


# Prevalence and Cost of Care Cascades Following Low-Value Preoperative Electrocardiogram and Chest Radiograph Within the Veterans Health Administration



Aimee N. Pickering, MD<sup>1,2</sup> , Xinhua Zhao, PhD<sup>1</sup>, Florentina E. Sileanu, MS<sup>1</sup>, Elijah Z. Lovelace, MS<sup>1</sup>, Liam Rose, PhD<sup>3</sup>, Aaron L. Schwartz, MD, PhD<sup>4,5</sup>, Allison H. Oakes, PhD<sup>1,6</sup>, Jennifer A Hale, BS<sup>1</sup>, Loren J. Schleiden, MS<sup>1</sup>, Walid F. Gellad, MD, MPH<sup>1,2</sup>, Michael J. Fine, MD, MSc<sup>1,2</sup>, Carolyn T. Thorpe, PhD, MPH<sup>1,7</sup>, and Thomas R. Radomski, MD, MS<sup>1,2</sup>

<sup>1</sup>Center for Health Equity Research and Promotion (CHERP), VA Pittsburgh Healthcare System, Pittsburgh, PA, USA; <sup>2</sup>Division of General Internal Medicine, University of Pittsburgh School of Medicine, Pittsburgh, PA, USA; <sup>3</sup>Health Economics Resource Center (HERC), VA Palo Alto Healthcare System, Palo Alto, CA, USA; <sup>4</sup>Center for Health Equity Research and Promotion (CHERP), Crescenz VA Medical Center, Philadelphia, PA, USA; <sup>5</sup>Department of Medical Ethics and Health Policy and Division of General Internal Medicine, University of Pennsylvania, Philadelphia, PA, USA; <sup>6</sup>Enterprise Health Services Research, Enterprise Analytics Hub, Anthem Inc., Wilmington, DE, USA; <sup>7</sup>Division of Pharmaceutical Outcomes and Policy, University of North Carolina at Chapel Hill Eshelman School of Pharmacy, Chapel Hill, NC, USA.

**BACKGROUND:** Low-value care cascades, defined as the receipt of downstream health services potentially related to a low-value service, can result in harm to patients and wasteful healthcare spending, yet have not been characterized within the Veterans Health Administration (VHA).

**OBJECTIVE:** To examine if the receipt of low-value preoperative testing is associated with greater utilization and costs of potentially related downstream health services in Veterans undergoing low or intermediate-risk surgery.

**DESIGN:** Retrospective cohort study using VHA administrative data from fiscal years 2017–2018 comparing Veterans who underwent low-value preoperative electrocardiogram (EKG) or chest radiograph (CXR) with those who did not.

**PARTICIPANTS:** National cohort of Veterans at low risk of cardiopulmonary disease undergoing low- or intermediate-risk surgery.

**MAIN MEASURES:** Difference in rate of receipt and attributed cost of potential cascade services in Veterans who underwent low-value preoperative testing compared to those who did not

**KEY RESULTS:** Among 635,824 Veterans undergoing low-risk procedures, 7.8% underwent preoperative EKG. Veterans who underwent a preoperative EKG experienced an additional 52.4 (95% CI 47.7–57.2) cascade services per 100 Veterans, resulting in \$138.28 (95% CI 126.19–150.37) per Veteran in excess costs. Among 739,005 Veterans undergoing low- or intermediate-risk surgery, 3.9% underwent preoperative CXR. These Veterans experienced an additional 61.9 (95% CI 57.8–66.1) cascade services per 100 Veterans, resulting in \$152.08 (95% CI \$146.66–157.51) per Veteran in excess costs. For both cohorts, care cascades consisted largely of repeat tests,

follow-up imaging, and follow-up visits, with low rates of invasive services.

**CONCLUSIONS:** Among a national cohort of Veterans undergoing low- or intermediate-risk surgeries, low-value care cascades following two routine low-value preoperative tests are common, resulting in greater unnecessary care and costs beyond the initial low-value service. These findings may guide de-implementation policies within VHA and other integrated healthcare systems that target those services whose downstream effects are most prevalent and costly.

**KEY WORDS:** low-value care; care cascades; preoperative testing; Veterans Health Administration.

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## INTRODUCTION

Low-value care, defined as the use of a health service whose costs or harms exceed its benefits, is common and accounts for over \$100 billion in annual US healthcare expenditures.<sup>1–5</sup> Low-value care may result in care cascades, which include unnecessary testing, treatments, procedures, or visits that occur as a result of a low-value service.<sup>6–12</sup> For example, among Medicare beneficiaries undergoing cataract surgery, 11% received a low-value preoperative electrocardiogram, which was associated with 5–11 cascade services per 100 beneficiaries, such as repeat electrocardiograms and stress tests.<sup>7</sup>

In addition to Medicare and private health insurers, low-value care is prevalent within the Veterans Health Administration (VHA), an integrated and federally operated healthcare system.<sup>13,14</sup> In a national cohort of Veterans who received VHA care in 2015, the frequency of low-value diagnostic

*Carolyn T. Thorpe and Thomas R. Radomski are co-senior authors.*

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testing for low back pain, headache, syncope, and sinusitis ranged from 5 to 20% among Veterans with each respective underlying condition.<sup>14</sup> While prior studies within VHA have focused on single low-value services, care cascades have not been well characterized.

Preoperative electrocardiograms (EKGs) and chest radiographs (CXRs) in low-risk patients undergoing low- or intermediate-risk surgeries provide an opportunity to understand low-value care cascades within VHA. Preoperative EKGs and CXRs in low-risk patients are widely recognized low-value services yet remain prevalent and are associated with care cascades.<sup>3,7,15–19</sup> Understanding the use and cost of low-value care as part of a cascade beyond the initial preoperative test would provide information regarding the full impact of low-value preoperative care within VHA. This would enable VHA to target de-implementation policies and interventions at those services that result in the greatest degree of overall low-value health service utilization and cost.

Our objective was to examine if the receipt of low-value preoperative testing is associated with greater utilization and costs of potentially related downstream health services in Veterans undergoing low or intermediate risk surgery.

## METHODS

### Study Design and Data Sources

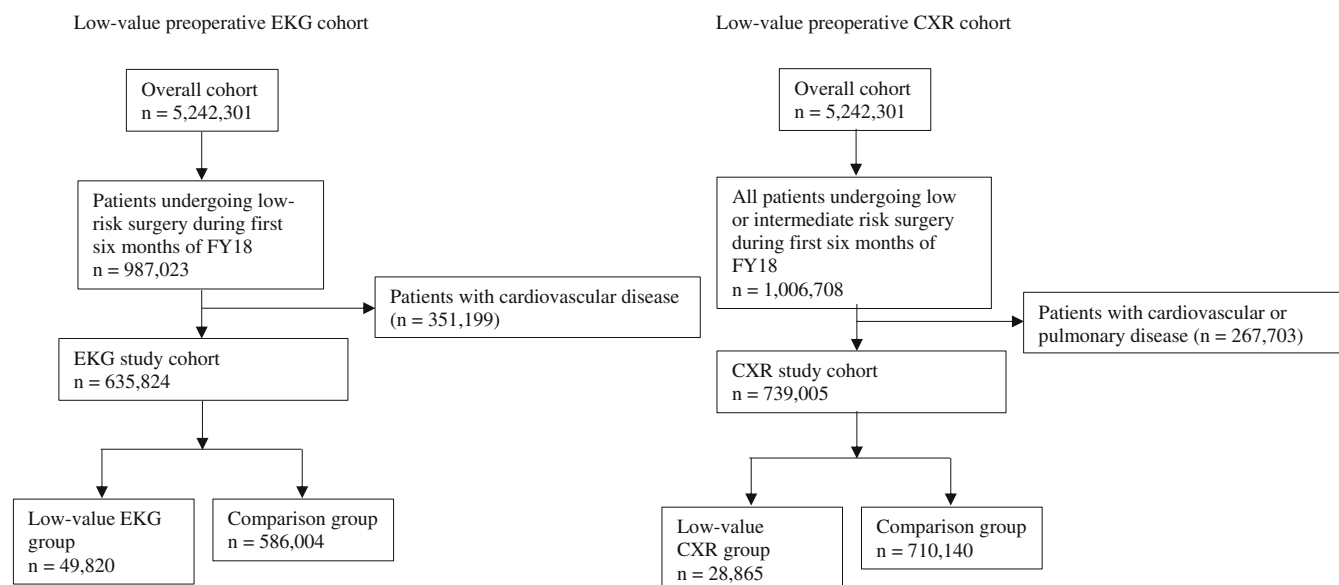
We conducted a retrospective cohort study of Veterans continuously enrolled in VHA in October 1, 2016–September 30, 2018 (FY17-FY18). We used the VA Corporate Data Warehouse to identify patient sociodemographic characteristics,

medical comorbidities, International Classification of Disease 10th Edition (ICD-10) codes, and Common Procedural (CPT) codes. We used the Area Health Resource File and the VHA Support Service Center files to determine facility-level covariates and the VA Planning Systems Support Group database to obtain patient driving distance to their nearest VA facility. This study was approved by the VA Pittsburgh Healthcare System Institutional Review Board.

### Study Cohort

From a national cohort of VHA beneficiaries ( $N=5,242,301$ ) established for a larger study examining the use and cost of low-value care within VHA,<sup>20</sup> we created two study cohorts, representing Veterans at risk of receiving a low-value preoperative EKG or CXR (Fig. 1). We generated the cohorts based on accepted preoperative guidelines, findings in peer-reviewed literature, and the clinical expertise of the research team.<sup>21–26</sup> Details on the algorithms and administrative billing codes used to generate the cohorts are found in Appendix Table 1.

To create the EKG study cohort, we identified Veterans who underwent a low-risk non-cardiothoracic surgery during the first 6 months of FY18. We excluded Veterans with a history of cardiac disease or who had seen a cardiologist in a year prior to their surgery date. Due to undercoding of diagnoses within VHA<sup>27,28</sup>, we applied broad exclusion criteria, such as recent cardiology visit, when creating the cohort of low-risk Veterans. The remaining Veterans represented those at low risk of cardiac disease undergoing low-risk surgery and thus at risk of receiving a low-value preoperative EKG.



**Fig. 1** Study cohort flow diagram for service-specific cohorts. Veterans with history of arrhythmia, coronary artery disease, valvular disease, heart failure, or a cardiology visit within 1 year prior to their surgery date or who had an EKG as part of an inpatient stay or ED visit within 30 days prior to their surgery date were excluded from the low-value preoperative EKG cohort. Veterans with history of valvular disease, heart failure, chronic obstructive pulmonary disease, asthma, other interstitial lung disease, or a pulmonary visit within one year prior to their surgery date or history of acute respiratory illness within 60 days prior to their surgery date or who had a CXR as part of an inpatient stay or ED visit within 30 days prior to their surgery date were excluded from the low-value CXR cohort. EKG = electrocardiogram; CXR – chest radiograph

**Table 1** Baseline patient and VA Medical Center (VAMC)-level characteristics within each service-specific cohort by receipt of low-value preoperative testing before propensity score weighting

	EKG study cohort <sup>†</sup>		CXR study cohort <sup>†</sup>	
	Low-value EKG group (n=49,820)	Comparison group (n=586,004)	Low-value CXR group (n=28,865)	Comparison group (n=710,140)
Patient-level characteristics				
Age, year, mean (SD)	63.2 (12.4)	63.5 (13.7)	64.4 (13.0)	64.5 (13.7)
Male sex, n (%)	45,269 (90.9)	532,878 (90.9)	26,655 (92.3)	653,626 (92.0)
Race/ethnicity, n (%)				
Non-Hispanic White	36,060 (72.4)	415,344 (70.9)	19,602 (67.9)	510,843 (71.9)
Non-Hispanic Black	9,843 (19.8)	118,794 (20.3)	6,342 (22.0)	136,961 (19.3)
Hispanic	2,625 (5.3)	35,460 (6.1)	2,183 (7.6)	43,022 (6.1)
Non-Hispanic/multiracial	1,292 (2.6)	16,406 (2.8)	738 (2.6)	19,314 (2.7)
VA priority group <sup>‡</sup> , n (%)				
1	18,409 (37.0)	228,698 (39.0)	10,884 (37.7)	276,583 (39.0)
2–6	24,911 (50.0)	276,651 (47.2)	14,278 (49.5)	332,328 (46.8)
7–8	6,500 (13.1)	80,655 (13.8)	3,703 (12.8)	101,229 (14.3)
Number of Elixhauser conditions <sup>§</sup> , mean (SD)	1.7 (1.8)	1.5 (1.6)	1.9 (1.9)	1.5 (1.6)
Driving distance to nearest VA facility, miles, mean (SD)	14.8 (14.7)	14.9 (14.6)	14.3 (14.1)	15.0 (14.5)
VAMC-level characteristics				
Academic affiliation, yes, n (%)	48,881 (98.1)	574,075 (98.0)	28,577 (99.0)	696,434 (98.1)
Facility size, total # outpatient visits FY18, mean (SD)	768,038 (366,899)	802,318 (395,800)	852,268 (389,269)	809,367 (400,211)
Census region, n (%)				
Northeast	5,932 (11.9)	7,4691 (12.8)	3,092 (10.7)	92,170 (13.0)
Midwest	12,677 (25.5)	133,995 (22.9)	5,825 (20.2)	162,437 (22.9)
South	19,154 (38.5)	256,116 (43.7)	14,164 (49.1)	310,237 (43.7)
West	12,057 (24.2)	121,202 (20.7)	5,784 (20.0)	145,296 (20.5)
Rurality, n (%)				
Large metropolitan	22,682 (45.5)	623,481 (45.0)	14,849 (51.4)	319,720 (45.0)
Small metropolitan	17,488 (35.1)	210,327 (35.9)	9,267 (32.1)	254,668 (35.9)
Micropolitan	5,557 (11.2)	64,652 (11.0)	2,644 (9.2)	77,975 (11.0)
Noncore rural	4,093 (8.2)	47,544 (8.1)	2,105 (7.3)	57,777 (8.1)
Facility complexity level <sup>  </sup> , n (%)				
High complexity	41,687 (83.7)	478,725 (81.7)	25,548 (88.5)	548,240 (82.3)
Medium complexity	4,857 (9.8)	54,428 (9.3)	2,064 (7.2)	65,279 (9.2)
Low complexity	3,276 (6.6)	52,851 (9.0)	1,253 (4.3)	60,621 (8.5)

EKG electrocardiogram, CXR chest radiograph

<sup>†</sup>With the exception of driving distance for the EKG study cohort and age and sex for the CXR cohort, the low-value service groups and comparison groups had statistically significant differences in characteristics ( $p < 0.05$ ). Absolute standardized mean differences were  $< 0.10$  for all variables after applying propensity score weights (Appendix Table 3 and Appendix Table 5)

<sup>‡</sup>Veterans are assigned to 1 of 8 priority groups at VA enrollment based on service-connected illnesses, era of Service, and socioeconomic status determined by means testing. Priority group determines level of co-payment. Priority groups are condensed for presentation in the table based on similarity of copays between groups but were included separately in our models

<sup>§</sup>Individual Elixhauser conditions shown in Appendix Table 3 and Appendix Table 5

<sup>||</sup>The complexity rating is based on a VAMC's patient volume, number and breadth of physician specialists, patient case mix, intensive care unit capabilities, and degree of teaching and research

Missing values for race/ethnicity (4% missing), VA priority group ( $< 0.1\%$ ), driving distance to nearest VA facility (0.1%), census region (0.8%), rurality (0.1%) generated using single imputation

For the CXR study cohort, we identified Veterans who underwent a low or intermediate-risk non-cardiothoracic surgery and then excluded those with history of cardiopulmonary disease to create a cohort of Veterans in which preoperative CXR would not be indicated.

## Low-Value Preoperative Test Groups and Comparison Groups

To create low-value EKG and low-value CXR groups (e.g., exposure groups), we identified those within each service-specific cohort who had undergone a preoperative EKG or CXR (Appendix Table 1). For Veterans undergoing more than one low-value preoperative test, we defined the first test as the index service and the corresponding surgery as the index surgery. Our comparison group consisted of the remaining Veterans within

each cohort who had undergone a qualifying surgery but did not undergo preoperative testing. In instances where those within the comparison group underwent more than one surgery, we chose the first qualifying surgery as the index surgery.

## Utilization and Cost of Potential Cascade Services

The primary outcomes were additional services that patients experienced within 6 months subsequent to and plausibly as a result of the low-value preoperative test, which we labeled as potential cascade services. The services were defined by practicing clinicians on the research team considering their clinical knowledge and based upon the findings of relevant literature.<sup>7,8,10</sup> For the EKG cohort, potential cascade services included subsequent EKGs, related outpatient visits, lab tests, cardiac imaging,

stress testing, evaluations for arrhythmias, and invasive procedures such as cardiac catheterizations. For the CXR cohort, potential cascade services included subsequent CXR, related outpatient visits, follow-up imaging, pulmonary function testing, and bronchoscopy (Appendix Table 1).

For the exposure groups, the outcome assessment period was 6 months from the date of the preoperative test. For the comparison group, the start of the 6-month outcome period corresponded to the mean time prior to undergoing the index surgery that patients in the corresponding low-value service groups underwent a preoperative EKG or CXR.<sup>7</sup> We chose this follow-up period based on literature examining wait times within VHA to capture services that may take several months to schedule.<sup>29</sup> We also conducted sensitivity analysis using a 90-day outcome period to allow for direct comparison with existing literature.<sup>7</sup>

We computed the costs by applying VA Health Economics Resource Center (HERC) value estimates to CPT codes associated with the initial preoperative test or cascade services. These validated estimates represent hypothetical reimbursement based on average national Medicare and private-sector reimbursement rates.<sup>30</sup>

### Patient and Facility-Level Covariates

Using data from FY17, we established the following patient-level covariates: age, sex, race/ethnicity, VA priority group (assigned at VHA enrollment based on service-connected illness, era of service, and socioeconomic status), driving distance to nearest VHA facility, and number and presence of specific Elixhauser conditions.<sup>31</sup> We also assigned Veterans to the VA Medical Center (VAMC) where they received most of their outpatient care in FY17 and determined the corresponding academic affiliation, census region, rurality, facility complexity level (based on patient volume, number and breadth of physician specialists, patient case mix, intensive care unit capabilities, and degree of teaching and research), and size (based on outpatient visit volume).<sup>32</sup>

We categorized Veterans' index surgeries based on Berenson-Eggers Type of Service (BETOS) categories and level of cardiopulmonary risk (Appendix Table 2).<sup>23</sup>

### Statistical Analysis

Within the low-value service and comparison groups of both cohorts, we determined the proportions of Veterans undergoing each potential cascade service as well as counts of the individual services during the 6-month outcome period, presented as the event rate per 100 Veterans. We imputed missing values ( $\leq 5\%$  on any individual variable) using single imputation by chained equations.

We used inverse probability of treatment weighting based on propensity scores to create balance among the low-value service and comparison groups with regard to baseline covariates and index surgery type. To generate the inverse probability of treatment weights (IPTWs), we first estimated propensity scores using

multivariable logistic regression models with receipt of the low-value preoperative test as the binary outcome variable and baseline covariates as the predictor variables. We then estimated the probability of receiving the low-value preoperative test for each Veteran and created an IPTW by taking the inverse of the propensity score.<sup>33,34</sup> We checked balance between groups after applying the IPTWs by calculating weighted standardized mean differences (SMDs) for all covariates. We defined balance between groups as a weighted SMD in the mean or proportion of each individual covariate of  $< 0.10$ .<sup>33,35</sup>

We created negative binomial regression models that included the IPTWs to determine adjusted rates of undergoing each potential cascade service for Veterans in the low-value service groups (cascade event rates) and in the comparison groups (baseline event rates). We calculated the cascade-attributable event rates (CAERs) by subtracting the baseline event rate from the cascade event rate. This represents the rate of receipt of a potential cascade service that can be plausibly attributed to the index low-value service.<sup>7</sup> We also applied robust variance estimates to adjust for clustering effects at the VAMC level.

We also created weighted linear regression models, adjusting for facility-level clustering effect, to determine the adjusted cost per Veteran of each individual potential cascade service as well as an overall adjusted cost per Veteran for those in the low-value service and comparison groups. We represented the difference in cost between both groups as the cascade-attributable cost. Analyses were conducted using SAS (version 7.1, SAS Institute) and Stata (version 15.1, StataCorp).

## RESULTS

### Prevalence and Cost of Care Cascades Following Low-Value Preoperative EKG Testing

We identified 635,824 Veterans at risk of undergoing a low-value EKG, of whom 7.8% underwent a low-value EKG (Fig. 1). Veterans who received a low-value EKG had a greater comorbidity burden and received care at VHA facilities with higher complexity ratings than those Veterans who did not (Table 1). After applying IPTWs, the SMDs were  $< 0.10$  for all covariates and index surgery types, including those individual comorbidities with baseline differences, indicating appropriate balance for all covariates through use of our propensity score model (Appendix Table 3 and Appendix Table 4).

Among those Veterans who underwent a low-value preoperative EKG, 29.0% received at least one potential cascade service within 6 months. Comparing Veterans who did and did not undergo a low-value preoperative EKG, we found an overall adjusted CAER of 52.4 per 100 Veterans (95% CI 47.7–57.2). Repeat EKG occurred at an adjusted CAER of 21.6 per 100 Veterans (95% CI 18.3–25.0) followed by a troponin test (6.7/100



Veterans, 95% CI 5.6–7.8) and echocardiogram (7.4/100 Veterans, 95% CI 6.8–8.0). Cardiac catheterization, coronary artery bypass/coronary repair, and valve replacement/repair occurred infrequently (Table 2). In our sensitivity analysis at 90 days, we found an overall adjusted CAER of 30.7 (27.1–34.3). Similar to the 6-month outcome period, noninvasive services and follow-up visits occurred at the highest rates.

The total cost associated with a low-value preoperative EKG was \$7,942,486, which includes \$1,802,182 for the initial EKG and \$6,140,304 for potential cascade services. Relative to the comparison group, those Veterans who underwent low-value preoperative EKG incurred, on average, an additional \$138.28 (95% CI 126.19–150.37) per Veteran in adjusted costs. This includes an average additional cost per Veteran of \$36.57 (95% CI 34.32–38.81) for the initial EKG and \$101.72 (95% CI 89.58–113.85) per Veteran for potential cascade services. Cardiac imaging and repeat EKG accounted for the greatest proportion of additional costs while invasive procedures accounted for very little of the additional costs due to their low frequency (Table 3).

### Prevalence and Cost of Care Cascades Following Low-Value Preoperative CXR Testing

Among 739,005 Veterans at risk, 3.9% underwent a low-value preoperative CXR (Fig. 1). Veterans who received a

preoperative CXR had higher comorbidity burden and received care at VHA facilities with higher complexity levels compared to those who did not (Table 1). The SMDs between all covariates and index surgery types in those who did and did not undergo a low-value CXR were <0.10 after applying the IPTWs, indicating appropriate balance for all covariates (Appendix Table 5 and Appendix Table 6).

Among those who underwent a low-value preoperative CXR, 37.9% received at least one potential cascade service. Comparing Veterans who did and did not undergo low-value preoperative CXR, we found an overall adjusted CAER of 61.9 cascade services per 100 Veterans (95% CI 57.8–66.1). Repeat CXR occurred at an adjusted CAER of 42.2 per 100 Veterans (95% CI 38.8–45.6). Computed tomography chest and pulmonary function tests occurred at adjusted CEAR of 9.1 per 100 Veterans (95% CI 8.6–9.7) and 5.3 per 100 Veterans (95% CI 4.5–6.0%), respectively. Other chest imaging and bronchoscopy occurred less frequently (Table 4). In our sensitivity analysis at 90 days, we found an overall adjusted CAER of 52.8 (48.3–57.3).

The Veterans who underwent low-value preoperative CXR were subject to \$5,739,35 in total costs associated with the low-value preoperative test, \$2,149,829 for the initial CXR and \$3,589,525 for potential cascade services. Relative to the comparison group, Veterans in the low-value CXR group incurred, on average, an additional \$152.08 (95% CI \$146.66–157.51) per Veteran in adjusted costs. This includes

**Table 2 Utilization of potential cascade services after low-value preoperative electrocardiogram (EKG)**

Cascade service	Unadjusted event rate per 100 Veterans		Unadjusted cascade-attributable event rate*	Adjusted cascade-attributable event rate (95% CI) <sup>†</sup>
	Low value-EKG group (n=49,820)	Comparison group (n=586,004)		
Any cascade service	76.4	29.3	47.1	52.4 (47.7–57.2)
Outpatient EKG	33.2	11.4	21.8	21.6 (18.3–25.0)
Outpatient visit for abnormal EKG <sup>‡</sup>	1.0	0.5	0.5	0.7 (0.4–1.1)
Outpatient visit to cardiologist	7.0	3.5	3.5	5.1 (4.8–5.4)
Troponin	11.9	4.9	7.0	6.7 (5.6–7.8)
Brain natriuretic peptide	5.4	2.6	2.8	3.1 (2.4–3.7)
Echocardiogram	9.5	3.5	6.0	7.4 (6.8–8.0)
Stress test	5.1	1.8	3.3	5.0 (4.4–5.5)
Other cardiac imaging <sup>§</sup>	0.4	0.1	0.3	0.4 (0.2–0.5)
Evaluation for arrhythmia <sup>  </sup>	2.6	1.0	1.6	2.3 (1.9–2.7)
Cardiac catheterization	0.1	0.1	0.1	0.14 (0.08–0.20)
CABG/coronary artery repair	0.08	0.02	0.06	0.07(0.04–0.10)
Valve replacement/repair	<0.1	<0.1	<0.1	<0.1

CABG coronary artery bypass graft, EKG electrocardiogram

\*Defined as the difference in the rate of care cascade service per 100 Veterans in those who received a low-value preoperative EKG compared who those who did not receive a low-value preoperative EKG

<sup>†</sup>Adjusted for patient and facility-level covariates (age, sex, race/ethnicity, VA priority group, driving distance to nearest VA, number of Elixhauser conditions, individual Elixhauser conditions, academic affiliation, facility size, census region, rurality, complexity level) and surgery type using propensity score weighting

<sup>‡</sup>Outpatient visit with primary diagnosis of abnormal electrocardiogram, abnormal result of cardiovascular function study, abnormal findings on diagnostic imaging of heart and coronary circulation, not including cardiology visits

<sup>§</sup>Includes cardiac magnetic resonance imaging (cMRI), cardiac positron emission tomography (PET), nuclear imaging, coronary ultrasound, coronary computed tomography angiography (CTA)

<sup>||</sup>Includes Holter monitor, event monitor, implantable loop recorder, electrophysiology (EP) testing, EP procedure, pacemaker evaluation, pacemaker procedure

Table 3 Cost of potential cascade services after low-value preoperative electrocardiogram (EKG)

Cascade service*	Average unadjusted cost per Veteran		Unadjusted cascade-attributable cost per Veteran <sup>†</sup> (\$)	Adjusted cascade-attributable cost per Veteran (95% CI) <sup>‡</sup> (\$)
	Low value-EKG group (\$) (n=49,820)	Comparison group (\$) (n=586,004)		
Any cascade service	123.3	45.9	77.3	101.7 (89.6–113.9)
Outpatient EKG	14.0	5.0	9.0	9.0 (7.6–10.3)
Outpatient visit for abnormal EKG <sup>§</sup>	0.6	0.3	0.3	0.4 (0.2–0.6)
Outpatient visit to cardiologist	4.4	2.1	2.3	3.3 (3.1–3.6)
Troponin	1.5	0.6	0.9	0.8 (0.7–1.0)
Brain natriuretic peptide	4.4	2.1	2.3	2.5 (2.0–3.0)
Echocardiogram	48.4	18.0	30.5	37.7 (34.5–40.8)
Stress test	14.9	5.5	9.4	13.9 (11.6–16.3)
Other cardiac imaging <sup>  </sup>	2.7	0.8	1.9	2.2 (0.8–3.6)
Evaluation for arrhythmia <sup>  </sup>	17.8	5.5	12.3	16.5 (9.9–23.1)
Cardiac catheterization	14.6	6.1	8.6	15.4 (9.1–21.7)

CABG coronary artery bypass graft, EKG electrocardiogram

\*Cost data unavailable for CPT codes associated with CABG/coronary repair and valve replacement/repair

<sup>†</sup>Determined by subtracting cost of care cascade services per Veteran in those who did not receive a low-value preoperative EKG from those who did receive a low-value preoperative EKG

<sup>‡</sup>Adjusted for patient and facility-level covariates (age, sex, race/ethnicity, VA priority group, driving distance to nearest VA, number of Elixhauser conditions, individual Elixhauser conditions, academic affiliation, facility size, census region, rurality, complexity level) and surgery type using propensity score weighting

<sup>§</sup>Outpatient visit with primary diagnosis of abnormal electrocardiogram, abnormal result of cardiovascular function study, abnormal findings on diagnostic imaging of heart and coronary circulation, not including cardiology visits

<sup>||</sup>Includes cardiac magnetic resonance imaging (cMRI), cardiac positron emission tomography (PET), nuclear imaging, coronary ultrasound, coronary computed tomography angiography (CTA)

<sup>||</sup>Includes Holter monitor, event monitor, implantable loop recorder, electrophysiology (EP) testing, EP procedure, pacemaker evaluation, pacemaker procedure

an average additional cost per Veteran of \$74.33 (95% CI 72.31–76.34) for the initial CXR and \$77.75 (95% CI 72.25–83.25) for potential cascade services. Related imaging and repeat CXR contributed most to the overall costs whereas pulmonary function testing and bronchoscopy accounted for very little (Table 5).

## DISCUSSION

Among a national cohort of VHA beneficiaries undergoing low- or intermediate-risk surgery, care cascades following low-value preoperative testing were common, resulting in 52 potential cascade services per 100 Veterans after low-value EKG and 62 potential cascade services per 100 Veterans after

Table 4 Utilization of potential cascade services after low-value preoperative chest radiograph (CXR)

Cascade service	Unadjusted event rate per 100 Veterans		Unadjusted cascade-attributable event rate*	Adjusted cascade-attributable event rate (95% CI) <sup>†</sup>
	Low-value CXR group(n=28,865)	Comparison group(n=710,140)		
Any cascade service	99.6	24.4	75.2	61.9 (57.8–66.1)
Outpatient CXR	67.5	13.0	54.5	42.2 (38.8–45.6)
Outpatient visit for abnormal CXR <sup>‡</sup>	2.6	1.4	1.2	1.1 (1.0–1.3)
Outpatient visit to pulmonologist	3.7	1.2	2.4	2.3 (1.9–2.8)
Outpatient visit to thoracic surgeon	1.4	0.3	1.1	0.9 (0.7–1.1)
Computed tomography chest	16.2	5.9	10.4	9.1 (8.6–9.7)
Other chest imaging <sup>§</sup>	1.1	0.4	0.7	0.59 (0.48–0.70)
Pulmonary function test	6.6	2.1	4.5	5.3 (4.5–6.0)
Bronchoscopy	0.5	0.1	0.4	0.36 (0.27–0.45)

CXR, chest radiograph

\*Defined as the difference in the rate of care cascade service per 100 Veterans in those who received a low-value preoperative CXR compared who those who did not receive a low-value preoperative CXR

<sup>†</sup>Adjusted for patient and facility-level covariates (age, sex, race/ethnicity, VA priority group, driving distance to nearest VA, number of Elixhauser conditions, individual Elixhauser conditions, academic affiliation, facility size, census region, rurality, complexity level) and surgery type using propensity score weighting

<sup>‡</sup>Defined as outpatient visit with primary diagnosis of solid pulmonary nodule or other nonspecific abnormal findings of the lung field, not including pulmonary visits

<sup>§</sup>Includes magnetic resonance imaging (MRI) of chest and thorax, magnetic resonance angiography (MRA) of chest

Table 5 Cost of potential cascade services after low-value preoperative chest radiograph (CXR)

Cascade service	Average unadjusted cost per Veteran		Unadjusted cascade-attributable cost per Veteran* (\$)	Adjusted cascade-attributable cost per Veteran (95% CI) <sup>†</sup> (\$)
	Low-value CXR group (\$) (n=28,865)	Comparison-group (\$) (n=710,140)		
Any cascade service	124.4	34.4	89.9	77.8 (72.3–83.3)
Outpatient CXR	49.0	9.5	39.4	30.6 (28.2–33.0)
Outpatient visit for abnormal CXR <sup>‡</sup>	1.6	0.9	0.6	0.6 (0.5–0.7)
Outpatient visit to pulmonologist	2.6	0.9	1.7	1.7 (1.3–2.0)
Outpatient visit to thoracic surgeon	0.7	0.2	0.6	0.5 (0.3–0.6)
Computed tomography chest	41.7	14.4	27.3	23.6 (22.2–25.0)
Other chest imaging <sup>§</sup>	4.8	1.8	3.1	2.6 (2.1–3.2)
Pulmonary function test	13.9	4.6	9.4	11.2 (9.5–12.8)
Bronchoscopy	10.0	2.2	7.8	7.1 (5.1–9.1)

*CXR chest radiograph*

\*Determined by subtracting cost of care cascade services per Veteran in those who did not receive a low-value preoperative CXR from those who did receive a low-value preoperative EKG

<sup>†</sup>Adjusted for patient and facility-level covariates (age, sex, race/ethnicity, VA priority group, driving distance to nearest VA, number of Elixhauser conditions, individual Elixhauser conditions, academic affiliation, facility size, census region, rurality, complexity level) and surgery type using propensity score weighting

<sup>‡</sup>Defined as outpatient visit with primary diagnosis of solid pulmonary nodule or other nonspecific abnormal findings of the lung field, not including pulmonary visits

<sup>§</sup>Includes magnetic resonance imaging (MRI) of chest and thorax, magnetic resonance angiography (MRA) of chest

undergoing a low-value CXR. Veterans who received preoperative testing incurred greater than \$100 in additional costs associated with the low-value test compared to those who did not undergo preoperative testing.

Prior studies have demonstrated that low-value care is prevalent within VHA; however, these studies have largely focused on single low-value services.<sup>13,14,36,37</sup> We build upon this work by examining the use and costs of a series of downstream services that could plausibly result from each of these low-value service. Our findings are also consistent with and add to prior studies examining care cascades in other patient populations. Among a sample of low-risk Medicare beneficiaries undergoing cataract surgery, Ganguli et al. showed that those who received a preoperative EKG experienced an overall CAER of approximately 11 cascade services per 100 beneficiaries during a 90-day outcome period.<sup>7</sup> The higher rate of total cascade services in our study, even after conducting sensitivity analysis using a 90-day outcome period, was largely driven by higher rates of subsequent EKGs. This may be partially explained by the fact that Veterans, in general, have higher medical complexity and thus clinicians may be more likely to order additional tests in anticipation of complications even if they are not necessary. Nonetheless, the authors similarly found that follow-up cardiac imaging and related outpatient visits occurred at a higher rate than invasive services such as cardiac catheterization.<sup>7</sup> By using a cohort of low-risk Veterans undergoing any low or intermediate-risk surgery as opposed to cataract surgery alone and in applying a longer outcome period, our work builds upon these studies by providing a more comprehensive examination of care cascades following low-value preoperative testing.

The cascade services in our study consisted of mostly repeat testing, follow-up imaging, and follow-up visits but few invasive procedures, which aligns with studies examining care cascades in other patient populations.<sup>7,8</sup> The fact that few Veterans experienced invasive procedures such as bronchoscopy suggests that the preoperative test did not reveal a meaningful finding that needed intervention and that the majority of the downstream care was unnecessary. For a subset of Veterans, these invasive downstream services may also be unnecessary. While the total frequency and cost of these invasive services are low in our study, on an individual-level, they are associated with high costs and risk of additional downstream consequences.

While low-value services, such as preoperative testing, may seem low-risk, downstream care may result in unanticipated harms to patients such as anxiety surrounding false-positive results, inconvenience associated with downstream testing and visits, and risks of invasive procedures. The total cost of nearly \$14 million associated with low-value preoperative testing in our study was low in comparison to the \$72.3 billion in total VA expenditures in FY18. However, patients may experience additional costs that we did not directly calculate such as those associated with transportation or missed work. These negative experiences may erode a patient's trust and cause them to ignore recommendations regarding future follow-up testing that is in fact necessary. Additional qualitative research examining patients' experiences with care cascades is warranted to further explore this.

Our study provides a template for characterizing often unmeasured, unnecessary downstream care and can inform future studies that seek to characterize care cascades following other low-value services. This has the potential to impact de-

implementation policies and interventions both within and outside VHA. Health systems should target those services associated with more prevalent or costly downstream care. For example, health systems could focus their de-implementation efforts on preoperative tests that result in greater cascades of care through interventions such as preoperative bundles within the electronic medical record or standardized preoperative clinics.

Our study has several important limitations. Using a claims-based approach lacks clinical granularity such as provider decision-making or the ability to determine if the downstream care revealed a meaningful finding. We may have identified an initial preoperative test to be low value when it was actually for diagnostic purposes. By using broad exclusion criteria, we hoped to better capture truly low-value tests. Similarly, we were unable to definitively identify downstream care that occurred as a result of the initial test; however, by using a comparison group, we attempted to account for the baseline level of care occurring in our study sample. Lastly, cost data was unavailable for several invasive services such as valve repair, valve replacement, and coronary bypass surgery. However, these occurred at very low rates within our cohort and likely contributed very little to the overall cost.

In summary, low-value care cascades following two common low-value preoperative tests are common and result in potentially unnecessary care and cost beyond the initial low-value service within the Veterans Health Administration. Characterizing care cascades that result from low-value services can aid health systems and payers to prioritize which low-value services to target for de-implementation, thus reducing the potential for patient harms and mistrust, while yielding the greatest degree of downstream cost savings.

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**Corresponding Author:** Aimee N. Pickering, MD; Center for Health Equity Research and Promotion (CHERP), VA Pittsburgh Healthcare System, Pittsburgh, PA, USA (e-mail: [pickeringan@upmc.edu](mailto:pickeringan@upmc.edu)).

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#### Declarations:

**Conflict of Interest:** Aaron Schwartz reports receiving personal fees from the Lown Institute, CVS Health, and the Medicare Payment Advisory Commission for prior research consulting outside the scope of the submitted work.

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