Trends in the Association Between Age and In-Hospital Mortality After Percutaneous Coronary Intervention
National Cardiovascular Data Registry Experience

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Background—Temporal trends and contemporary data characterizing the impact of patient age on in-hospital outcomes of percutaneous coronary interventions are lacking. We sought to determine the importance of age by assessing the in-hospital mortality of stratified age groups in the National Cardiovascular Data Registry.

Methods and Results—In-hospital mortality after percutaneous coronary intervention on 1,410,069 patients was age stratified into 4 groups—group 1 (age <40, n=25,679), group 2 (40 to 59, n=496,204), group 3 (60 to 79, n=732,574), and group 4 (≥80, n=155,612)—admitted from January 1, 2001, to December 31, 2006. Overall in-hospital mortality was 1.22%; in-hospital mortality was 0.60%, 0.59%, 1.26%, and 3.16% in groups 1 to 4, respectively, \( P<0.0001 \). Overall temporal improvement per calendar year in the adjusted in-hospital mortality after percutaneous coronary intervention was noted in most groups; however, this finding was significant only in the 2 older age groups, group 3 (odds ratio, 0.94; 95% CI, 0.92 to 0.96) and group 4 (odds ratio, 0.95; 95% CI, 0.92 to 0.97). The absolute mortality reduction was greatest in the most elderly group, those over the age of 80 years.

Conclusions—In-hospital mortality after percutaneous coronary intervention has fallen for all age groups over the past 6 years. However, the largest absolute reduction was seen among patients 80 years of age or older. (Circ Cardiovasc Intervent. 2009;2:20-26.)

Key Words: age | percutaneous coronary interventions | mortality | temporal trends

With improving life expectancy, it is projected that over the next 30 years, the proportion of people ≥65 years of age will increase from 12.4% to 19.6% in the United States.1 During the same time interval, the absolute number of the oldest old (≥85 years of age) will double, from 9.3 to 19.5 million. Coronary heart disease is the leading cause of death among patients in the United States and with changing demographics the burden of ischemic heart disease will be experienced most by the elderly population.

Increasing age is a powerful predictor of adverse events in patients with coronary heart disease, including patients undergoing coronary revascularization.2-5 The time trends in decline in heart disease-related mortality over the past 2 decades have demonstrated disparities with lesser decline noted in heart disease–related mortality in older compared with younger ages.6

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Although, percutaneous coronary intervention (PCI) has been established as an excellent revascularization strategy for higher risk patients, older age is known to influence short- and long-term outcomes after PCI both in the setting of acute myocardial infarction (MI) and during elective percutaneous intervention.7,8 Age is an important covariate that determines death and other major adverse cardiovascular events in all risk adjustment revascularization models.9-13 Much of the data on the effect of age as an independent determinant of outcome are relatively old and are derived from late 1990s and early 2000, and therefore, do not include patients receiving current therapies, including drug-eluting stents. Temporal improvement in the outcomes after PCI has been documented in various risk groups undergoing PCI, however, such trends in various age groups are not well studied.14-16 To that end, we examined the influence of patient age on in-hospital mortality from a contemporary cohort, and analyzed the temporal trends in stratified age groups included within the National Cardiovascular Data Registry (NCDR) Cath PCI registry.
Procedural success was defined as residual stenosis ≤20% in all lesions attempted.

**Methods**

The NCDR Cath PCI registry is designed to evaluate patient and lesion selection criteria and in-hospital outcomes/complications using standardized data definitions in a large sample with wide geographic diversity. We studied in-hospital mortality in 1,410,069 patients undergoing PCI. We age stratified the study sample into 4 groups—group 1 (age ≤40, n = 25,679), group 2 (40 to 59, n = 496,204), group 3 (60 to 79, n = 732,574), and group 4 (≥80, n = 155,612)—from January 1, 2001, to December 31, 2006. The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

**Definitions**

Death was defined as all-cause mortality during each hospital stay. Procedural success was defined as residual stenosis ≤50% with thrombolysis in myocardial infarction (TIMI) 3 flow and decrease in stenosis ≥20% in all lesions attempted.

**Statistical Methods**

For descriptive analyses, baseline characteristics, angiographic characteristics, procedure use, and clinical outcomes were compared between age groups. Continuous variables are presented as mean with standard deviation and categorical variables are expressed as frequencies with percentages. To test for independence of a patient’s baseline characteristics, angiographic characteristics, and outcomes with respect to different age groups, Kruskal-Wallis tests were used for continuous variables and Pearson χ² tests were used for categorical variables.

Overall mortality rate was calculated for each age group. To graphically display the temporal trend of mortality, the mortality rates were also calculated for each age group in a given year and plotted on the same graph.
In-Hospital Outcomes

Mortality trend over time was also analyzed and stratified according to presentation as elective or urgent/emergent/salvage PCI. To demonstrate any influence of introduction of drug-eluting stents on mortality, linear spline was used in the multivariable model. Year of PCI was chosen to be the knot for linear spline. For each age group, we now have 2 sets of odds ratio (OR), one for the year effect before 2004 and the other for the year effect after 2004. If drug-eluting stent (DES) has an impact on mortality trend, then the OR for year effect before 2004 will be different from the year effect after 2004. If periprocedural MI, stroke, renal failure, vascular occlusion, and bleeding complications were higher in older age, Table 2.

**Temporal Trends**

The effect of time on mortality after PCI differed according to age. Figure 2A demonstrates the temporal trends in mortality from 2001 to 2006. The decline in mortality was greater in patients in the older 2 age groups, when compared with younger 2 groups. Table 3 illustrates the unadjusted and adjusted outcomes for mortality per 1 year increase in calendar year in different age groups. These data suggest improvements in acute outcomes after contemporary PCI compared with earlier experiences. However, the decrease in risk-adjusted mortality was only statistically significant among patients in group 3 (OR, 0.94; 95% CI, 0.92 to 0.96) and group 4 (OR, 0.95; 95% CI, 0.92 to 0.97). Although reduction in odds of mortality was greatest in young patients, absolute mortality reduction was greatest in the elderly (Table 3).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total N (410 069)</th>
<th>Overall N</th>
<th>Age&lt;40 (25 679) N</th>
<th>40≤Age&lt;60 (496 204) N</th>
<th>60≤Age&lt;80 (732 574) N</th>
<th>Age≥80 (155 612) N</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>17 238</td>
<td>1.22</td>
<td>154</td>
<td>0.60</td>
<td>2922</td>
<td>0.59</td>
<td>9242</td>
</tr>
<tr>
<td>Procedural success</td>
<td>1 303 996</td>
<td>92.72</td>
<td>23740</td>
<td>92.63</td>
<td>461 840</td>
<td>93.22</td>
<td>676 528</td>
</tr>
<tr>
<td>Periprocedural MI</td>
<td>16 137</td>
<td>1.15</td>
<td>208</td>
<td>0.81</td>
<td>4703</td>
<td>0.95</td>
<td>8876</td>
</tr>
<tr>
<td>Stroke</td>
<td>4190</td>
<td>0.30</td>
<td>30</td>
<td>0.16</td>
<td>927</td>
<td>0.19</td>
<td>2319</td>
</tr>
<tr>
<td>Renal failure</td>
<td>7078</td>
<td>0.53</td>
<td>65</td>
<td>0.26</td>
<td>1125</td>
<td>0.23</td>
<td>4002</td>
</tr>
<tr>
<td>Vascular-site occlusion</td>
<td>977</td>
<td>0.07</td>
<td>19</td>
<td>0.07</td>
<td>302</td>
<td>0.06</td>
<td>512</td>
</tr>
<tr>
<td>Any bleeding complication</td>
<td>26 999</td>
<td>1.92</td>
<td>369</td>
<td>1.44</td>
<td>6480</td>
<td>1.31</td>
<td>14 841</td>
</tr>
</tbody>
</table>

MI indicates myocardial infarction.
Subgroup Analyses

We stratified the 4 age groups into 2 distinct categories, elective or urgent/emergent/salvage, based on the presentation at the time of PCI. Figure 2B and 2C demonstrate the temporal trends in mortality from 2001 and 2006 in patients undergoing elective (Figure 2B) or urgent/emergent/salvage PCI, Figure 2C. The decline in mortality was greater in the older 2 age groups, Table 3. To note the effect of introduction of drug-eluting stents on outcomes, we arbitrarily chose the year 2004 as in 2003 this technology became available. Table 4 summarizes the results. There was no mortality reduction noted after the year 2004 when compared with the earlier years.

Discussion

These results obtained in over 1 million PCI patients enrolled in the NCDR demonstrates the continued adverse effect of increasing age on in-hospital outcome after PCI in contemporary practice using current interventional techniques and pharmacological therapy but also shows declining mortality rates over time. Although reduction in mortality after adjustment is noted in all age groups undergoing PCI in the modern era, the absolute reduction is greatest in the most elderly, those 80 years old or greater.

Age and Outcome

The relationship between age and outcome after PCI has been previously reported. In this study, the mortality rate in octogenarians was 5 times higher compared with the younger population and represents almost 30% of all deaths after PCI. Age in other studies was an independent predictor of outcomes after percutaneous coronary revascularization overall, and also in the setting of primary PCI. Despite higher in-hospital mortality in elderly, we previously demonstrated survival at follow-up after primary PCI similar to expected survival in the general US population. Similar observations were made by Cohen et al from the National Heart, Lung, and Blood Institute Dynamic Registry. They demonstrated that although the adjusted risks of in-hospital and 1-year mortality rates increased with age, the relative magnitude of excess mortality rates at 1 year was comparable with that observed by age in the US general population.

Effect of age on outcomes was evaluated in the NCDR dataset in the past. Shaw et al analyzed the NCDR demonstrated age among other risk factors predictive of adverse outcomes. Klein et al specifically evaluated the outcomes of PCI in octogenarians in this registry at an earlier time frame and found age to be an independent risk factor for in-hospital mortality after PCI; the OR was 1.03 (95% CI, 1.00 to 1.07) for each additional year of age. The results of this study are consonant with the recent studies demonstrating higher in-hospital mortality in older age groups. Increased in-hospital mortality in the elderly is likely due to higher prevalence of cardiac risk factors, comorbid conditions, and lower procedural success with PCI. In addition, the prevalence of acute coronary syndrome was higher in older age groups. These findings assume importance with limited randomized clinical trial data to guide care in elderly patients and answer some of the lingering uncertainties about benefits of coronary angioplasty in this population. In addition to chronologic age, biological age, comorbid conditions, frailty, quality-of-life indicators, and other age-associated impairment might be more relevant in elderly in decision making for revascularization procedures.

Temporal Trends

The available data on age as a predictor of adverse outcome are relatively old, and recent temporal trends in various age groups in patients with coronary heart disease undergoing PCI are lacking. Our study demonstrated significant improvement in the in-hospital mortality in all the age groups during the study period. Even though the reasons for decline in the younger groups are uncertain, the relative risk reduction was
most notable in the younger patients. The elderly patients undergoing PCI had the greatest absolute mortality reduction. With higher proportional mortality in older group, the temporal decline in this high-risk subgroup is of great importance. The reduction in mortality is likely due to improvement in operator and technology and availability of evidence-based medications, including glycoprotein IIb/IIIa inhibitors, dual antiplatelet therapy, β-blockers, and statins. This reduction in mortality was noted despite higher prevalence of comorbid and angiographic risks. The observed temporal improvement in the mortality after PCI as demonstrated by our study is consonant with other studies demonstrating significant improvements in outcomes noted in various high-risk clinical and angiographic subsets, eg, older age, unstable angina, angiographic thrombus, and MI, underscoring significant technological and pharmacological advances, including higher use of evidence-based medications, glycoprotein receptor inhibitors, and stents. Despite noting significant improvements in the in-hospital outcomes after PCI, one recent

### Table 3. Unadjusted and Adjusted Outcomes for Mortality per Calendar Year Increase in Different Age Groups

<table>
<thead>
<tr>
<th>Outcome Category</th>
<th>Total N</th>
<th>OR (95% CI) Lower</th>
<th>OR (95% CI) Upper</th>
<th>P</th>
<th>OR (95% CI) Lower</th>
<th>OR (95% CI) Upper</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality (overall)</td>
<td>1,410,069</td>
<td>0.998</td>
<td>0.943</td>
<td>0.953</td>
<td>0.001</td>
<td>0.948</td>
<td>0.923</td>
</tr>
<tr>
<td>Year effect in patients &lt;40 years</td>
<td>25,679</td>
<td>0.958</td>
<td>0.868</td>
<td>1.058</td>
<td>0.396</td>
<td>0.906</td>
<td>0.819</td>
</tr>
<tr>
<td>Year effect in patients 40–59 years</td>
<td>496,204</td>
<td>1.015</td>
<td>0.989</td>
<td>1.042</td>
<td>0.256</td>
<td>0.989</td>
<td>0.961</td>
</tr>
<tr>
<td>Year effect in patients 60–79 years</td>
<td>732,574</td>
<td>0.960</td>
<td>0.943</td>
<td>0.977</td>
<td>&lt;0.001</td>
<td>0.942</td>
<td>0.924</td>
</tr>
<tr>
<td>Year effect in patients ≥80 years</td>
<td>155,612</td>
<td>0.965</td>
<td>0.943</td>
<td>0.987</td>
<td>0.002</td>
<td>0.948</td>
<td>0.923</td>
</tr>
<tr>
<td>Mortality (urgent/emergent/salvage)</td>
<td>693,655</td>
<td>0.964</td>
<td>0.943</td>
<td>0.981</td>
<td>0.008</td>
<td>0.948</td>
<td>0.923</td>
</tr>
<tr>
<td>Year effect in patients &lt;40 years</td>
<td>16,704</td>
<td>0.953</td>
<td>0.858</td>
<td>1.058</td>
<td>0.368</td>
<td>0.934</td>
<td>0.840</td>
</tr>
<tr>
<td>Year effect in patients 40–59 years</td>
<td>264,708</td>
<td>0.998</td>
<td>0.970</td>
<td>1.027</td>
<td>0.092</td>
<td>0.999</td>
<td>0.970</td>
</tr>
<tr>
<td>Year effect in patients 60–79 years</td>
<td>332,593</td>
<td>0.961</td>
<td>0.941</td>
<td>0.981</td>
<td>&lt;0.001</td>
<td>0.966</td>
<td>0.946</td>
</tr>
<tr>
<td>Year effect in patients ≥80 years</td>
<td>79,650</td>
<td>0.957</td>
<td>0.932</td>
<td>0.982</td>
<td>&lt;0.001</td>
<td>0.963</td>
<td>0.937</td>
</tr>
</tbody>
</table>

*ORs are associated with year (per 1-year increase) for mortality.

### Table 4. Effect of Drug-Eluting Stents on Mortality in Different Age Groups

<table>
<thead>
<tr>
<th>Outcome Category</th>
<th>Total N</th>
<th>OR (95% CI) Lower</th>
<th>OR (95% CI) Upper</th>
<th>P</th>
<th>OR (95% CI) Lower</th>
<th>OR (95% CI) Upper</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>1,410,069</td>
<td>0.926</td>
<td>0.899</td>
<td>0.960</td>
<td>0.001</td>
<td>0.965</td>
<td>0.934</td>
</tr>
<tr>
<td>Year effect in patients &lt;40 years (before 2004)</td>
<td>25,679</td>
<td>0.933</td>
<td>0.765</td>
<td>1.138</td>
<td>0.494</td>
<td>0.860</td>
<td>0.699</td>
</tr>
<tr>
<td>Year effect in patients &lt;40 years (after 2004)</td>
<td>12,287</td>
<td>0.989</td>
<td>0.788</td>
<td>1.240</td>
<td>0.922</td>
<td>0.964</td>
<td>0.754</td>
</tr>
<tr>
<td>Year effect in patients 40–59 years (before 2004)</td>
<td>496,204</td>
<td>0.966</td>
<td>0.915</td>
<td>1.020</td>
<td>0.216</td>
<td>0.946</td>
<td>0.891</td>
</tr>
<tr>
<td>Year effect in patients 40–59 years (after 2004)</td>
<td>242,157</td>
<td>1.071</td>
<td>1.012</td>
<td>1.134</td>
<td>0.018</td>
<td>1.037</td>
<td>0.977</td>
</tr>
<tr>
<td>Year effect in patients 60–79 years (before 2004)</td>
<td>732,574</td>
<td>0.946</td>
<td>0.914</td>
<td>0.979</td>
<td>0.001</td>
<td>0.934</td>
<td>0.902</td>
</tr>
<tr>
<td>Year effect in patients 60–79 years (after 2004)</td>
<td>359,153</td>
<td>0.976</td>
<td>0.944</td>
<td>1.010</td>
<td>0.166</td>
<td>0.952</td>
<td>0.916</td>
</tr>
<tr>
<td>Year effect in patients ≥80 years (before 2004)</td>
<td>155,612</td>
<td>0.943</td>
<td>0.901</td>
<td>0.988</td>
<td>0.013</td>
<td>0.907</td>
<td>0.864</td>
</tr>
<tr>
<td>Year effect in patients ≥80 years (after 2004)</td>
<td>78,430</td>
<td>0.989</td>
<td>0.946</td>
<td>1.033</td>
<td>0.618</td>
<td>0.994</td>
<td>0.946</td>
</tr>
<tr>
<td>Year effect in patients ≥80 years (after 2004)</td>
<td>693,655</td>
<td>0.966</td>
<td>0.934</td>
<td>0.999</td>
<td>&lt;0.001</td>
<td>0.965</td>
<td>0.934</td>
</tr>
</tbody>
</table>

*ORs are associated with year (per 1-year increase) for mortality.

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Variables in the model are body mass index, ST elevation myocardial infarction, cardiogenic shock, previous congestive heart failure, previous valve surgery, cerebrovascular disease, peripheral vascular disease, chronic lung disease, previous PCI, preoperative intra-aortic balloon pump, highest risk lesion features (pre-TIMI flow, Society for Cardiovascular Angiography and Interventions class, and segment), diabetes/treatment, renal failure/dialysis, smoker, PCI status.
study from the Mayo Clinic could not demonstrate additional reduction in mortality in the 2 recent time periods (1996 to 2003 and 2003 to 2004) with in-hospital mortality of 1.7% and 1.8%, respectively.\textsuperscript{27} No reduction in other major adverse cardiac end points was noted, in fact, the incidence of Q-wave MI and stroke increased in the most recent group.

Limitations

The limitations inherent to retrospective design are applicable to this study. Even as we establish temporal decline in the in-hospital mortality in all age groups undergoing PCI, causality cannot be determined from our analyses. We may not have accounted for some unmeasured confounders, however, that would bias the results toward the null. It is difficult to determine the relative importance of better operator skills, improvement in technology, use of stents, and improved antiplatelet and other adjunctive therapy in improving the results in the most recent period. We realize that the increase in levels of cardiac biomarkers is an important prognostic marker; however, because of the inherent complexity of this large data set, the nonavailability of these markers in the early time periods, and changing definitions, we chose not to elaborate on the temporal trends of MI across various age groups.

Conclusions

Advancing age continues to be associated with adverse outcomes after PCI; however, from 2001 to 2006, in-hospital mortality rates have declined. The temporal decline in this particular adverse outcome after PCI was seen in all age groups and was most evident in the older age groups.

Disclosures

None.

References

We analyzed the in-hospital mortality following percutaneous coronary interventions (PCI) on 1,410,069 patients enrolled in the National Cardiovascular Data Registry. Patients were age-stratified into 4 groups, Group 1 (age < 40, n = 25,679), Group 2 (40–59, n = 496,204), Group 3 (60–79, n = 732,574), and Group 4 (≥80, n = 155,612), admitted from 2001 to 2006. Overall in-hospital mortality was 1.22%, and was significantly higher in older age groups (0.60%, 0.59%, 1.26%, and 3.16% in groups 1 to 4 respectively). Overall temporal improvement per calendar year in the adjusted in-hospital mortality following PCI was noted in most groups, however, this finding was significant only in the two older age groups (3 and 4). The absolute mortality reduction was greatest in the most elderly group, those over the age of 80 years. Increased in-hospital mortality in the elderly is likely due to higher presentation with acute coronary syndrome and higher prevalence of cardiac risk factors, comorbid conditions, and lower procedural success with PCI. Our study demonstrated significant improvement in the in-hospital mortality in all the age groups for the study period. It is likely due to improvement in operator and technology and prescription of evidence-based medications, including glycoprotein IIb/IIIa inhibitors, dual antiplatelet therapy, beta blockers, and statins. In conclusion, advancing age continues to be associated with adverse outcomes after PCI, however, from 2001 to 2006, in-hospital mortality rates have declined. The temporal decline in the adverse outcomes following PCI seen in all age groups and was most evident in the older age groups.
Trends in the Association Between Age and In-Hospital Mortality After Percutaneous Coronary Intervention: National Cardiovascular Data Registry Experience

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