Proper patient selection for invasive coronary procedures is important to ensure that the clinical benefits outweigh the 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 PCIs 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 (nonacute) PCIs 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 PCIs for higher-acuity conditions remained stable despite decreasing use of PCI for elective and inappropriate clinical indications, this would suggest that temporal changes in patient selection processes have resulted in more appropriate use of PCI.
In addition to demonstrating gaps in PCI appropriateness, previous studies have found that up to 40% of elective PCIs could not be mapped to the AUC owing 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 of PCI classified as inappropriate or with insufficient preprocedural assessment. Understanding these aspects of PCI appropriateness may guide efforts to improve patient selection and to reduce inappropriate use of the procedure.

Methods

Design and Setting

COAP is a regional quality-improvement initiative of the Foundation for Health Care Quality, a nonprofit 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 PCIs in the state of Washington participate in COAP. Data on all PCIs 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 and verification of the number of PCIs performed through comparison with 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.

Patient Population

Beginning in June 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 the 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 Web site annual dashboard, which 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 levels. 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 2012,12 our audit and feedback of elective PCI appropriateness were consistent with the 2012 criteria throughout because we chose to consider PCI for all non–ST-segment–elevation myocardial infarction (NSTEMI) and unstable angina as acute indications. 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 study.

Concurrent with 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 the assessment of temporal trends in the number of PCIs performed, we evaluated the period from January 1, 2006, to December 31, 2013, to provide a comparator time frame before 2010 during which PCI appropriateness assessment was not yet occurring in COAP or NCDR CathPCI.

Outcome Measure

Using previously developed algorithms,3 we mapped PCIs performed in COAP to the 2012 publication of the AUC for coronary revascularization to assign procedural appropriateness of appropriate, uncertain, or inappropriate. Details on the AUC have previously been published.13,14 In these criteria, PCI is considered inappropriate when the procedure is unlikely to improve the patient’s health status (symptoms, functional status, or quality of life) or survival.12 The process of mapping PCI to the AUC was automated with the use of 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-segment–elevation myocardial infarction (STEMI), NSTEMI, unstable angina, and stable angina. Temporal trends in the number of PCIs performed for the time periods of 2006 through 2009 and 2010 through 2013 were determined from linear regression and compared by use of t tests.

We then compared baseline patient demographics, clinical characteristics (risk factors, previous revascularization, comorbidities), and clinical indication (STEMI, NSTEMI, unstable angina, stable angina/other) by calendar year. Comparisons of patient characteristics were completed by use of linear trend tests for continuous variables and χ2 for trend test for categorical variables.

Because previous work has shown PCI for acute indications to be nearly uniformly appropriate,3,4 we report the appropriateness of PCI stratified by acute (STEMI, NSTEMI, or unstable angina) 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 with the χ2 for trend test. Compared with hospital-level average and temporal trends in the proportion of inappropriate PCI, we limited our comparisons to elective PCIs at the 22 hospitals performing an average of ≥20 elective PCIs annually to avoid inflation of variance resulting from small numbers. We first determined the overall hospital average proportion of elective PCIs classified as inappropriate during the study period. We then compared hospitals by tertiles of their average proportion of inappropriate PCIs. We conducted this analysis to identify hospitals with low proportions of inappropriate PCIs throughout the study period, consistent with hospitals that had patient selection processes to optimize PCI appropriateness in place before 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 with 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 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 with 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 PCIs 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 PCIs for stable angina, from 3,818 PCIs in 2010 to 2,193 PCIs in 2013 (Figure 1). Over this same time period, the number of PCIs for STEMI and unstable angina remained largely unchanged, whereas the number of PCIs for NSTEMI increased 17%, from 2,747 PCIs in 2010 to 3,226 PCIs in 2013. Compared with trends in the number of PCIs performed between 2006 and 2009, trends in the number of PCIs performed between 2010 and 2013 were significantly different for the indications of unstable angina (\( P < 0.001 \)) 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, and 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 owing 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 PCIs for elective indications that were classified as appropriate increased from 26% in 2010 to 38% in 2014. Concurrently, the proportion of elective PCIs 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 PCIs that could not be mapped to the AUC as a result of insufficient preprocedural assessment. We repeated our analyses after limiting to PCIs with adequate preprocedural assessment to map to the AUC and found a similar increase over time in

![Figure 1. Percutaneous coronary intervention (PCI) volumes by clinical indication. After 2010, the number of elective PCIs for stable angina decreased by 43%; PCIs for non–ST-segment–elevation myocardial infarction (NSTEMI) increased by 17%, and PCIs for ST-segment–elevation myocardial infarction (STEMI) and unstable angina (UA) remained largely unchanged. Compared with the trend in PCI use before the onset of PCI appropriateness assessment in 2010, the trend in PCI use after 2010 was significantly different for UA (\( P < 0.001 \)) and stable angina (\( P = 0.03 \)). Trends in PCI use for STEMI and NSTEMI were similar before and after 2010.](http://circ.ahajournals.org/)

**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 (SD), y</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>Previous MI</td>
<td>29</td>
<td>30</td>
<td>29</td>
<td>28</td>
<td>29</td>
<td>0.59</td>
</tr>
<tr>
<td>Previous PCI</td>
<td>38</td>
<td>39</td>
<td>38</td>
<td>37</td>
<td>38</td>
<td>0.012</td>
</tr>
<tr>
<td>Previous 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>
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<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>

CABG indicates coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; HTN, hypertension; MI, myocardial infarction; and PCI, percutaneous coronary intervention.
the proportion of elective PCIs classified as appropriate (37\% in 2010 to 49\% in 2013), with a concurrent decline in the proportion of inappropriate elective PCIs (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\%, compared with 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 observed only in the hospital tertile with the greatest decline in PCIs 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 PCIs (12\% in 2010 to 20\% in 2013; \( P < 0.01 \)).

Similar hospital-level differences were noted in the average proportion of PCIs with insufficient preprocedural assessment for appropriateness determination (Figures I and II in the online-only Data Supplement). By hospital tertile, the average proportion of PCIs with insufficient preprocedural assessment ranged from 14\% to 24\% for hospitals in the lowest tertile compared with 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 mapped to AUC.

Table 2. Calendar Year Trends in PCI Appropriateness by Indication

<table>
<thead>
<tr>
<th>All PCI</th>
<th>Total, n (%)</th>
<th>2010, n (%)</th>
<th>2011, n (%)</th>
<th>2012, n (%)</th>
<th>2013, n (%)</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute indications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appropriate</td>
<td>37561 (94)</td>
<td>8662 (92)</td>
<td>9321 (93)</td>
<td>9857 (94)</td>
<td>9721 (95)</td>
<td>&lt;0.001</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>Nonacute indications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appropriate</td>
<td>3495 (30)</td>
<td>1010 (26)</td>
<td>933 (28)</td>
<td>748 (21)</td>
<td>804 (38)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Uncertain</td>
<td>3216 (27)</td>
<td>1129 (29)</td>
<td>897 (27)</td>
<td>627 (21)</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</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>

AUC indicates appropriate use criteria; and PCI, percutaneous coronary intervention.

Figure 2. Facility-level average rates of inappropriate elective percutaneous coronary intervention (PCI) by hospital tertiles. Lowest average tertile hospitals (A), middle tertile hospitals (B), and highest average tertile hospitals (C). Circle sizes reflect the elective PCI volume at a site for a given year: Largest to smallest circles indicate 500, 250, 100, and 50 PCIs.
were noted only 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 as a result of a nearly 45% reduction in the number of PCIs for elective indications. 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 with the decline in elective PCI procedures, the appropriateness of PCI for elective indications has improved, with the proportion ofappropriate PCIs increasing from 26% to 38% and the proportion of inappropriate PCIs 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 that these improvements were limited to a minority of hospitals, whereas 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. AUC reflect a standardized method to assess quality domains related to preprocedural processes of patient assessment and patient selection for PCI. Previous 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 PCIs were classified as inappropriate. Similar proportions of elective PCIs 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 that up to 40% of PCIs could not be mapped to the AUC because of 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 noninvasive 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 affecting the overall number of procedures used (ie, 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 observed a small increase in the number of PCIs performed for NSTEMI and unstable angina, which 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 after the onset of appropriateness assessment. These findings suggest that the trend in lower proportions of inappropriate and insufficiently assessed PCI observed in our study largely reflects improvements in patient assessment and selection processes rather than an artificial change resulting from 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 use 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 the use of PCI for inappropriate

**Figure 3.** Tertile of the largest temporal decline (A), middle tertile (B), and tertile of the smallest temporal decline (C). Circle sizes reflect the elective percutaneous coronary intervention (PCI) volume at a site for a given year. Largest to smallest circles indicate 500, 250, 100, and 50 PCIs. 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.
and insufficiently assessed clinical indications, publications highlighting the findings of PCI appropriateness assessment in national and regional PCI registries,3–5,13 or the publication of and attention given to the AUC themselves,1,2,14–16 including attention by healthcare payers.

Although the overall proportion of PCIs 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,17,18 study of hospitals with low or declining proportions of inappropriate and insufficiently assessed PCIs 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 PCIs 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 that gaming of procedural appropriateness is not the predominant explanation for our findings. Efforts should be made in the future to capture patient-reported health status measures, including symptom burden, functional status, and health-related quality of life, to inform appropriateness assessment and to minimize the potential for appropriateness misclassification related to physician assessment of symptom burden. Second, although AUC are frequently updated to reflect current evidence, there is currently minimal incorporation of fractional flow reserve assessment as an alternative to stress testing. However, during the period of study, <3.5% of patients in COAP were assessed with fractional flow reserve before PCI, suggesting that procedures that could not be mapped owing to a lack of stress testing results do not represent use of fractional flow reserve in place of noninvasive testing. Furthermore, it is important to note that stress testing is not mandated by the AUC before consideration of all elective PCIs. 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.14,16 However, studies have previously demonstrated that inappropriate use of PCI is due predominantly to procedural use in asymptomatic patients in whom there is no symptom reduction benefit.4,6

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 these data. However, our findings suggest that 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 United States.

Conclusions

In a complete cohort of PCIs performed in Washington State from 2010 to 2013, the statewide volume of PCIs for elective indications decreased by 43%. At the same time, the proportion of elective PCIs classified as appropriate increased from 26% to 38%, the proportion of inappropriate PCIs decreased from 16% to 13%, and the proportion of elective PCIs that could not be mapped by the AUC owing to a 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.

Sources of Funding

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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 US government.

References

Increasing attention is being given to proper patient selection for elective percutaneous coronary intervention (PCI) to ensure that the clinical benefits outweigh the procedural risks. The appropriate use criteria for coronary revascularization permit a guidelines-concordant approach to assessing the quality of patient selection for PCI. Although previous studies have suggested gaps in the quality of patient selection for PCI, it is unknown whether the appropriateness of elective PCI has changed over time. In this complete cohort of >50,000 PCIs performed in Washington State between 2010 and 2013, the proportion of elective PCIs classified as appropriate increased over time (26% in 2010 to 38% in 2013; P for trend <0.001), whereas the proportion of inappropriate PCI decreased (16% in 2010 to 13% in 2013; P for trend <0.001). The number of PCIs performed for elective indications dropped by nearly 50% during this time period, and this decline in use of elective PCI was larger than in the preceding time period of 2006 to 2009. Together, these findings suggest that there have been improvements in patient selection for PCI in the state of Washington, resulting in less frequent and more appropriate use of elective PCI. However, when evaluated at the hospital level, improvements in PCI appropriateness were limited to a minority of hospitals. Future study of hospitals with low or improving proportions of inappropriate PCI may identify patient selection processes that could be adopted by other hospitals to improve the quality of patient selection for PCI.
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

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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.

- \( \text{●} \) 500 PCI; \( \bigcirc \) 250 PCI; \( \square \) 100 PCI; \( \triangle \) 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.