Temporal Trends in Percutaneous Coronary Intervention Appropriateness: Insights from the Clinical Outcomes Assessment Program

Running title: Bradley et al.; Trends in PCI Appropriateness

Steven M. Bradley, MD, MPH; Chad M. Bohn, MS; David J. Malenka, MD; Michelle M. Graham, MD; Chris L. Bryson, MD, MPH; James M. McCabe, MD; Jeptha P. Curtis, MD; Anne Lambert-Kerzner, PhD; Charles Maynard, PhD

1VA Eastern Colorado Health Care System, Denver, CO and the University of Colorado School of Medicine, Aurora, CO; 2Dartmouth-Hitchcock Medical Center, Hanover, NH; 3Mazankowski Alberta Heart Institute, University of Alberta, Edmonton, Alberta, Canada; 4University of Washington and the Clinical Outcomes Assessment Program, Foundation for Health Care Quality, Seattle, WA; 5Center for Outcomes Research and Evaluation, Yale New Haven Health Services Corporation and the Yale University School of Medicine, New Haven, CT

Address for Correspondence:
Steven M. Bradley, MD, MPH
VA Eastern Colorado Health Care System, Department of Veterans Affairs
1055 Clermont Street (111B)
Denver, CO 80220-3808
Tel: 720-857-5120
Fax: 303-370-7580
E-mail: Steven.Bradley@va.gov

Journal Subject Codes: Treatment:[24] Catheter-based coronary interventions:stents, Ethics and policy:[100] Health policy and outcome research
Abstract

Background—It is unknown if the appropriate use of PCI has improved over time and whether trends in PCI appropriateness have been accompanied by changes in the use of PCI.

Methods and Results—We applied Appropriate Use Criteria to determine the appropriateness of all 51,872 PCI performed in Washington State from 2010 through 2013. We evaluated the number of PCI performed from 2006 through 2013 to provide a comparator period that preceded statewide appropriateness assessment beginning in 2010. Between 2010 and 2013, the overall number of PCI decreased by 6.8% (13,267 PCI in 2010 to 12,193 in 2013) with a 43% decline in the number of PCI for elective indications (3,818 PCI in 2010 to 2,193 in 2013). The decline in use of elective PCI was significantly larger following the onset of statewide PCI appropriateness assessment in 2010 (P = 0.03). The proportion of elective PCI classified as appropriate increased from 26% in 2010 to 38% in 2013 while the proportion of inappropriate PCI decreased from 16% to 13% (P<0.001 for trends). Significant improvements in the proportion of inappropriate PCI were limited to the tertile of hospitals with the largest decline in PCI classified as inappropriate (25% in 2010 to 12% in 2013; P=0.03).

Conclusions—In Washington State, the use of PCI for elective indications has decreased over time with concurrent improvements in PCI appropriateness. However, improvements in PCI appropriateness were limited to a minority of hospitals. Understanding processes at these high-performing hospitals may inform efforts to improve PCI appropriateness.

Key words: percutaneous coronary intervention, appropriateness criteria, utilization
Proper patient selection for invasive coronary procedures is important to ensure the clinical benefits outweigh procedural risks. The Appropriate Use Criteria (AUC) for Coronary Revascularization support an evidence-based guidelines-concordant approach to assessing the quality of patient selection for percutaneous coronary intervention (PCI). In these criteria, inappropriate PCI reflect clinical scenarios in which the patient’s health status (symptoms, function, or quality of life) or survival is unlikely to be improved by the procedure. Application of the AUC has demonstrated quality gaps in patient selection for PCI, with as many as 1 in 6 elective (non-acute) PCI being classified as inappropriate. Whether the use of inappropriate PCI has changed in response to a growing emphasis on proper patient selection and procedural appropriateness is unknown.

The determination of PCI appropriateness is influenced by a number of factors, including clinical acuity and patient symptom burden. In response to pressures to reduce inappropriate use of PCI, providers may be motivated to inflate clinical acuity or patient reported symptoms to influence apparent appropriateness. This may result in the appearance of more frequent use of PCI for higher acuity clinical indications with concurrent declining inappropriate use. In contrast, if the number of PCI for higher acuity conditions remained stable despite decreasing use of PCI for elective and inappropriate clinical indications, this would suggest temporal changes in patient selection processes have resulted in more appropriate use of PCI.

In addition to demonstrating gaps in PCI appropriateness, prior studies have found up to 40% of elective PCI could not be mapped to the AUC due to a lack of preprocedural stress testing in settings where the results of stress testing influence procedural appropriateness. Furthermore, the extent to which elective PCI occurred in clinical scenarios that were inappropriate or lacked adequate preprocedural assessment varied at the hospital-level.
Identifying hospitals with low or declining use of PCI classified as inappropriate or with insufficient preprocedural assessment may afford opportunities to learn from the patient selection processes at these high-performing hospitals.

Using data from the Washington State Clinical Outcomes Assessment Program (COAP), we sought to describe temporal trends in the number of PCI procedures performed and the appropriateness of PCI. Furthermore, we sought to identify high-performing hospitals as determined by a low overall proportion or a declining temporal proportion of PCI classified as inappropriate or with insufficient preprocedural assessment. Understanding these aspects of PCI appropriateness may guide efforts to improve patient selection and reduce inappropriate use of the procedure.

Methods

Design and Setting

The Clinical Outcomes Assessment Program (COAP) is a regional quality-improvement initiative of the Foundation for Health Care Quality, a non-profit 501(c)3 corporation, designed to produce clinical information to improve quality of care for patients receiving cardiac interventions. All 31 non-Veterans Affairs hospitals that perform PCI in the state of Washington participate in COAP. Data on all PCI performed in the state are abstracted on-site by trained abstractors with data reviewed for errors on a quarterly basis. Data quality is ensured through audits of 100% of sites on an ongoing basis and includes data elements captured at the time of PCI as well as verification of the number of PCI performed through comparison to the Washington State Department of Health Comprehensive Hospital Abstract Reporting System. In addition to ongoing quality improvement programs, participating hospitals receive individual
quarterly reports and an annual, comprehensive, hospital identified statewide risk-adjusted
dashboard report. Elements of the annual dashboard are also publically reported, with measures
of elective PCI appropriateness added to public reporting in 2014.9

**Patient Population**

Beginning in June of 2009, COAP began collecting data for PCI in accordance with the
American College of Cardiology National Cardiovascular Data Registry (NCDR) CathPCI
version 4.3, which includes data elements necessary for determination of appropriateness. In our
analysis of PCI appropriateness, we included all patients who underwent PCI in the state of
Washington between January 1, 2010, and December 31, 2013. We began statewide assessment
of PCI appropriateness 6 months after the implementation of NCDR version 4.3 to provide an
opportunity for all facilities to become compliant with this data collection tool. Beginning in
2011, measures of PCI appropriateness were reported on the COAP website annual dashboard
that is accessible to COAP participating facilities and these results were discussed with
participating hospitals at the COAP Annual Statewide Meeting. Beginning in 2012, COAP
participating hospitals were given access to run ad hoc reports of their own PCI appropriateness
at the hospital and physician level. Beginning in 2014, hospital-level measures of PCI
appropriateness were incorporated into annual dashboard reports accessible by the public.

Although the AUC for coronary revascularization were first published in 2009 and
revised in 2012,1,2 our audit and feedback of elective PCI appropriateness was consistent with the
2012 criteria throughout as we chose to consider PCI for all non-ST elevation myocardial
infarction (NSTEMI) and unstable angina (UA) as acute indications.3 This decision differs from
the 2009 AUC, but is consistent with the 2012 revision of the AUC. Accordingly, the 2012 AUC
for coronary revascularization were also applied to the analysis for the present manuscript.
Concurrent to efforts by COAP, the NCDR CathPCI registry began to collect and provide PCI appropriateness ratings as part of quarterly benchmark reports to participating hospitals. Of the 31 PCI hospitals participating in COAP, 24 (77%) concurrently participated in NCDR CathPCI in 2010 with all COAP hospitals concurrently participating in NCDR CathPCI since the beginning of 2013. In assessment of temporal trends in the number of PCI performed, we evaluated the period from January 1, 2006 to December 31, 2013 to provide a comparator timeframe prior to 2010 during which PCI appropriateness assessment was not yet occurring in COAP or NCDR CathPCI.

**Outcome Measure**

Using previously developed algorithms, we mapped PCIs performed in COAP to the 2012 publication of the Appropriate Use Criteria for Coronary Revascularization to assign procedural appropriateness of “appropriate”, “uncertain”, or “inappropriate.” Details on the Appropriate Use Criteria have been previously published.1-2,10 In these criteria, PCI are considered inappropriate when the procedure is unlikely to improve the patient’s health status (symptoms, functional status, or quality of life) or survival.1,2

The process of mapping PCI to the AUC was automated using our algorithm and data elements entered at the facility. There was no secondary chart review, coronary angiography review, or manual determination of PCI appropriateness. We verified our AUC mapping processes through comparison of site-level reports of PCI appropriateness obtained from the NCDR CathPCI for facilities participating in both registries.

**Statistical Analysis**

We report the annual statewide number of PCI procedures from 2006 through 2013 by clinical indications of ST elevation myocardial infarction (STEMI), non-ST elevation myocardial
infarction (NSTEMI), unstable angina (UA), and stable angina. Temporal trends in the number of PCI procedures for the time periods of 2006 through 2009 and 2010 through 2013 were determined from linear regression and compared with t-tests.

We then compared baseline patient demographics, clinical characteristics (risk factors, prior revascularization, comorbidities), and clinical indication (ST-segment elevation myocardial infarction, non-ST segment myocardial infarction, unstable angina, stable angina/other) by calendar year. Comparisons of patient characteristics were completed using linear trend tests for continuous variables and Chi-square for trend test for categorical variables.

As prior work has shown PCI for acute indications to be nearly uniformly appropriate,\textsuperscript{3,4} we report the appropriateness of PCI stratified by acute (STEMI, NSTEMI, or UA) and elective (stable angina) coronary presentations. We compared the statewide appropriateness of PCI for acute and elective indications by calendar year. Statewide trends were assessed using the Chi-square for trend test.

In the comparison of hospital-level average and temporal trends in the proportion of inappropriate PCI, we limited our comparisons to elective PCI at the 22 hospitals performing an average of > 20 elective PCIs annually to avoid inflation of variance due to small numbers. We first determined the overall hospital average proportion of elective PCI classified as inappropriate during the study period. We then compared hospitals by tertiles of their average proportion of inappropriate PCI. We conducted this analysis to identify hospitals with low proportions of inappropriate PCI throughout the study period, consistent with hospitals that had patient selection processes to optimize PCI appropriateness in place prior to the period of study. We next used weighted linear regression to determine individual hospital trends by calendar year in the proportion of PCI classified as inappropriate. Standard errors of the regression coefficients
were adjusted using the Huber White Sandwich Estimator to account for clustering of observations within hospitals. We then compared hospitals by tertiles of temporal trend in the proportion of inappropriate PCI. We conducted this analysis to identify hospitals with large absolute reductions in the proportion of inappropriate PCI, consistent with the implementation of patient selection processes to optimize PCI appropriateness during the period of study. These hospital-level analyses were repeated to also assess average and temporal trends in the proportion of PCI for insufficiently assessed clinical indications.

All statistical tests of significance were 2 sided, with values of $P<0.05$ considered statistically significant. All analyses were performed using SPSS version 19.0 and STATA version 13.0. This study was approved by the Colorado Multiple Institutional Review Board.

Results

Since 2010, the overall number of PCI has decreased by 6.8%, from 13,267 procedures in 2010 to 12,367 procedures in 2013. This trend was driven by a 43% decline in the number of elective PCI for stable angina, from 3,818 PCI in 2010 to 2,193 PCI in 2013 (Figure 1). Over this same time period, the number of PCI for STEMI and unstable angina remained largely unchanged while the number of PCI for NSTEMI increased 17%, from 2,747 PCI in 2010 to 3,226 PCI in 2013. Compared with trends in the number of PCI performed between 2006 and 2009, trends in the number of PCI performed between 2010 and 2013 were significantly different for indications of unstable angina ($P<.001$) and stable angina ($P=0.03$).

Among 51,872 patients who underwent PCI between 2010 and 2013 in Washington State, 79% were classified as appropriate, 8% as uncertain, 4% as inappropriate and 9% were unable to be classified by the AUC. Little to no change in patient demographics, risk factors, or comorbid
conditions was observed between 2010 and 2013 (Table 1).

Appropriateness of PCI by calendar year is shown in Table 2. Although statistically significant due to the size of our cohort, the appropriateness of PCI for acute indications was largely similar by calendar year (>92% appropriate for all years). In comparison, the proportion of PCI for elective indications that were classified as appropriate increased from 26% in 2010 to 38% in 2014. Concurrently, the proportion of elective PCI that were classified as inappropriate decreased from 16% to 13%. A larger temporal decline from 29% in 2010 to 23% in 2013 was noted for the proportion of elective PCI that could not be mapped to the AUC due to insufficient preprocedural assessment. We repeated our analyses after limiting to PCI with adequate preprocedural assessment to map to the AUC and found a similar increase over time in the proportion of elective PCI classified as appropriate (37% in 2010 to 49% in 2013) with a concurrent decline in the proportion of inappropriate elective PCI (23% in 2010 to 17% in 2013).

By hospital tertiles, the average proportion of inappropriate PCI among hospitals in the lowest tertile ranged from 1% to 13%, as compared to an average proportion of 13% to 20% for hospitals in the middle tertile, and 20% to 30% for hospitals in the highest tertile (Figure 2). Temporal improvements in the proportion of inappropriate PCI were limited to a small number of hospitals (Figure 3). Reductions in the proportion of inappropriate PCI were only observed in the hospital tertile with the greatest decline in PCI classified as inappropriate (25% in 2010 to 12% in 2013; P=0.03). Concurrently, hospitals in the tertile with the least improvement in the proportion of inappropriate PCI saw a temporal increase in the proportion of inappropriate PCI (12% in 2010 to 20% in 2013; P<0.01).

Similar hospital level differences were noted in the average proportion of PCI with insufficient preprocedural assessment for appropriateness determination (Supplemental Figures.
1 and 2). By hospital tertile, the average proportion of PCI with insufficient preprocedural assessment ranged from 14% to 24% for hospitals in the lowest tertile, as compared to an average proportion of 24% to 27% for hospitals in the middle tertile, and 29% to 40% for hospitals in the lowest tertile. In addition, temporal improvements in the proportion of PCI with insufficient preprocedural assessment were only noted in the hospital tertile with the greatest decline in PCI that lacked adequate preprocedural assessment to map to the AUC (41% to 18%, P<0.001).

Discussion
We assessed temporal trends in the number and appropriateness of PCIs performed in Washington State. The number of PCIs performed in the state of Washington decreased by nearly 7% between 2010 and 2013, due to a nearly 45% reduction in the number of PCI for elective indications. When compared with elective PCI use from 2006 through 2009, a time period for which statewide PCI appropriateness assessment was not yet occurring, the decline in elective PCI use was significantly larger between 2010 and 2013. Concurrent to the decline in elective PCI procedures, the appropriateness of PCI for elective indications has improved, with the proportion of appropriate PCI increasing from 26% to 38% and the proportion of inappropriate PCI decreasing from 16% to 13%. In addition, preprocedural assessment was more complete over time, with the proportion of patients undergoing elective PCI with insufficient preprocedural assessment to facilitate appropriateness determination declining from 29% to 23%. Although these findings suggest statewide improvements in preprocedural assessment and appropriate patient selection for elective PCI, evaluation at the hospital level demonstrated these improvements were limited to a minority of hospitals, while some hospitals even saw temporal
increases in the proportion of inappropriate PCI.

For many years, quality improvement programs for PCI were limited to the assessment of PCI processes and procedural outcomes that aim to reflect how well the procedure was performed. Appropriate use criteria reflect a standardized method to assess quality domains related to preprocedural processes of patient assessment and patient selection for PCI. Prior studies have demonstrated suboptimal performance in these preprocedural PCI quality domains. For example, in a national study of PCI from the NCDR CathPCI registry, 12% of elective PCI were classified as inappropriate. Similar proportions of elective PCI classified as inappropriate were observed in studies from regional quality improvement programs. In addition to gaps in the appropriate use of PCI, these studies found up to 40% of PCI could not be mapped to the Appropriate Use Criteria due to a lack of preprocedural stress testing. The present study is the first to assess temporal trends in appropriateness measures of PCI quality. We observed declining proportions of elective PCI classified as inappropriate or with insufficient preprocedural assessment for appropriateness assessment, suggestive of temporal improvements in the quality of preprocedural assessment and patient selection for elective PCI.

The appropriateness of PCI is determined by aspects of a patient’s clinical presentation, including clinical acuity, symptom severity, adequacy of antianginal therapy, ischemic risk by non-invasive testing, and severity of anatomic coronary disease. Concerns have been raised about the potential for providers to increase the reported severity of patient presentations to achieve the appearance of improved PCI appropriateness. This type of gaming should result in lower proportions of inappropriate PCI without impacting the overall number of procedures used (i.e. lower use of PCI for stable angina would be accompanied by a matching increase in the use of PCI for unstable angina and NSTEMI). Although we did observe a small increase in the
number of PCI performed for NSTEMI and unstable angina that may in part reflect an aspect of gaming, this was accompanied by a much larger decline in the use of elective PCI. Furthermore, the decline in elective PCI use was steeper in the years following the onset of appropriateness assessment. These findings suggest the trend in lower proportions of inappropriate and insufficiently assessed PCI observed in our study largely reflect improvements in patient assessment and selection processes, rather than an artificial change due to upcoding of the clinical indication for PCI.

Several factors may have contributed to declining use of elective PCI and improvements in procedural appropriateness in Washington State. First, the findings of the Clinical Outcomes Utilizing Revascularization and Aggressive Drug Evaluation (COURAGE) trial were published in 2007 and may have encouraged less utilization of elective PCI given the lack of mortality or myocardial infarction benefit in this setting. However, the rate of decline in elective PCI was larger in the years that followed the onset of statewide assessment of procedural appropriateness. This may relate to feedback and quality improvement efforts occurring through COAP and NCDR CathPCI to address use of PCI for inappropriate and insufficiently assessed clinical indications, publications highlighting the findings of PCI appropriateness assessment in national and regional PCI registries, or the publication and attention given to the AUC themselves, including attention by healthcare payers.

Although the overall proportion of PCI classified as inappropriate or insufficient preprocedural assessment improved in the state of Washington, these improvements were not uniform across hospitals. A small number of hospitals already appeared to have high quality patient assessment and selection processes for elective PCI as reflected in their low proportion of inappropriate or insufficiently assessed clinical indications throughout the study period. In
addition, we observed a small number of hospitals with large declines in the proportion of inappropriate or insufficiently assessed PCI. Similar to the mixed methods approach used to identify care processes associated with improvement in door to balloon time for STEMI, study of hospitals with low or declining proportions of inappropriate and insufficiently assessed PCI may inform strategies to optimize patient selection processes and procedural appropriateness. Furthermore, qualitative study of hospitals with increasing proportions of inappropriate PCI may serve to validate the importance of patient selection processes identified at hospitals with improvements in PCI appropriateness.

Strengths of our study include the assessment of all PCI performed in the state of Washington over the time period of study. Our findings should be considered in light of the following limitations. First, as previously discussed, providers who are aware of the clinical determinants of PCI appropriateness may be motivated to upcode patient reported symptoms to influence apparent appropriateness. However, the reduction in elective PCI numbers concurrent with an increasing appropriateness of these procedures suggests gaming of procedural appropriateness is not the predominant explanation for our findings. Future efforts should be made to capture patient reported health status measures, including symptom burden, functional status, and health related quality of life, to inform appropriateness assessment and minimize the potential for appropriateness misclassification related to physician assessment of symptom burden. Second, although Appropriate Use Criteria are frequently updated to reflect current evidence, there is currently minimal incorporation of fractional flow reserve (FFR) assessment as an alternative to stress testing. However, during the period of study fewer than 3.5% of patients in COAP were assessed with FFR prior to elective PCI suggesting procedures that could not be mapped due to a lack of stress testing results do not represent use of FFR in place of non-
invasive testing. Further, it is important to note that stress testing is not mandated by the AUC prior to consideration of all elective PCI. In settings of higher symptom burden or coronary anatomy associated with higher risk, PCI remains appropriate by the AUC even in the absence of preprocedural stress testing. Third, concerns have been raised that the AUC do not capture patient preferences in the use of procedural care for symptom reduction. However, studies have previously demonstrated inappropriate use of PCI is predominantly due to procedural use in asymptomatic patients where there is no symptom reduction benefit. Fourth, as with other registry studies of PCI appropriateness, our study is dependent on site-level entry of clinical data. Additional chart or angiography review was not undertaken to confirm the accuracy of this data. However, our findings suggest the apparent increase in procedural appropriateness mirrored a decline in procedural use as would be expected with changes in patient selection practice.

Finally, we lack a control region for comparison of the temporal findings in Washington State. Further study is needed to inform the extent of temporal change in PCI use and appropriateness in the U.S.

In conclusion, in a complete cohort of PCI performed in Washington State from 2010 to 2013, the statewide volume of PCI for elective indications decreased by 43%. At the same time, the proportion of elective PCI classified as appropriate increased from 26% to 38% while the proportion of inappropriate PCI decreased from 16% to 13% and the proportion of elective PCI that could not be mapped by the AUC due to lack of preprocedural stress testing decreased from 29% to 23%. Temporal improvements in PCI appropriateness were limited to a small number of hospitals, suggesting an opportunity to identify best practices in patient assessment and selection processes through targeted investigation of these high-performing hospitals.
**Funding Sources:** This study was supported by a grant from the American Heart Association (13CRP16920075). Dr. Bradley is supported by a Career Development Award (HSR&D-CDA2 10-199) from Veterans Affairs Health Services Research and Development.

**Conflict of Interest Disclosures:** Dr. Curtis receives salary support under contract with the Centers for Medicare and Medicaid Services to support development of quality measures and holds equity interests in Medtronic. The other authors report no conflicts. The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States government.

**References:**


17. Bradley EH, Roumanis SA, Radford MJ, Webster TR, McNamara RL, Mattera JA, Barton

### Table 1. Patient Characteristics by Calendar Year.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total (n=51,872)</th>
<th>2010 (n=13,267)</th>
<th>2011 (n=13,313)</th>
<th>2012 (n=12,925)</th>
<th>2013 (n=12,367)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient Demographics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, yrs (SD)</td>
<td>65 (12)</td>
<td>65 (12)</td>
<td>65 (12)</td>
<td>65 (12)</td>
<td>65 (12)</td>
<td>0.27</td>
</tr>
<tr>
<td>Men</td>
<td>72%</td>
<td>72%</td>
<td>71%</td>
<td>71%</td>
<td>72%</td>
<td>0.61</td>
</tr>
<tr>
<td>White</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>0.52</td>
</tr>
<tr>
<td><strong>Clinical Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior MI</td>
<td>29%</td>
<td>30%</td>
<td>29%</td>
<td>28%</td>
<td>29%</td>
<td>0.59</td>
</tr>
<tr>
<td>Prior PCI</td>
<td>38%</td>
<td>39%</td>
<td>38%</td>
<td>37%</td>
<td>38%</td>
<td>0.012</td>
</tr>
<tr>
<td>Prior CABG</td>
<td>17%</td>
<td>18%</td>
<td>17%</td>
<td>16%</td>
<td>16%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HTN</td>
<td>77%</td>
<td>77%</td>
<td>76%</td>
<td>75%</td>
<td>77%</td>
<td>0.10</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>76%</td>
<td>77%</td>
<td>76%</td>
<td>75%</td>
<td>77%</td>
<td>0.14</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>33%</td>
<td>32%</td>
<td>32%</td>
<td>33%</td>
<td>34%</td>
<td>0.017</td>
</tr>
<tr>
<td>Current smoker</td>
<td>24%</td>
<td>24%</td>
<td>25%</td>
<td>24%</td>
<td>24%</td>
<td>0.84</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>11%</td>
<td>0.06</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>11%</td>
<td>11%</td>
<td>0.053</td>
</tr>
<tr>
<td>Heart failure</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>12%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>COPD</td>
<td>12%</td>
<td>13%</td>
<td>12%</td>
<td>12%</td>
<td>13%</td>
<td>0.54</td>
</tr>
</tbody>
</table>
Table 2. Calendar Year Trends in PCI Appropriateness by Indication.

<table>
<thead>
<tr>
<th>All PCI</th>
<th>Total</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Indications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Appropriate</td>
<td>37,561 (94%)</td>
<td>8662 (92%)</td>
<td>9321 (93%)</td>
<td>9857 (94%)</td>
<td>9721 (95%)</td>
<td></td>
</tr>
<tr>
<td>Uncertain</td>
<td>1124 (3%)</td>
<td>289 (3%)</td>
<td>313 (3%)</td>
<td>286 (3%)</td>
<td>236 (2%)</td>
<td></td>
</tr>
<tr>
<td>Inappropriate</td>
<td>224 (0.6%)</td>
<td>72 (0.8%)</td>
<td>66 (0.7%)</td>
<td>55 (0.5%)</td>
<td>31 (0.3%)</td>
<td></td>
</tr>
<tr>
<td>Inadequate Assessment</td>
<td>1210 (3%)</td>
<td>362 (4%)</td>
<td>314 (3%)</td>
<td>288 (3%)</td>
<td>246 (2%)</td>
<td></td>
</tr>
<tr>
<td>Non-Acute Indications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Appropriate</td>
<td>3495 (30%)</td>
<td>1010 (26%)</td>
<td>933 (28%)</td>
<td>748 (31%)</td>
<td>804 (38%)</td>
<td></td>
</tr>
<tr>
<td>Uncertain</td>
<td>3216 (27%)</td>
<td>1129 (29%)</td>
<td>897 (27%)</td>
<td>627 (26%)</td>
<td>563 (26%)</td>
<td></td>
</tr>
<tr>
<td>Inappropriate</td>
<td>1785 (15%)</td>
<td>622 (16%)</td>
<td>498 (15%)</td>
<td>391 (16%)</td>
<td>274 (13%)</td>
<td></td>
</tr>
<tr>
<td>Inadequate Assessment to Map to AUC</td>
<td>3235 (28%)</td>
<td>1111 (29%)</td>
<td>963 (29%)</td>
<td>671 (28%)</td>
<td>490 (23%)</td>
<td></td>
</tr>
</tbody>
</table>

PCI Mapped to AUC

| Acute Indications                |             |            |            |            |            | <0.001  |
| Appropriate                      | 37,561 (97%)| 8662 (96%) | 9321 (96%) | 9857 (97%) | 9721 (97%) |         |
| Uncertain                        | 1124 (3%)   | 289 (3%)   | 313 (3%)   | 286 (3%)   | 236 (2%)   |         |
| Inappropriate                    | 224 (0.6%)  | 72 (0.8%)  | 66 (0.7%)  | 55 (0.5%)  | 31 (0.3%)  |         |
| Non-Acute Indications            |             |            |            |            |            | <0.001  |
| Appropriate                      | 3495 (41%)  | 1010 (37%) | 933 (40%)  | 748 (42%)  | 804 (49%)  |         |
| Uncertain                        | 3216 (38%)  | 1129 (41%) | 897 (39%)  | 627 (36%)  | 563 (34%)  |         |
| Inappropriate                    | 1785 (21%)  | 622 (23%)  | 498 (21%)  | 391 (22%)  | 274 (17%)  |         |

Abbreviations: AUC, appropriate use criteria; PCI, percutaneous coronary intervention.
Figure Legends:

**Figure 1.** PCI Volumes by Clinical Indication. After 2010, the number of elective PCI for stable angina decreased by 43%, PCI for NSTEMI increased by 17%, and PCI for STEMI and UA remained largely unchanged. In comparison to the trend in PCI use prior to the onset of PCI appropriateness assessment in 2010, the trend in PCI use after 2010 was significantly different for unstable angina (P<.001) and stable angina (P=0.03). Trends in PCI use for STEMI and NSTEMI were similar before and after 2010.

**Figure 2.** Facility-Level Average Rates of Inappropriate Elective PCI by Hospital Tertiles. A. Lowest Average Tertile Hospitals. B. Middle Tertile Hospitals. C. Highest Average Tertile Hospitals. Circle sizes reflect the elective PCI volume at a site for a given year:
- ○ 500 PCI; ○ 250 PCI; ○ 100 PCI; ○ 50 PCI.

**Figure 3.** A. Tertile of Largest Temporal Decline. B. Middle Tertile. C. Tertile of Smallest Temporal Decline. Circle sizes reflect the elective PCI volume at a site for a given year:
- ○ 500 PCI; ○ 250 PCI; ○ 100 PCI; ○ 50 PCI.

Trend lines represent the average hospital trend for the tertile. These trends were significant for the tertiles with the largest (P=0.03) and smallest (P<0.01) temporal declines.
Figure 1
Figure 2

A. Lowest Average Tertile Hospitals
B. Middle Tertile Hospitals
C. Highest Average Tertile Hospitals
Figure 3

A. Tertile of Largest Temporal Decline

B. Middle Tertile

C. Tertile of Smallest Temporal Decline
Temporal Trends in Percutaneous Coronary Intervention Appropriateness: Insights from the Clinical Outcomes Assessment Program
Steven M. Bradley, Chad M. Bohn, David J. Malenka, Michelle M. Graham, Chris L. Bryson, James M. McCabe, Jeptha P. Curtis, Anne Lambert-Kerzner and Charles Maynard

Circulation. published online May 28, 2015;
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2015 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/early/2015/05/28/CIRCULATIONAHA.114.015156

Data Supplement (unedited) at:
http://circ.ahajournals.org/content/suppl/2015/05/28/CIRCULATIONAHA.114.015156.DC1

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org/subscriptions/
**Supplemental Figure 1.** Facility-Level Average Rates of Unmappable (Insufficiently Assessed) Elective PCI by Hospital Tertiles

A. Lowest Average Tertile Hospitals

B. Middle Tertile Hospitals

C. Highest Average Tertile Hospitals

Circle sizes reflect the elective PCI volume at a site for a given year.

- 500 PCI
- 250 PCI
- 100 PCI
- 50 PCI
Supplemental Figure 2. Facility-Level Temporal Trends in Unmappable (Insufficiently Assessed) Non-Acute PCI by Hospital Tertiles

A. Tertile of Largest Temporal Decline

B. Middle Tertile

C. Tertile of Smallest Temporal Decline

Circle sizes reflect the elective PCI volume at a site for a given year.

- ○ 500 PCI;
- □ 250 PCI;
- ● 100 PCI;
- ○ 50 PCI

Trend lines represent the average hospital trend for the given tertile. These trends were significant for the tertiles with the largest (P<0.001) and smallest (P<0.01) temporal declines.