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Temporal Trends and Improved Outcomes of Percutaneous Coronary Revascularization in Nonagenarians

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Objectives The aim of this study was to describe the clinical characteristics and the outcomes of patients 90 years of age or older who were treated with percutaneous coronary intervention (PCI).

Background There is a paucity of outcomes data among nonagenarians undergoing PCI.

Methods We evaluated the outcomes of all patients 90 years of age or older in the Mayo Clinic PCI registry and examined trends over time.

Results Over a period of 19 years, we identified 138 nonagenarians (66% women; age 92.2 ± 2.0 years). Mean duration of hospitalization was 3.7 ± 3.1 days, and the median follow-up duration was 3.6 years. Ninety-one percent of patients presented with an acute coronary syndrome and underwent urgent or emergent revascularization. Technical success rate was 91%. Overall, the frequency of in-hospital death, Q-wave myocardial infarction, and major adverse cardiac events (composite of death, Q-wave myocardial infarction, urgent or emergent coronary artery bypass grafting, and cerebrovascular accident) were 9.4%, 0.7%, and 12.3%, respectively. The long-term survival of the cohort was not significantly different than that of an age, gender, and calendar year of birth-matched Minnesota cohort. The cohort was divided into 2 groups according to the time of their intervention: pre-2000 (n = 32) and 2000 to 2006 (n = 106). The in-hospital mortality decreased markedly: 22% to 6% (p = 0.006), respectively.

Conclusions Our study demonstrates that, in carefully selected patients, PCI in contemporary practice may be performed with high technical success with relatively low mortality and morbidity. Thus, advanced age alone must not be considered a contraindication to performing coronary angiography and PCI when clear indications are present. (J Am Coll Cardiol Intv 2008;1:692–8) © 2008 by the American College of Cardiology Foundation

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The elderly are the most rapidly growing segment of the U.S. population (1,2). Approximately two-thirds of these individuals have cardiovascular disease and approximately one-third die as a direct consequence of coronary atherosclerosis (3). The changing demographics are reflected in the contemporary practice of interventional cardiology, where an increasing number of older patients are being referred for percutaneous coronary interventions (PCI) (4). Increasing age is an important determinant of outcomes after percutaneous revascularization (5). However, advances in technology, procedural techniques, and adjunctive medical therapies have resulted in improvement in procedural outcomes (4,6). Thus, advanced age by itself is not a contraindication to PCI (7), and these days it is not uncommon for it to be performed in octogenarians. Long-term outcomes in octogenarians requiring PCI appears to be similar to age-matched cohorts (8), and in selected patients, in-hospital outcomes are comparable to younger patients (9,10).

As these trends continue, PCI is being performed in a small but increasing number of nonagenarians. However, there is a paucity of outcomes data in this population, limited to case reports and small series (11–14). These patients have generally been excluded from randomized trials (15). As a result, there are no evidence-based guidelines regarding PCI in the very elderly (16–18). Thus, the aim of this study was to describe the clinical characteristics and the outcomes of patients age 90 years or older who were treated with PCI at the Mayo Clinic in Rochester, Minnesota.

Methods

Study population. Since 1979, all patients undergoing percutaneous revascularization at the Mayo Clinic have been prospectively followed in a registry. The registry includes demographic, clinical, angiographic, and procedural data. Immediate and in-hospital events are recorded, and each patient is surveyed by telephone contact by trained research coordinators using a standardized questionnaire at 6 months, 1 year, and then annually after the procedure. All adverse events are confirmed by reviewing the medical records of the patients followed at our institution and by contacting the patients' physicians and reviewing the hospital records of patients followed elsewhere.

Approval for the present study was obtained from the Institutional Review Board of the Mayo Foundation. Inclusion criteria were patients who were 90 years or older at the time of their PCI, who had undergone the procedure before 2007, and consented to the use of their medical records for research. There were 140 such patients between 1979 and 2006 (inclusive). There were no PCIs on nonagenarians before 1987. Two patients did not allow use of their records for research and were excluded.

Definitions. The number of diseased coronary arteries was assessed in orthogonal views and defined by at least 1 coronary artery with 70% stenosis and 50% stenosis in the others. Patients with ≥50% stenosis in the left main coronary artery were considered to have 2-vessel disease if there was right dominance and 3-vessel disease if there was left dominance. Major adverse cardiovascular events (MACE), defined as 1 or more of the following: 1) in-hospital death; 2) Q-wave myocardial infarction (MI); 3) urgent or emergent coronary artery bypass grafting (CABG) during the index hospitalization; and 4) cerebrovascular accident defined as transient ischemic attack or stroke. MI was diagnosed in the presence of 2 of the following 3 criteria: 1) typical chest pain for at least 20 min; 2) elevation of creatine kinase (or the MB fraction) >2× normal; and 3) a new Q-wave on electrocardiogram. In-hospital deaths included all deaths during the index hospital admission. Procedural success was defined as a reduction of residual luminal diameter stenosis to ≤20% without in-hospital death, Q-wave MI, or need for CABG. Technical success was defined as a reduction of residual luminal diameter stenosis to ≤20% in the treated segment. Complete revascularization was defined as no residual stenosis >70% in the left main, left anterior descending, the first diagonal (if ≥2.5 mm in diameter), circumflex, the first or second obtuse marginals (if ≥2.5 mm in diameter), ramus intermediate, and the right coronary arteries. The analyses of long-term outcomes included all-cause mortality, death or any MI, and the composite end point of death, MI, or target lesion revascularization (TLR). Other procedural complications, such as those related to the vascular access site were not included in the present analysis. TLR was defined as any attempted percutaneous or surgical revascularization of the target lesion at any time after the initial procedure. The Mayo risk score for determining periprocedural complications was calculated for each patient and was derived from 7 variables (age, creatinine, ejection fraction, shock, MI within 24 h, heart failure at presentation, and history of peripheral vascular disease) as described previously (19). Shock was defined as prolonged systolic blood pressure <95 mm Hg in patients not on inotropes or intra-aortic balloon pump support or <110 mm Hg in patients in patients requiring treatment with inotropes or intra-aortic balloon pump support. To analyze temporal trends, the cohort was divided into 2 groups according to the time of their intervention: pre-January 2000 (n = 32) and January 2000 to December 2006 (n = 106). The second group represents contemporary practice.

Abbreviations and Acronyms

CABG = coronary artery bypass grafting
IQR = interquartile range
MACE = major adverse cardiac events
MI = myocardial infarction
PCI = percutaneous coronary intervention(s)
TLR = target lesion revascularization

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Statistical analysis. Continuous variables, summarized as mean ± SD, were compared between groups with 1-way analysis of variance (unless otherwise noted). The interquartile range (IQR) represents the 25th to 75th percentile and thus represents the middle 50% of the data. Discrete variables are presented as frequency (percentages) and compared with Pearson's chi-square test. Missing values were excluded from the denominator in the calculation of percentages. Kaplan-Meier methods were used to estimate survival rates on follow-up. The survival experience of patients who survived to discharge was compared with the expected survival as estimated by an age, sex, and calendar year of birth-matched cohort of the Minnesota white population (20). The smoothed fitted lines used to display trends were created by fitting a cubic spline, which minimizes a linear combination of the sum of squared residuals and the integral of the square of the second derivative of the curve. All hypotheses tests are 2-sided with a 0.05 type-1 error rate. Analyses were performed using SAS version 9.1 (SAS Institute Inc., Cary, North Carolina).

Results

Baseline characteristics. The clinical characteristics of the 138 patients included in the analysis are summarized in Table 1. The patients were predominantly women, and the vast majority presented with an acute coronary syndrome. Troponin T has been routinely measured in our laboratory from August 1, 2000, the pre-procedure levels were elevated in 81% of the 94 subjects with measurements available. There was a high prevalence of hypertension and hyperlipidemia. A past history of congestive heart failure, cerebrovascular disease, peripheral vascular disease, and prior coronary revascularization was frequently present. The Mayo risk score ranged from 6 to 22 (median [IQR]: 8 [6 to 10]) for in-hospital MACE, and 4 to 20 (median [IQR]: 8 [5 to 10]) for in-hospital death. The median (IQR) estimated risks were 6.7% (4.4% to 10.2%) for MACE and 2.2% (0.8% to 4.3%) for death.

Angiographic and procedural characteristics. Table 2 summarizes the angiographic and procedural characteristics. Most (75%) of patients underwent either urgent or emergent revascularization at the time of presentation; elective PCI was performed in only 25% of the cohort. The majority (88%) had multivessel disease with American College of Cardiology/American Heart Association type B2 or C culprit lesions. Coronary thrombus (39%), calcification (63%), and bifurcation (17%) lesions were common. Despite the lesion complexity, technical success and procedural success rates were 91% and 84%, respectively.

Outcomes. One hundred fifteen nonagenarians (83%) had follow-up within 1 year, 131 (95%) had follow-up within 18 months, and all but 1 (99%) had follow-up within 2 years of the analysis period. Mean duration of hospitalization was 3.7 ± 3.1 days. The frequency of in-hospital death, Q-wave MI, and MACE was 9.4%, 0.7%, and 12.3%, respectively. The distribution of the Mayo risk score and the associated in-hospital mortality in each risk category is shown in Table 3. Three patients suffered a stroke. From January 2003 onward, patients presenting with acute MI were classified as either non–ST-segment elevation MI (n = 8) or ST-segment elevation MI (n = 20) in the registry. The in-hospital mortality for the 2 groups was 0% and 10%, respectively. The MACE rates were 13% and 15%, respectively. Complete revascularization was achieved in 36% of patients. Median follow-up duration was 3.6 years (IQR: 1.8 to 6.1 years). Mortality at 1, 3, and 5 years was 25%, 41%, and 71%, respectively. The frequency of the combined end point of death and any MI was 38%, 53%, and 78%, respectively. The combined end point of death, MI, CABG, or TLR was 44%, 60%, and 81%, respectively. The long-

Table 1. Baseline Clinical Characteristics

Variable, n (%)	Overall (N = 138)
Age, yrs	92.2 ± 2.0
Male gender	61 (44%)
Diabetes	20 (15%)
Hypertension	104 (78%)
Hypercholesterolemia	70 (59%)
Smoking status	
Never	85 (64%)
Former	47 (36%)
Unstable angina	85 (62%)
Acute coronary syndrome (MI <7 days or unstable angina)	125 (91%)
Pre-procedural shock	17 (13%)
Predominant symptom	
Chest pain	127 (92%)
CHF	5 (4%)
Other/unknown	6 (4%)
CHF status	
Never	75 (60%)
Previous	12 (10%)
Current	39 (31%)
Body mass index, kg/m^2	25.2 ± 4.6
Prior PTCA	39 (28%)
Prior CABG	13 (9%)
Peripheral vascular disease	17 (13%)
CVA/TIA	30 (23%)
Average creatinine, mg/dl	1.4 ± 0.7
LVEF measure	
>40%	39 (28%)
≤40%	16 (12%)
Not available	83 (60%)

Values are mean ± SD or n (90). Data on peripheral vascular disease and renal disease were not recorded in the registry before 1993.

CABG = coronary artery bypass grafting; CHF = congestive heart failure; CVA = cerebrovascular accident; LVEF = left ventricular ejection fraction; MI = myocardial infarction; PTCA = percutaneous transluminal angioplasty; TIA = transient ischemic attack.

Table 2. Baseline Angiographic and Procedural Characteristics

Variable, n (%)	Overall (N = 138)
Multivessel disease	113 (88%)
Worst lesion type	
A	2 (2%)
B1	8 (7%)
B2	31 (26%)
C	77 (65%)
Urgency of PCI	
Elective	35 (25%)
Urgent	68 (49%)
Emergency	35 (25%)
Stent use	113 (82%)
Drug-eluting stent use	48 (35%)
Number of stents placed >1	50 (36%)
GP IIb/IIIa inhibitor use	60 (43%)
Number of vessels treated	
1	107 (78%)
2	27 (20%)
3	4 (3%)
Elevated post-procedure troponin, number (%)	88 (91%)
Post-troponin, median (IQR)	0.9 (0.1, 3.4)

GP = glycoprotein; IQR = interquartile range; PCI = percutaneous coronary intervention.

term survival of the cohort was not significantly different compared with an age, gender, and calendar year of birth-matched Minnesota cohort (Fig. 1). Furthermore, in the 106 nonagenarians treated in 2000 and after, 48 (45%) received a drug-eluting stent and 56 (53%) received a bare-metal stent. Seven (7%) of those patients received both; 9 (8%) received neither. Comparing the 48 drug-eluting stent recipients versus the 49 with bare-metal stent only, there is no difference is survival among patients in these 2 groups (p = 0.93).

Trends over time. There has been a progressive increase in the number of nonagenarians being referred for PCI (Fig. 2). The risk profile of the patients, and hence the estimated periprocedural risk of death and MACE, as estimated from the Mayo Clinic risk score, has not changed between the 2 groups (Table 4). However, there has been a marked reduction in the actual in-hospital mortality (Fig. 2) and MACE (Table 4) over time. This is most likely due to the

Table 3. Distribution of Mayo Risk Score and the Expected/Observed Mortality

	Risk Category				
	Very Low (n = 36)	Low (n = 29)	Moderate (n = 45)	High (n = 10)	Very High (n = 18)
Score interval	0–5	6–7	8–10	11–12	≥13
Expected rate	0.7%	1.2%	3.2%	6.3%	36%
Observed rate	5.6%	3.4%	8.9%	10%	28%

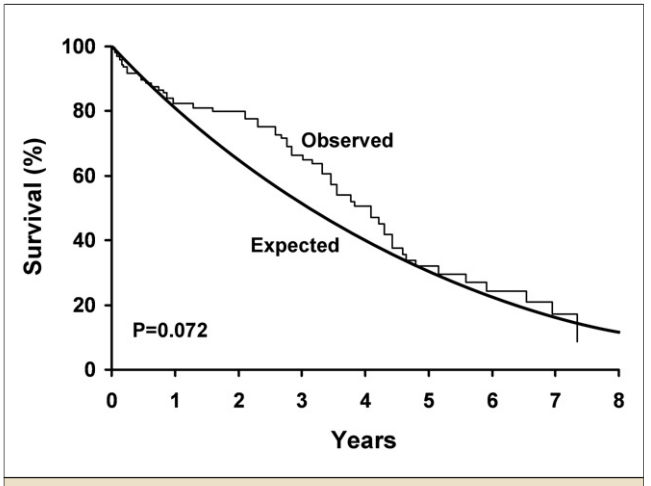

Figure 1. Long-Term Survival

Long-term survival during follow-up among patients versus age, gender, and calendar year of birth-matched controls.

improvement in technical success and the increasing use of stents and adjunctive glycoprotein IIb/IIIa inhibitor. Significant changes also occurred in the medical therapy that was prescribed at discharge. The use of cardioprotective medications such as antiplatelets, beta-blockers, statins, and angiotensin-converting enzyme inhibitors increased over time, reflecting the accumulating evidence for their efficacy. While the use of aspirin, clopidogrel, and beta-blockers was high, statins were prescribed to only 51% of the patients.

Comparison with octogenarians. When compared with patients who were in their 80s, nonagenarians were more likely to have multivessel disease, present with an acute coronary syndrome, and cardiogenic shock. As expected, the estimated risk for death and MACE by the Mayo risk score was

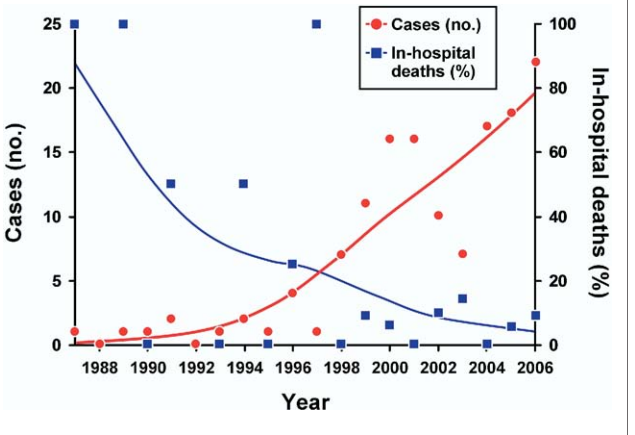

Figure 2. Trends in In-Hospital Mortality and Case Volume

Over time there has been a steady increase in the number of nonagenarians undergoing percutaneous coronary intervention, with a decrease in in-hospital mortality.

Table 4. Trends in Characteristics and Outcomes

Variable	Pre-2000 (n = 32)	2000 Onward (n = 106)	p Value	80–89 Yr Olds (n = 1,339)	p Value*
Age, yrs	91.6 ± 1.2	92.4 ± 2.2	0.07	83.5 ± 2.6	
Male, n (%)	13 (41%)	48 (45%)	0.64	735 (55%)	0.06
Body mass index, kg/m^2	25.1 ± 4.6	25.2 ± 4.6	0.98	27.4 ± 4.6	<0.001
Hypertension, n (%)	21 (66%)	83 (81%)	0.06	1,092 (85%)	0.39
Diabetes, n (%)	5 (16%)	15 (14%)	0.85	341 (26%)	0.010
Prior revascularization, n (%)	8 (25%)	37 (35%)	0.29	512 (38%)	0.50
Acute coronary syndrome	31 (97%)	94 (89%)	0.16	1,055 (79%)	0.015
Cardiogenic shock	3 (11%)	14 (13%)	0.72	70 (5%)	<0.001
Estimated risk of MACE, median (Q1, Q3) (Mayo risk score)	6.7 (4.9, 8.3)	6.7 (4.4, 12.5)	0.43	4.4 (3.5, 6.7)	<0.001
Estimated risk of death, median (Q1, Q3) (Mayo risk score)	1.3 (1.1, 3.7)	2.2 (0.8, 4.3)	0.56	1.1 (0.6, 2.2)	<0.001
Multivessel disease (70/50), n (%)	28 (93%)	85 (87%)	0.33	945 (75%)	0.011
Complete revascularization, n (%)	7 (22%)	42 (40%)	0.07	605 (45%)	0.26
Stent usage, n (%)	16 (50%)	97 (92%)	<0.001	1,237 (92%)	0.75
GP IIb/IIIa use, n (%)	8 (25%)	52 (49%)	0.016	734 (55%)	0.24
In-hospital death, n (%)	7 (22%)	6 (6%)	0.006	55 (4%)	0.44
In-hospital Q-wave MI, n (%)	0 (0%)	1 (1%)	0.58	9 (1%)	0.75
In-hospital stroke, n (%)	0 (0%)	3 (3%)	0.34	19 (1%)	0.25
In-hospital CABG, n (%)	0 (0%)	0 (0%)		11 (1%)	0.35
MACE, n (%)	7 (22%)	10 (9%)	0.06	83 (6%)	0.19
Medications at discharge, n (%)					
Aspirin at discharge	22 (88%)	99 (99%)	0.005	1,213 (95%)	0.06
Plavix at discharge	14 (82%)	96 (97%)	0.012	1,216 (95%)	0.39
Lipid-lowering medication at discharge	5 (20%)	51 (51%)	0.005	832 (65%)	0.004
Beta-blocker at discharge	19 (76%)	88 (88%)	0.13	1,067 (83%)	0.23
ACE inhibitor at discharge	8 (33%)	59 (59%)	0.023	774 (60%)	0.77

*p value comparison between nonagenarians undergoing PCI 2000 onward compared with all octogenarians who underwent percutaneous coronary intervention in the same time period.
ACE = angiotensin-converting enzyme; GP = glycoprotein; MACE = major adverse cardiac events; Q1 = 25th percentile; Q3 = 75th percentile; other abbreviations as in Table 1.

higher in nonagenarians. However, the actual frequencies of in-hospital mortality, Q-wave MI, stroke, and the composite end point of MACE were not significantly different in the 2 groups (Table 4). The use of dual antiplatelet therapy and beta-blockers was similar in the octogenarians and nonagenarians, but lipid-lowering therapy was less often prescribed in the very elderly.

Discussion

The major findings of the present study are that there has a been a marked increase in the number of nonagenarians undergoing percutaneous revascularization, and among these patients: 1) PCI is typically performed for an acute coronary syndrome in the setting of complex lesion morphology; 2) the technical success rate is high (91%); 3) there has been a marked reduction in-hospital mortality over time; and 4) long-term outcomes after discharge are similar to age- and gender-matched control subjects.

Though nonagenarians represent a small subset of patients in contemporary practice, there has clearly been an exponential rise in the number of patients referred for percutaneous revascularization in recent years (Fig. 2). It is a global trend (12) and is likely to continue with the aging population. This is reflected in the data from the CRUSADE (Can Rapid risk stratification of Unstable angina patients Suppress ADverse outcomes with Early implementation of the American College of Cardiology/American Heart Association Guidelines) registry from which data were recently published on the outcomes of over 5,000 nonagenarians treated for non–ST-segment elevation acute coronary syndromes (21). These investigators report that these patients have high in-hospital mortality (12%), but outcomes are better among those patients treated with guideline-recommended care, which in the case of acute coronary syndromes involves an invasive strategy for treating ischemia. In the present study, we have noted improvement in procedural success rates over time, likely due to advances in techniques, operator experience, and adjunctive therapy. This has been accompanied by a reduction in in-hospital mortality and MACE rates (Table 4 and Fig. 2). Moreover, it is encouraging that during follow-up extending up to 7 years after discharge, the survival of our patients was similar to an age- and gender-matched population (Fig. 1).

Our study is the largest case series with the longest follow-up published to date on the characteristics and outcomes of nonagenarians treated with PCI. As reported in prior studies (12,13), PCI in nonagenarians is largely being performed in the setting of an acute coronary syndrome. Not surprisingly, the very elderly patients have advanced atherosclerosis, with 88% having multivessel disease. The culprit lesions have complex morphology, with two-thirds of patients having type C lesions. The adverse lesions characteristic accounts for a procedural success rate (89% in the most recent cohort) that is lower than what is achieved in general (94%) at our institution (4). However, despite the high-risk characteristics, the in-hospital mortality (6%) and MACE (9%) rates in the recent cohort of nonagenarians were not prohibitively high, and not significantly different from the estimated risk using the Mayo risk score (Table 3). Moreover, it is notable that the in-hospital outcomes were similar to those seen in octogenarians who were treated during the same time period, despite a higher frequency of multivessel disease, acute coronary syndrome, and cardiogenic shock in the nonagenarians. Among patients in whom PCI was performed for acute MI, the in-hospital mortality was almost exclusively in those with ST-segment elevation MI compared with those with non–ST-segment elevation MI. It is reassuring to note that the frequency of post-procedure stroke is extremely low in this very elderly population in whom antiplatelet and anticoagulant therapy might be expected to be associated with a significantly increased risk of bleeding.

The present study complements recent publications describing the outcomes in nonagenarians undergoing other cardiovascular surgical procedures. Bridges et al. (22) recently published the experience from the Society of Thoracic Surgeons national database of outcomes after cardiac surgery for coronary artery disease and valvular heart disease in over 1,000 nonagenarians. They concluded that while surgical mortality increased with age, reasonable outcomes could be achieved with careful selection of patients (22). However, the operative mortality for CABG was high at 11.8% and frequency of stroke was 2.9%. Similarly, Baril et al. (23) have reported their experience in performing endovascular repair of abdominal aortic aneurysms in nonagenarians and reported a high success rate, although the perioperative mortality was 11%. These studies, together with our data, support the feasibility of performing a wide spectrum of percutaneous and surgical cardiac procedures in very elderly patients.

Study limitations. Although the data were collected prospectively, this is a retrospective single-center analysis and is subject to the limitations of such analyses. 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 that have developed over the time-frame of the data collection. The study setting involved a single-center tertiary-care referral center. Furthermore, the study was limited to selected patients treated with PCI, and we cannot comment on the trends in outcomes in patients who are managed medically or with surgical revascularization. Indeed, data from the CRUSADE registry confirm that coronary revascularization is performed in only a minority (12.6%) of nonagenarians presenting with non–ST-segment elevation acute coronary syndromes (21). Due to the retrospective design of the CRUSADE data and the present study, it is not possible to ascertain why certain patients are selected for PCI over others. Clearly, they appear to represent a small proportion of all nonagenarians presenting with an acute coronary syndrome. The absence of comorbidities is likely to be a major factor that determines selection for revascularization. Further research efforts are required to characterize which nonagenarians would benefit from revascularization, and to some extent this requires the development of methods to quantify fitness and frailty (24) in the elderly. Finally, the control population was only matched for age, gender, and calendar year of birth. Consequently, there may have been significant unmeasured differences between the cases and control subjects, but it was not possible to match for all potential variables of interest due to a small number of nonagenarians in the general population.

Conclusions

Our study demonstrates that, in carefully selected patients, PCI may be performed with high technical success with relatively low mortality and morbidity. Thus, advanced age alone must not be a contraindication for performing coronary angiography and PCI when clear indications are present. If current trends continue, it is very likely that in the coming years we will see a marked increase in the number of nonagenarians being referred for PCI.

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REFERENCES

1. Day J. Population projections of the United States by age, sex, race, and Hispanic origins: 1995–2050. Current Population Reports. Washington, DC: U.S. Bureau of the Census, 1996.
2. Centers for Disease Control, Prevention. Trends in aging—United States and worldwide. MMWR Morb Mortal Wkly Rep 2003;52:101–4.
3. Roberts WC, Shirani J. Comparison of cardiac findings at necropsy in octogenarians, nonagenarians, and centenarians. Am J Cardiol 1998;82:627–31.
4. Singh M, Rihal CS, Gersh BJ, et al. Twenty-five-year trends in in-hospital and long-term outcome after percutaneous coronary intervention: a single-institution experience. Circulation 2007;115:2835–41.

5. Singh M, Rihal CS, Lennon RJ, Garratt KN, Mathew V, Holmes DR Jr. Prediction of complications following nonemergency percutaneous coronary interventions. Am J Cardiol 2005;96:907–12.
6. Batchelor WB, Anstrom KJ, Muhlbaier LH, et al. Contemporary outcome trends in the elderly undergoing percutaneous coronary interventions: results in 7,472 octogenarians. National Cardiovascular Network Collaboration. J Am Coll Cardiol 2000;36:723–30.
7. Graham MM, Ghali WA, Faris PD, Galbraith PD, Norris CM, Knudtson ML. Survival after coronary revascularization in the elderly. Circulation 2002;105:2378–84.
8. Cohen HA, Williams DO, Holmes DR Jr, et al. Impact of age on procedural and 1-year outcome in percutaneous transluminal coronary angioplasty: a report from the NHLBI Dynamic Registry. Am Heart J 2003;146:513–9.
9. Halon DA, Adawi S, Dobrecky-Mery I, Lewis BS. Importance of increasing age on the presentation and outcome of acute coronary syndromes in elderly patients. J Am Coll Cardiol 2004;43:346–52.
10. Thompson RC, Holmes DR Jr., Gersh BJ, Mock MB, Bailey KR. Percutaneous transluminal coronary angioplasty in the elderly: early and long-term results. J Am Coll Cardiol 1991;17:1245–50.
11. Gowda RM, Chamakura SR, Khan IA, Vasavada BC, Sacchi TJ. Percutaneous coronary intervention in a nonagenarian woman for intractable post-infarction angina. Int J Cardiol 2004;93:77–8.
12. Moreno R, Salazar A, Banuelos C, et al. Effectiveness of percutaneous coronary interventions in nonagenarians. Am J Cardiol 2004;94:1058–60.
13. Teplitsky I, Assali A, Lev E, Brosh D, Vaknin-Assa H, Kornowski R. Results of percutaneous coronary interventions in patients ≥90 years of age. Catheter Cardiovasc Interv 2007;70:937–43.
14. Wu Y, Hou C, Chou Y, Tsa C. Percutaneous coronary intervention in nonagenarians. Acta Cardiol 2004;20:73–82.
15. Lee PY, Alexander KP, Hammill BG, Pasquali SK, Peterson ED. Representation of elderly persons and women in published randomized trials of acute coronary syndromes. JAMA 2001;286:708–13.
16. Alexander KP, Roe MT, Chen AY, et al. Evolution in cardiovascular care for elderly patients with non–ST-segment elevation acute coronary syndromes: results from the CRUSADE National Quality Improvement Initiative. J Am Coll Cardiol 2005;46:1479–87.
17. Rathore SS, Mehta RH, Wang Y, Radford MJ, Krumholz HM. Effects of age on the quality of care provided to older patients with acute myocardial infarction. Am J Med 2003;114:307–15.
18. Yan AT, Yan RT, Tan M, et al. Management patterns in relation to risk stratification among patients with non-ST elevation acute coronary syndromes. Arch Intern Med 2007;167:1009–16.
19. Singh M, Rihal CS, Lennon RJ, Spertus J, Rumsfeld JS, Holmes DR Jr. Bedside estimation of risk from percutaneous coronary intervention: the new Mayo Clinic risk scores. Mayo Clin Proc 2007;82:701–8.
20. Therneau T, Sicks J, Bergstralh E, Offord J. Expected Survival Based on Hazard Rates, Section of Biostatistics. Rochester, Minnesota: Technical Report Series 1994;52.
21. Skolnick AH, Alexander KP, Chen AY, et al. Characteristics, management, and outcomes of 5,557 patients age ≥90 years with acute coronary syndromes: results from the CRUSADE Initiative. J Am Coll Cardiol 2007;49:1790–7.
22. Bridges CR, Edwards FH, Peterson ED, Coombs LP, Ferguson TB. Cardiac surgery in nonagenarians and centenarians. J Am Coll Surg 2003;197:347–56, discussion 356–7.
23. Baril DT, Palchik E, Carroccio A, et al. Experience with endovascular abdominal aortic aneurysm repair in nonagenarians. J Endovasc Ther 2006;13:330–7.
24. Rockwood K, Song X, MacKnight C, et al. A global clinical measure of fitness and frailty in elderly people. CMAJ 2005;173:489–95.

Key Words: percutaneous coronary intervention ■ nonagenarians ■ age ■ outcomes.