD.

There are several potential reasons that the CWC did not have an impact on the receipt of oxygen reassessment or appropriate oxygen prescription therein. First, the CWC approach of disseminating information to impact patient care is a passive intervention within the "intervention ladder" framework.[8,35] Our findings suggest that passive dissemination of recommendations is insufficient to sustainably impact the quality of patients' care. In contrast, active interventions more effectively influence clinical practice. Setting default options, for example, is the highest intervention on the "intervention ladder." Default protocols can influence clinician and patient choices toward high-value care practices, without restricting options or devaluing provider discretion.[36,37] Default options have previously been shown to align patient and clinician decision-making with high-quality, guideline-concordant care.[37–39] In this instance, a change in default clinical care may include, for example, an automatically scheduled follow-up visit for oxygen reassessment with a pre-pended order for oxygen discontinuation. Still, prior studies of pragmatic interventions have suggested that effectiveness is contingent on thoughtful implementation tailored to each care setting.[35,37]

Second, despite the clear recommendations, the onus of implementing programs and policy for those changes has fallen on individual practices or health systems. The use of structured frameworks for adoption and implementation may facilitate more impactful dissemination of recommendations.[40] Multiple dissemination models have been suggested for approaches to implementing and disseminating new evidence or recommendations.[41] Multi-level approaches to policy or protocol implementation may provide an effective approach to addressing low-value care and improving patient outcomes.[42] The Veterans Health Administration is an integrated health system that is well-positioned to implement changes in evidence-based clinical practice through protocols and policy at a national scale.[43,44] Still, implementation requires reconciliation of local, regional and national health system priorities for resource allocation. Policymakers, medical societies, and patient advocacy groups must collaborate on alternative or supplemental approaches to improve delivery of high-quality care.

Lastly, the care that patients receive is influenced both by clinician recommendations, and patient preferences. Our data contains patient-level outcomes but does not ascertain the patient-clinician shared decision-making that comprises the care ultimately received. A qualitative study of clinicians assessing factors influencing oxygen prescription suggested that clinicians use a combination of research evidence, clinical experience, as well as patient symptoms and preferences to inform decision-making around home oxygen assessments and prescriptions.[45] Other studies have suggested that barriers to oxygen reassessment occur at the clinician or health system level.[15,46] Although we used facility complexity – a composite score within the VA reflecting facility resources – to adjust for site characteristics in our regression model, heterogeneity of Choosing Wisely's impact on clinician practice patterns between sites or clinic-specific protocol implementation may not be captured in our analysis. Future studies should address the health system factors that may limit implementation of oxygen reassessment and translation of these programs to patient level outcomes.

Our analysis has several strengths. We used an interrupted time series approach with regression modeling to allow for estimation of longitudinal causal effects of an intervention, while accounting for pre-intervention trends.[24] Our study population is based in the Veterans

Health Administration, in which health insurance is not a barrier to accessing health services. The VA-based nature of the data also allowed for broad ascertainment of oxygen supplementation status on a national scale. Still, this study has notable limitations. While we accounted for patient and facility characteristics that may confound the relationship between exposure and outcome, residual or unmeasured confounding may impact the results. We used an administrative dataset, which may contain misclassification of the outcome and bias toward the null, although we would anticipate non-differential misclassification. Our definition of appropriate supplemental oxygen prescription did not include comorbidity criteria for the use of supplemental oxygen (e.g., cor pulmonale, dependent edema, erythrocytosis), because these factors could not be reliable ascertained in our administrative dataset. Lastly, the impact of new evidence or updates in recommendations requires action at multiple levels, including the health system, provider, and patient levels. Our study focused on patient-level outcomes, which is ultimately the intent of such practice updates. Future work should assess the impact of passive dissemination on the implementation of protocols or policies at the organizational or system level.

**Conclusion**

Passive dissemination is a frequently used approach to influence clinical practice and improve patient outcomes. The Choosing Wisely Campaign was developed to improve quality of care for patients by curtailing the use of low-value interventions. We found that the CWC did not significantly impact the reassessment of supplemental oxygen among patients with COPD. Future work should implement multi-level approaches or higher “intervention ladder” approaches.

**Table 1**. Participant characteristics at the time of discharge, stratified whether index date was pre- or post-Choosing Wisely Campaign.

| | **Overall** n = 21,429 | **Pre-Intervention** October 2010 - September 2013 n = 6,992 | **Post-Intervention** October 2013 - September 2019 n = 14,437 |
|---|---|---|---|
| Age, mean (standard deviation [SD]) | 70.30 (8.84) | 69.34 (9.30) | 70.77 (8.56) |
| Male, n (%) | 20669 (96.5) | 6780 (97.0) | 13889 (96.2) |
| Ethnicity, n (%) | | | |
| Hispanic | 482 (2.2) | 134 (1.9) | 348 (2.4) |
| Not Hispanic | 20291 (94.7) | 6637 (94.9) | 13654 (94.6) |
| Unknown | 656 (3.1) | 221 (3.2) | 435 (3.0) |
| Race, n (%) | | | |
| Black | 2114 (9.9) | 620 (8.9) | 1494 (10.3) |
| Other minoritized race | 359 (1.7) | 123 (1.8) | 236 (1.6) |
| White | 18110 (84.5) | 5937 (84.9) | 12173 (84.3) |
| Unknown | 846 (3.9) | 312 (4.5) | 534 (3.7) |
| VA facility complexity code,* n (%) | | | |
| 1a | 7639 (35.6) | 2256 (32.3) | 5383 (37.3) |
| 1b | 3543 (16.5) | 836 (12.0) | 2707 (18.8) |
| 1c | 5142 (24.0) | 1651 (23.6) | 3491 (24.2) |
| 2 | 3576 (16.7) | 1500 (21.5) | 2076 (14.4) |
| 3 | 1497 (7.0) | 723 (10.3) | 774 (5.4) |
| Unknown | 32 (0.1) | 26 (0.4) | 6 (0.0) |
| Elixhauser score, mean (SD) | 5.62 (2.86) | 5.37 (2.71) | 5.74 (2.92) |
| Smoking status, n (%) | | | |
| Active smoking | 8493 (39.6) | 2746 (39.3) | 5747 (39.8) |
| No active smoking | 10630 (49.6) | 3199 (45.8) | 7431 (51.5) |
| Unknown | 2306 (10.8) | 1047 (15.0) | 1259 (8.7) |
| Rural Urban Commuting Area Code category, n (%) | | | |
| Urban | 17822 (83.2) | 5762 (82.4) | 12060 (83.5) |
| Rural | 2811 (13.1) | 941 (13.5) | 1870 (13.0) |
| Highly Rural | 796 (3.7) | 289 (4.1) | 507 (3.5) |

* VA facility complexity code represents levels of complexity assigned to facilities by the VA according to various factors, including patient volume, risk, number and breadth of specialists, intensive care units and presence of teaching and/or research. 1 represents the highest complexity and 3 represents the lowest complexity.

**Table 2**. Unadjusted and adjusted models of oxygen reassessment over time, relative to the Choosing Wisely Campaign.

| | Model Parameter | Estimate of the log-odds (95% confidence interval) | p-value |
|---|---|---|---|
| Unadjusted model | Pre-CWC trend | 0.005 (>-0.001, 0.010) | 0.08 |
| | Immediate CWC impact | 0.135 (0.008, 0.262) | 0.04 |
| | Change in trend post-CWC | > -0.001 (-0.005, 0.005) | 0.98 |
| Adjusted model* | Pre-CWC trend | 0.004 (-0.001, 0.009) | 0.12 |
| | Immediate CWC impact | 0.124 (-0.004, 0.252) | 0.06 |
| | Change in trend post-CWC | <0.001 (-0.005, 0.006) | 0.92 |

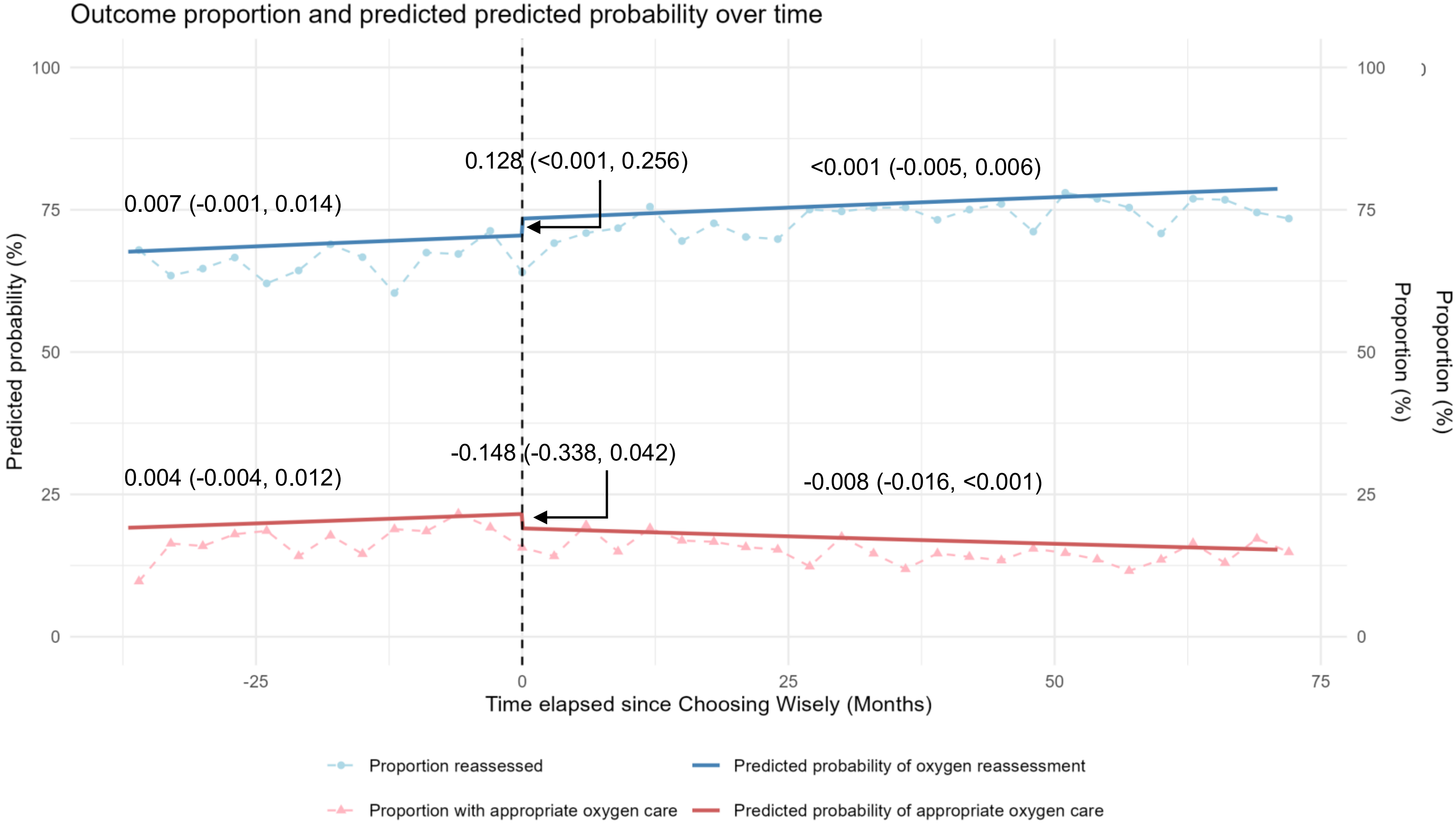
* Adjusted for age, sex, race, ethnicity, Elixhauser score, smoking status, rurality, facility complexity

**Table 3**. Unadjusted and adjusted models of appropriate oxygen prescription among those who had oxygen reassessment, over time relative to the Choosing Wisely Campaign.

| | Model Parameter | Estimate of the log-odds (95% confidence interval) | p-value |
|---|---|---|---|
| Unadjusted model | Pre-CWC trend | 0.007 (-0.001, 0.014) | 0.09 |
| | Immediate CWC impact | -0.167 (-0.354, 0.022) | 0.08 |
| | Change in trend post-CWC | -0.010 (-0.018, -0.002) | 0.02 |
| Adjusted model* | Pre-CWC trend | 0.004 (-0.004, 0.012) | 0.34 |
| | Immediate CWC impact | -0.134 (-0.323, 0.056) | 0.17 |
| | Change in trend post-CWC | -0.008 (-0.016, <0.001) | 0.07 |

* Adjusted for age, sex, race, ethnicity, Elixhauser score, smoking status, rurality, facility complexity

**Figure 1**. Plot of unadjusted proportion of each outcome (oxygen reassessment and appropriate oxygen management) and adjusted predicted probability of each outcome over time relative to the publication of Choosing Wisely. The log-odds of the adjusted pre-CWC slope, immediate impact of the CWC, and change in CWC slope post-CWC are overlayed (left to right) and reflect adjustment for age, sex, race, ethnicity, rurality, smoking status, facility complexity, and Elixhauser comorbidity index. Calculated predicted probabilities incorporate mean age, male sex, White race, non-Hispanic ethnicity, urban residence, active smoking, high facility complexity (1a), and mean Elixhauser comorbidity index.



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**SUPPLEMENTAL MATERIAL**

**e-Appendix 1**

**Determination of supplemental oxygen prescription**

In the Veterans Health Administration, supplemental oxygen is considered durable medical equipment, which is classified as a "prosthetic" in the VA Corporate Data Warehouse (CDW). We used the prosthetics table in the VA CDW to identify patients who were prescribed supplemental oxygen using Healthcare Common Procedure Coding System (HCPCS) codes. Oxygen prescriptions are billed, and therefore recorded, on a monthly basis. This monthly, patient-level entry into the prosthetics table was used to determine continuation of supplemental oxygen therapy. Continuation of supplemental oxygen was assigned if one of the HCPCS codes was billed in a given month (e-Table 1). Discontinuation was assigned if there was an absence of monthly billing for home oxygen for a minimum of 90 days. These criteria allowed for brief, administrative gaps in monthly billing information for those who had uninterrupted supplemental oxygen use. Patients discharged on supplemental oxygen were identified using oxygen prescription status within 3 months prior to discharge to 1 month post-discharge.

**Determination of oxygen reassessment**

Among patients who were discharged on oxygen, reassessment within 90 days was defined using either an arterial oxygen saturation measurement using pulse oximetry (SpO2) or arterial partial pressure of oxygen by arterial blood gas (PaO2). These values were extracted from the electronic health record (EHR) using three primary sources:

1. SpO2 was abstracted from structured vital sign data in the EHR. SpO2 in vital signs qualified as an oxygen reassessment if the source was from an outpatient visit with a clinician likely to routinely prescribe supplemental oxygen. These outpatient visits were identified using stop codes, administrative VA coding of clinical services. This criterion

was used to exclude vital signs that may have been measured in visits where a clinician would be unlikely change an oxygen prescription.

2. SpO2 was also abstracted from EHR notes in pulmonary diagnostic testing. These tests included, for example, pulmonary function testing, 6-minute walk tests, dedicated oxygen clinic reassessments and were identified in the EHR using specific note titles. KID and LCF conducted manual abstraction of SpO2 from such notes. Abstractions were duplicated and discrepancies were resolved by consensus.
3. PaO2 was abstracted from structured EHR data. Arterial blood gases conducted in the outpatient setting were used to obtain PaO2 measurements.

**Determination of supplemental oxygen appropriateness**

We used the above determinations of oxygen saturation and reassessment to inform our definition of supplemental oxygen appropriateness, which aligned with American Thoracic Society guidelines, and Medicare coverage criteria.[1-3] Using outpatient oxygen reassessment values within 90 days, appropriateness of supplemental oxygen continuation was defined by documented hypoxemia (SpO2 ≤ 88% or PaO2 ≤ 55 mmHg) on room air either at rest or with exertion; or hypoxemia on supplemental oxygen either at rest or with exertion (e-Table 2). When multiple reassessments present within 90 days, the reassessment closest to 90 days was selected, to maximize allotted time to appropriately address oxygen prescription. We did not include secondary Medicare criteria (i.e., conditional on presence of cor pulmonale, dependent edema, or erythrocytosis) in our definition, as these factors could not be consistently, accurately identified in our administrative dataset.

| **e-Table 1.** Supplemental oxygen Healthcare Common Procedure Coding System codes. | |
|---|---|
| Code | Description |
| E0424 | Stationary gaseous oxygen system |

| | |
|---|---|
| E0431 | Portable gaseous oxygen system |
| E0433 | Portable liquid oxygen system |
| E0434 | Portable liquid oxygen system |
| E0439 | Stationary liquid oxygen system |
| E0441 | Oxygen contents, gaseous |
| E0442 | Oxygen contents, liquid |
| E0443 | Portable oxygen contents, gaseous |
| E0444 | Portable oxygen contents, liquid |
| E1390 | Oxygen concentrator, single port |
| E1391 | Oxygen concentrator, dual port |
| E1392 | Portable oxygen concentrator |
| K0738 | Portable gaseous oxygen system |

**e-Table 2**. Supplemental oxygen appropriateness definitions.

| Appropriateness | Oxygen status | Reassessment | | |
|---|---|---|---|---|
| | | Documented hypoxemia[a] | Oxygen measured at rest or exertion | Oxygen measured on room air or on supplemental oxygen |
| Appropriate | Prescribed | Yes | Rest | Room air |
| | | Yes | Rest | Supplemental oxygen |
| | Prescribed or not prescribed | Yes | Exertion | Room air |
| | | Yes | Exertion | Supplemental oxygen |
| | Not Prescribed | No | Rest | Room air |
| | | No | Exertion | Room air |
| | | No | Rest | Supplemental oxygen |
| | | No | Exertion | Supplemental oxygen |
| Inappropriate | Prescribed | No | Rest | Room air |
| | | No | Exertion | Room air |
| | | No | Rest | Supplemental oxygen |
| | | No | Exertion | Supplemental oxygen |
| | Not prescribed | Yes | Rest | Room air |
| | | Yes | Rest | Supplemental oxygen |

a: $SpO_2 \leq 88\%$ or $PaO_2 \leq 55$ mmHg

**e-Table 3**. Unadjusted and multivariable models of oxygen reassessment over time, relative to the Choosing Wisely Campaign, among a subset of patients who were not prescribed supplemental oxygen prior to the index date.

| | Model Parameter | Estimate of the log-odds (95% confidence interval) | p-value |
|---|---|---|---|
| Unadjusted model | Pre-CWC trend | 0.008 (-0.003, 0.019) | 0.17 |
| | Immediate CWC impact | 0.124 (-0.142, 0.389) | 0.36 |
| | Change in trend post-CWC | -0.003 (-0.014, 0.009) | 0.63 |
| Multivariable model* | Pre-CWC trend | 0.007 (-0.003, 0.019) | 0.20 |
| | Immediate CWC impact | 0.127 (-0.142, 0.393) | 0.35 |
| | Change in trend post-CWC | -0.002 (-0.014, 0.010) | 0.71 |

* Adjusted for age, sex, race, ethnicity, Elixhauser score, smoking status, rurality, facility complexity

**e-Table 4**. Unadjusted and multivariable models of appropriate oxygen prescription among those who had oxygen reassessment, over time relative to the Choosing Wisely Campaign, among a subset of patients who were not prescribed supplemental oxygen prior to the index date.

| | Model Parameter | Estimate of the log-odds (95% confidence interval) | p-value |
|---|---|---|---|
| Unadjusted model | Pre-CWC trend | 0.001 (-0.014, 0.016) | 0.91 |
| | Immediate CWC impact | -0.110 (-0.454, 0.240) | 0.54 |
| | Change in trend post-CWC | -0.002 (-0.017, 0.014) | 0.83 |
| Multivariable model* | Pre-CWC trend | >-0.001 (-0.015, 0.015) | 0.98 |
| | Immediate CWC impact | -0.158 (-0.507, 0.197) | 0.38 |
| | Change in trend post-CWC | -0.001 (-0.017, 0.015) | 0.92 |

* Adjusted for age, sex, race, ethnicity, Elixhauser score, smoking status, rurality, facility complexity