Percutaneous Coronary Intervention in the Elderly
Changes in Case-Mix and Periprocedural Outcomes in 31 758 Patients Treated Between 2000 and 2007

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Background—The elderly account for an increasing proportion of the population and have a high prevalence of coronary heart disease. Percutaneous coronary intervention (PCI) is the most common method of revascularization in the elderly. We examined whether the risk of periprocedural complications after PCI was higher among elderly (age ≥75 years) patients and whether it has changed over time.

Methods and Results—The Scottish Coronary Revascularization Register was used to undertake a retrospective cohort study on all 31 758 patients undergoing nonemergency PCI in Scotland between April 2000 and March 2007, inclusive. There was an increase in the number and percentage of PCIs undertaken in elderly patients, from 196 (8.7%) in 2000 to 752 (13.9%) in 2007. Compared with younger patients, the elderly were more likely to have multivessel disease, multiple comorbidity, and a history of myocardial infarction or coronary artery bypass grafting (χ² tests, all P<0.001). The elderly had a higher risk of major adverse cardiovascular events within 30 days of PCI (4.5% versus 2.7%, χ² test P<0.001). Over the 7 years, there was a significant increase in the proportion of elderly patients who had multiple comorbidity (χ² test for trend, P<0.001). Despite this, the underlying risk of complications did not change significantly over time either among the elderly (χ² test for trend, P=0.142) or overall (χ² test for trend, P=0.083).

Conclusions—Elderly patients have a higher risk of periprocedural complications and account for an increasing proportion of PCIs. Despite this, the risk of complications after PCI has not increased over time. (Circ Cardiovasc Interv. 2010; 3:00-00.)

Key Words: elderly ■ angioplasty ■ percutaneous transluminal coronary ■ coronary artery disease ■ outcome

The prevalence of coronary heart disease increases with age. In line with other developed countries, the elderly account for an increasing proportion of the Scottish population, as the result of a combination of reduced fertility rates and increased life expectancy. Therefore, elderly patients represent an increasing proportion of those presenting for cardiovascular investigation and treatment. Previous studies have suggested that elderly patients are at greater risk of complications after percutaneous coronary intervention (PCI).1–4 The past decade has seen the adoption into clinical practice of many developments shown to be effective at improving outcomes and reducing complications such as coronary stents, transradial access, and adjuvant drug therapies.5–9 Clinical trials have tended to exclude elderly patients.5 Those studies that have included elderly patients suggest that the absolute benefit of these developments may be even higher in the elderly due to their high baseline risk.5–9 The aim of this study was to examine whether the risk of periprocedural complications after PCI is higher among elderly (age ≥75 years) patients than younger patients and whether it has changed over time.

Clinical Perspective on p ●●●

Methods

Data Sources and Inclusion Criteria
The Scottish Coronary Revascularization Register collects comprehensive, prospective information on all patients undergoing PCI in Scotland, including demographic characteristics, postcode of residence, cardiac disease severity, comorbidity, procedure details, medical and surgical history, and in-hospital complications (http://www.scs-online.org.uk/cardreg.php). The Scottish Morbidity Record (SMR1) collects information on all admissions to acute hospitals.

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Table 1. Comparison of Characteristics of Patients Undergoing Nonemergency PCI by Age Group

<table>
<thead>
<tr>
<th></th>
<th>≥75 y n (%)</th>
<th>&lt;75 y n (%)</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>2062 (58.7)</td>
<td>20 151 (71.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Current smoker</td>
<td>1122 (35.7)</td>
<td>8284 (32.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Multivessel disease</td>
<td>1899 (55.5)</td>
<td>11 041 (40.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Obese</td>
<td>457 (19.1)</td>
<td>6005 (31.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>631 (18.6)</td>
<td>4879 (17.8)</td>
<td>0.228</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1780 (55.8)</td>
<td>11 877 (45.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Extracardiac arteriopathy</td>
<td>478 (16.0)</td>
<td>2263 (9.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Renal impairment</td>
<td>91 (3.0)</td>
<td>330 (1.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Left ventricular failure</td>
<td>1644 (52.6)</td>
<td>10 845 (42.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Multiple comorbidity</td>
<td>629 (17.9)</td>
<td>3875 (13.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Previous PCI</td>
<td>481 (15.0)</td>
<td>4130 (15.7)</td>
<td>0.277</td>
</tr>
<tr>
<td>Previous CAGB</td>
<td>547 (16.6)</td>
<td>2861 (10.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Previous AMI</td>
<td>1353 (38.5)</td>
<td>9623 (34.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Family history</td>
<td>807 (26.0)</td>
<td>10 974 (42.9)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

CAGB indicates coronary artery bypass grafting; and AMI, acute MI.

*Pearson χ² test.

in Scotland, including disease and procedure codes (http://www.datadictionaryadmin.scot.nhs.uk/isddd/9065.html). The General Registrar for Scotland collates death certificate data across Scotland, including cause of death. Diseases are recorded using the International Classification of Diseases and procedures using the Operating Procedure Codes. The revascularization register is linked annually to the SMR1 and death certificate data at an individual level, providing information on fatal and nonfatal events that occur after discharge.

Our cohort comprised all patients who underwent nonemergency PCI in Scotland between April 2000 and March 2007 inclusive. The last linkage undertaken before our study provided follow-up events up to June 27, 2007.

Definitions
Elderly was defined as ≥75 years of age. Obesity was defined as a body mass index >30. Diabetes included both type I and type II diabetics. Hypertension was defined as systolic blood pressure ≤140 mm Hg, diastolic blood pressure ≥90 mm Hg, or antihypertensive therapy. Noncardiac arteriopathy included peripheral arterial disease, previous stroke, recurrent transient ischemic attacks, and carotid stenosis ≥70%. Impaired renal function was defined as serum creatinine >200 mmol/L or use of renal replacement therapy. Impaired left ventricular function was defined as an ejection fraction of <50%. Multiple comorbidity was defined as the presence of 2 or more of these conditions. Socioeconomic status was measured using the Scottish Index of Multiple Deprivation (SIMD) (http://www.scotland.gov.uk/Topics/Statistics/SIMD/). The SIMD is derived from 37 indicators across 7 domains (income, employment, health, education, skills and training, housing, geographic access, and crime) and is used to rank data zones of residence (mean population of 750).

The rankings have been used to produce deprivation quintiles for the general population, which could then be applied to our study cohort using their postcode of residence. Periprocedural outcomes were defined as events that occurred either in-hospital or after discharge up to 30 days after PCI. The binary outcomes studied were all-cause death, fatal/nonfatal myocardial infarction (MI), and cardiac surgery, as well as the composite outcome of major adverse cardiovascular event (MACE), which was defined as being any of the above individual outcomes. Routine troponin measurement has not been adopted across Scotland. Periprocedural MI was defined as ECG evidence of a Q-wave MI over the entire study period. We also studied target vessel revascularization as a secondary outcome. This was defined as a repeat coronary revascularization procedure, whether PCI or coronary artery bypass graft, undertaken on the same vessel as the original procedure.

Statistical Analyses
The 7 years of data were combined to compare binary case-mix variables in elderly and younger patients using χ² tests. The overall risk of adverse outcomes was compared using univariable and multivariable binary logistic regression models. In the latter, we adjusted for the potential confounding effects of sex, deprivation quintile, body mass index, comorbidities, smoking status, and disease severity. Changes in case-mix and crude outcomes over time were analyzed using χ² tests for trend (linear-by-linear association) or Cuzick test for trend¹⁰ for variables that did not satisfy the assumptions of the χ² test for trend (linear by linear). Multivariable binary logistic regression analysis was performed including an interaction term for age group and year of procedure to determine whether the association between age group and outcome changed over time after adjusting for the potential confounding factors listed above. The goodness of fit of the models was assessed using the Hosmer and Lemeshow test applied to 8, 10, and 12 groups of observed and predicted MACE. The analyses were undertaken using SPSS 15.0 and STATA 10.

Table 2. Comparison of Crude 30-Day Outcomes After Nonemergency PCI by Age Group

<table>
<thead>
<tr>
<th></th>
<th>≥75 y n (%)</th>
<th>&lt;75 y n (%)</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cause death</td>
<td>57 (1.7)</td>
<td>154 (0.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>AMI</td>
<td>114 (3.3)</td>
<td>546 (2.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cardiac surgery</td>
<td>155 (0.6)</td>
<td>19 (0.6)</td>
<td>0.954</td>
</tr>
<tr>
<td>MACE</td>
<td>156 (4.5)</td>
<td>734 (2.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>TVR</td>
<td>47 (1.1)</td>
<td>309 (1.1)</td>
<td>0.193</td>
</tr>
</tbody>
</table>

AMI indicates acute MI; and TVR, target vessel revascularization.

*Pearson χ² test.

from 37 indicators across 7 domains (income, employment, health, education, skills and training, housing, geographic access, and crime) and is used to rank data zones of residence (mean population of 750).

The rankings have been used to produce deprivation quintiles for the general population, which could then be applied to our study cohort using their postcode of residence. Periprocedural outcomes were defined as events that occurred either in-hospital or after discharge up to 30 days after PCI. The binary outcomes studied were all-cause death, fatal/nonfatal myocardial infarction (MI), and cardiac surgery, as well as the composite outcome of major adverse cardiovascular event (MACE), which was defined as being any of the above individual outcomes. Routine troponin measurement has not been adopted across Scotland. Periprocedural MI was defined as ECG evidence of a Q-wave MI over the entire study period. We also studied target vessel revascularization as a secondary outcome. This was defined as a repeat coronary revascularization procedure, whether PCI or coronary artery bypass graft, undertaken on the same vessel as the original procedure.

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Results
Overall Comparison
Of the 35 888 patients who underwent PCI in Scotland between 2000 and 2007, 31 758 (88.9%) were classed as nonemergencies. Of these, 3513 (11.1%) were performed in elderly patients and 28 245 (88.9%) in younger patients. Compared with younger patients, the elderly were more likely to be female, have multivessel disease, have multiple comorbidity, and have a medical history of acute MI or coronary...
artery bypass grafting (Table 1). Of the 31 758 patients, 567 (1.8%) were excluded from the outcome analysis because of missing or incomplete follow-up data. The missing patients were comparable to those included in the analysis in terms of demographics (Table 1). Of the 31 191 (98.2%) patients, the overall crude risk of MACE within 30 days of PCI was 4.5% in the elderly compared with 2.7% in younger patients (Pearson chi-squared test, \( P < 0.001 \)).

In the remaining cohort of 31 191 (98.2%) patients, the overall crude risk of MACE within 30 days of PCI was 4.5% in the elderly compared with 2.7% in younger patients (Pearson chi-squared test, \( P < 0.001 \)).

The elderly patients had an increased risk of both death and MI, but there was no significant difference in the risk of surgery or target vessel revascularization (Table 2). In the overall logistic regression model, the increased risk of MACE among the elderly (unadjusted odds ratio, 1.74; 95% confidence interval, 1.46 to 2.08, \( P < 0.001 \)) was attenuated after adjustment for differences in case-mix (sex, smoking status, multivessel disease, obesity, hypertension, extracardiac arteriopathy, renal impairment, left ventricular dysfunction, and deprivation) but remained statistically significant (adjusted odds ratio, 1.52; 95% confidence interval, 1.17 to 1.98, \( P < 0.001 \)).

### Time Trends

The overall number of nonemergency PCI procedures performed each year more than doubled, from 2254 in 2000 to 5522 in 2006 (Figure). Thereafter, the number fell slightly to 5427 in 2007, mainly because of a reduction in procedures among younger patients. The absolute number of PCIs performed on the elderly increased from 196 in 2000 to 752 in 2007. The incidence of PCI among the elderly general population increased from 56/100 000 per annum in 2000 to 216/100 000 per annum in 2007. Among the general population ages 35 to 74 years, the incidence of PCI increased from 80/100 000 per annum to 192/100 000 per annum.

The elderly accounted for an increasing proportion of nonemergency PCIs, from 8.7% in 2000 to 13.9% in 2007 (chi-squared test for trend, linear-by-linear association).
Among elderly patients, there was a significant increase in the prevalence of comorbidity because of diabetes and renal impairment (Table 3). There was a 4-fold increase in multiple comorbidity in elderly patients, compared with only a 2-fold increase in younger patients. The elderly were also characterized by increasing severity of cardiac disease with the prevalence of left ventricular dysfunction increasing from 37.7% to 55.4% among elderly patients (10% to 66% among younger patients) and the proportion with coronary stents increased from 64% to 90% among elderly patients (64% to 94% among younger patients), and the use of ticlopidine or clopidogrel increased from 8.2% to 63% among elderly patients (10% to 66% among younger patients). In 2000, radial access was used in <5% of patients. In 2000, it was used in 40% patients (both elderly and younger). Our findings suggest that these advances have been sufficient to offset the effect of worsening risk profiles among patients.

The crude risk of MACE did not change significantly over time among elderly or younger patients ($\chi^2$ test for trend, linear-by-linear association; $P<0.0001$). The prevalence of multivessel disease remained the same in the elderly, compared with a 16.5% fall in younger patients.

The crude risk of MACE did not change significantly over time among elderly or younger patients ($\chi^2$ test for trend, linear-by-linear association; $P=0.142$ and $P=0.405$) (Table 4) but did overall ($\chi^2$ test for trend, linear-by-linear association; $P<0.001$). In the multivariable binary logistic regression analysis, there was no significant interaction between year of procedure and age group ($P=0.967$), suggesting that the association between age and outcome did not change significantly over time. The Hosmer and Lemeshow tests confirmed that the model was a good fit (8 groups, $P=0.598$; 10 groups, $P=0.605$; 12 groups, $P=0.667$).

### Discussion

Our results suggest that elderly patients have a higher risk profile and more adverse events and that they account for an increasing number and proportion of nonemergency PCIs. Our findings add to the existing evidence from previous studies, focused on in-hospital events, that have reported a 4- to 5-fold increased risk of death and a 4- to 6-fold increased risk of MACE among elderly patients. The dramatic increase in numbers of PCI over time suggests a change in patient selection. Among elderly patients, the worsening case mix suggests that PCI may now be used for patients who previously underwent surgery or were considered unfit for intervention. Among younger patients, the proportion with multivessel disease fell, suggesting that the increasing number may reflect use of PCI in less severe cases that may previously have been treated by medical therapy only. Despite these trends, we demonstrated that over time, the risk of adverse events has not increased either in the elderly or overall. Over the period studied, many technical developments, new devices, and adjuvant therapies have been shown to be effective at improving PCI outcomes and have adopted into routine clinical practice in Scotland, as elsewhere. For example, over the period studied, deployment of coronary stents increased from 64% to 90% among elderly patients (64% to 94% among younger patients), and the use of ticlopidine or clopidogrel increased from 8.2% to 63% among elderly patients (10% to 66% among younger patients). In 2000, radial access was used in <5% of patients. In 2000, it was used in 40% patients (both elderly and younger). Our findings suggest that these advances have been sufficient to offset the effect of worsening risk profiles among patients.

Our cohort comprised all patients undergoing PCI in Scottish NHS hospitals, not a selected sample, and therefore avoids selection bias. The registry data are detailed and comprehensive and are collected prospectively by clinical staff at the patient’s hospital. Most studies have only been able to report in-hospital complications. This has the potential to introduce bias because length of stay in hospital is longer in elderly patients and has fallen over time as the result of an increase in day-case procedures. Through linkage to routine data, we were able to obtain outcomes up to 30 days of follow-up in both the elderly and younger patients. In Scotland, the follow-up information derived from SMRI has been shown to be as complete and accurate as that obtained using conventional follow-up methods. Unlike previous studies, we excluded patients presenting with MI because the use of primary and rescue PCI has significantly increased over time and varies by age.

In any cohort study, there is always the potential for loss to follow-up, for example, that caused by migration from Scotland. However, this is less likely to occur with 30-day outcomes than long-term outcomes. The vast majority of patients were successfully linked to the follow-up databases. Only 2% could not be linked, but there is no reason to suspect
a systematic bias in the success of linkage, and analysis confirmed no significant statistical differences according to whether or not linkage was achieved.

**Conclusion**

The increasing percentage of elderly in the general population is expected to continue until at least 2031, suggesting that the need for PCI in the elderly will continue to increase. This demographic trend, together with changes in patient selection and case mix, will increase the underlying risk of perioperative complications. Our retrospective study suggests that we have managed to offset this effect, presumably as a result of technical improvements and the adoption of new devices and adjuvant therapies. However, further developments may be required if we are to avoid worsening outcomes in the future.

**Sources of Funding**

This study was supported by the Hutcheson Bequest Fund Fellowship.

**Disclosures**

None.

**References**


**CLINICAL PERSPECTIVE**

The elderly account for an increasing proportion of the population and have a high prevalence of coronary heart disease. Percutaneous coronary intervention (PCI) is the most common method of revascularization in the elderly. Therefore, exploring time trends and clinical outcomes in this group is of great clinical importance. We used the national revascularization registry in Scotland to identify all patients undergoing nonemergency PCI between April 2000 and March 2007, inclusive. Over the time period, we found an increase in the number and percentage of PCIs being undertaken in elderly patients. Compared with younger patients, the elderly were more likely to have multivessel disease, multiple comorbidities, and a history of myocardial infarction or coronary artery bypass grafting. The elderly had a higher risk of major adverse cardiovascular events within 30 days of PCI. Over the 7 years, there was a significant increase in the proportion of elderly patients who had multiple comorbidities. Despite this, the risk of complications did not change significantly over time either among the elderly or overall. Our retrospective study suggests that we have managed to maintain the safety of PCI, presumably as a result of technical improvements and the adoption of new devices and adjuvant therapies. However, further developments may be required if we are to avoid worsening outcomes in the future.
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