ORIGINAL ARTICLE

Cardiac Surgery in Octogenarians

Does Age Alone Influence Outcomes?

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Hypothesis: Outcome differences in octogenarians vs patients younger than 80 years undergoing coronary artery bypass grafting or valve surgery can be analyzed to isolate the effect of age alone on morbidity and mortality.

Design: Eight-year hospitalization cohort study. Physicians, nurses, and perfusionists prospectively collected data on 225 variables.

Setting: Community hospital.

Patients: A consecutive sample of 7726 patients undergoing coronary artery bypass grafting or valve surgery between October 1, 1993, and February 28, 2001.

Main Outcome Measures: There were 9 main outcomes of interest: mortality, length of hospital stay, gastrointestinal tract complications, neurologic complications, pulmonary complications, renal complications, return to intensive care unit, intraoperative complications, and reoperation to treat bleeding. We controlled for 16 potential confounding variables to isolate outcome differences according to age.

Results: Of 7726 patients who fit the inclusion criteria, 522 were octogenarians. Compared with nonoctogenarians, octogenarians had a significantly higher New York Heart Association functional classification, higher incidence of hypertension, and underwent a greater number of coronary artery bypass grafting plus valve surgical procedures ($P<.05$). They also had significantly lower body surface area, fewer total number of grafts used, less history of tobacco use, and less abnormal left ventricular hypertrophy, and there were fewer nonwhite patients and fewer men. At multivariate analysis, octogenarians had a higher risk for death (relative risk [RR], 1.72; 95% confidence interval [CI], 1.52-1.83), longer hospital stay (RR, 1.03; 95% CI, 1.01-1.04), more neurologic complications (RR, 1.51; 95% CI, 1.26-1.67), and were more likely to undergo a reoperation to treat bleeding (RR, 1.49; 95% CI, 1.09-1.72). Univariate analyses revealed no difference between octogenarians and nonoctogenarians for diabetes mellitus, urgency of procedure, prior myocardial infarction, time since last myocardial infarction, cerebrovascular history, chronic obstructive pulmonary disease, or pump time.

Conclusions: Age alone has been shown to influence outcomes after cardiac bypass or valve surgery. Octogenarians undergoing cardiac surgery have more comorbidities and higher mortality even after controlling for 16 potential confounding variables, compared with nonoctogenarians.

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OPEN HEART SURGERY FOR coronary artery bypass grafting (CABG) or valve replacement in octogenarians has risen dramatically since 1980, increasing by 67% from 1987 to 1990.[1] In 2000 the average life expectancy at birth for the US population was 76.9 years.[2] According to the Administration on Aging, there were 4.2 million Americans aged 85 years or older in 2000, and this number is projected to increase to 8.9 million by 2030.[3] Approximately 40% of all octogenarians have symptomatic cardiovascular disease, including 18% with ischemic heart disease.[4] Increasingly, elderly patients with ischemic heart disease are being referred for coronary artery revascularization by surgical and percutaneous means. However, these strategies are being questioned because of reports of poor outcomes in the elderly.

Previous observational studies have shown that octogenarians undergoing open heart surgery for CABG or valve replacement are at higher risk for postoperative death.[5,6] However, these studies have reported different predictors of mortality. For example, Akins et al[5] identified chronic lung disease and congestive heart failure as independent predictors of

Table 1. Definition of Variable Categories

Variable	Categories
Race	White or other
Sex	Male or female
Diabetes mellitus	Dietary control or medical control
Body surface area, m^2	
Urgency of surgical procedure	Elective, nonelective (urgent, emergent, or desperate)
Hypertension	Diastolic blood pressure >90 mm Hg
NYHA functional class*	I-IV
Previous MI	Reported MI in preoperative history and physical examination
Interval since last MI, d	<7 or ≥7
Cerebrovascular history	Reported TIA, CVA, carotid bruit, or abnormal carotid pulse
Tobacco use history	Yes or no
Chronic obstructive pulmonary disease	Mild, no medications; moderate, symptoms on exertion; or severe, symptoms at rest
Pump time, min	Operative time with mechanical perfusion
Left ventricular hypertrophy	Mild, moderate, or severe
Total grafts used	Number of coronary arteries surgically bypassed with venous or arterial grafts
Type of surgery	CABG, valve, CABG plus valve, or other
Mortality	Percentage of patients who died during postoperative hospitalization
Length of hospital stay, d	Duration from operation to discharge
GI tract complications	Any GI complication, including severe GI tract bleeding, perforated ulcer, cholecystitis, hepatitis, and pancreatitis
Neurologic complications	Any neurologic complication, including mental status change, CVA, peripheral nerve injury, seizure, and TIA
Pulmonary complications	Any pulmonary complication except mild atelectasis
Renal complications	Mild, double preoperative creatinine concentration; moderate, creatinine concentration >4.0 mg/dL; or severe, dialysis required
Return to intensive care unit	Yes or no
Intraoperative complications	Dissection, hemorrhage, arrhythmia, cardiac laceration, cardiac dilation, air embolism, MI, aortic tear, cardiac arrest, valve trauma, or unsatisfactory graft harvest
Reoperation to treat bleeding	Yes or no

Abbreviations: CABG, coronary artery bypass grafting; CVA, cerebrovascular accident; GI, gastrointestinal; MI, myocardial infarction; NYHA, New York Heart Association; TIA, transient ischemic attack.

*The NYHA classes are as follows: class I: patients with cardiac disease, but without resulting limitation of physical activity; ordinary physical activity does not cause undo fatigue, palpitations, dyspnea, or anginal pain; class II: patients with cardiac disease resulting in slight limitation of physical activity, comfortable at rest, ordinary physical activity results in fatigue, palpitations, dyspnea, or anginal pain; class III: patients with cardiac disease resulting in marked irritation with physical activity, comfortable at rest, but less than ordinary physical activity results in fatigue, palpitation, dyspnea, or anginal pain; class IV: patients with cardiac disease resulting in the inability to carry out any physical activity without discomfort, symptoms of cardiac insufficiency or the anginal syndrome may be present even at rest, discomfort is increased with any physical activity.

mortality, while Edmunds et al[7] found that preoperative variables predictive of early death include New York Heart Association (NYHA) functional classification IV (ie, the person is unable to carry out any physical activity without discomfort; there are symptoms of cardiac insufficiency at rest; and if any physical activity is undertaken, discomfort is increased) previous myocardial infarction (MI), and emergency operation. Until recently, no large series has determined whether age is an independent risk factor for morbidity and mortality in octogenarians undergoing open heart surgery.

This study compared the characteristics of octogenarians with nonoctogenarians undergoing open heart surgery for CABG or valve replacement. By controlling for differences between these groups, we sought to determine whether being an octogenarian is an independent risk factor for mortality as well as for 9 other measured outcomes.

METHODS

PARTICIPANTS

We conducted a cohort study, using cases and control subjects from an 8-year hospitalization cohort. Inclusion criteria for the cohort were CABG or valve replacement between October 1, 1993, and February 28, 2001, and age older than 18 years. Physicians, nurses, and perfusionists collected data on 225 variables concurrently with admission (**Table 1**). Data were grouped into demographic, medical history, postoperative, perfusion, and procedure sections. Using a series of cross-checking questions, 2 individuals audited all data forms for completeness and consistency. In addition, a physician audited a random 10% of patient forms for accuracy and consistency on an ongoing basis. Data were entered into an interactive multi-institutional database (Patient Analysis and Tracking System; Axis Clinical Systems, Portland, Ore).

Patients were grouped according to age. Patients (n=522) were aged 80 to 89 years (octogenarians), and control subjects (n=7204) were 18 to 79 (nonoctogenarian). We controlled for the following 16 potential confounding variables: race, sex, diabetes mellitus, body surface area, urgency of surgical procedure, hypertension, NYHA functional classification, previous MI, time since last MI, cerebrovascular history, tobacco history, chronic obstructive pulmonary disease, pump time, left ventricular hypertrophy, total number of grafts used, and surgery type. We were interested in the following 9 outcomes: mortality, length of hospital stay, gastrointestinal tract complications, neurologic complications, pulmonary complications, renal complications, return to the intensive care unit, intraoperative complications, and reoperation to treat bleeding.

STATISTICAL ANALYSIS

We performed univariate analysis using χ^2 and t tests to compare cases and controls with each of the 16 potential confounding variables (**Table 2**). To generate the unadjusted risks of each outcome, we performed χ^2 and t tests comparing cases and controls with each of the 9 outcomes of interest (**Table 3**). Additional analyses were conducted to compare cases and controls with the total number of grafts used, both venous and arterial, and specifically the number of arterial grafts used. Using logistic regression analysis for dichotomous variables and linear regression for continuous variables, we then de-

Table 2. Univariate Analysis of Potential Confounding Variables*

Variable	Octogenarian	Nonoctogenarian	*P* Value
Race			
White	466 (96)	5932 (92)	.02
Other	21 (4.0)	498 (8.0)	
Sex			
Male	266 (51)	4745 (66)	.00
Female	256 (49)	2459 (34)	
Diabetes mellitus	158 (30)	2058 (29)	.43
Body surface area, mean ± SD, m^2	1.8 ± 0.2	2.0 ± 0.2	.00
Urgency of surgical procedure			
Urgent	120 (24)	1733 (26)	.37
Elective	386 (76)	5059 (75)	
Hypertension	339 (65)	4303 (60)	.02
NYHA class†			
I	48 (11)	750 (13)	.02
II	116 (25)	1745 (30)	
III	171 (37)	1913 (33)	
IV	124 (27)	1385 (24)	
Previous MI	226 (43)	3048 (42)	.70
Last MI, mean ± SD, d			
<7	373 (72)	5206 (73)	.60
≥7	146 (28)	1934 (27)	
Cerebrovascular history	40 (8)	404 (6)	.09
Tobacco use history	170 (38)	3365 (58)	.00
Chronic obstructive pulmonary disease	75 (14)	1089 (15)	.64
Pump time, mean ± SD, min	103.8 ± 49.5	103.4 ± 54.0	.87
Left ventricular hypertrophy			
Yes	152 (30)	2563 (38)	.00
No	347 (70)	4134 (62)	
Total grafts used, mean ± SD, No.	3.1 ± 1.2	3.3 ± 1.2	.00
Type of surgery			
CABG	35 (73)	5148 (80)	.00
Valve	38 (8)	596 (9)	
CABG and valve	82 (17)	566 (9)	
Other	9 (2)	137 (2)	

Abbreviations: CABG, coronary artery bypass grafting; MI, myocardial infarction; NYHA, New York Heart Association.

*Data are given as the number (percentage) of cases and control subjects unless otherwise indicated.

†See Table 1 footnote for an explanation of the NYHA classes.

termined the adjusted risk between case patients and control subjects with each of the 9 outcomes of interest while controlling for the 16 confounding variables (**Table 4**). Analysis was performed with Stata statistical software (Stata Corp, College Station, Tex).

RESULTS

Overall, 7726 patients met the inclusion criteria. Of these, 5011 (65%) were men and 2715 (35%) were women. Among the 522 octogenarians, 266 (51%) were men and 256 (49%) were women. Among the 7204 nonoctogenarians, 4745 (66%) were men and 2459 (34%) were women; their mean±SD age was 63.3±10.5 years. **Figure 1** shows the number of octogenarians in this cohort undergoing surgery in each calendar year.

Table 3. Univariate Analysis of Hospital Outcome Variables*

Outcome Variable	Octogenarian	Nonoctogenarian	*P* Value
Mortality	41 (8)	170 (2)	<.01
Neurologic complications	62 (12)	392 (5)	<.01
Reoperation to treat bleeding	25 (5)	153 (2)	<.01
Pulmonary complications	75 (14)	624 (9)	<.01
Renal complications	41 (8)	312 (4)	<.01
Return to intensive care unit	20 (4)	137 (2)	<.01
Gastrointestinal tract complications		1348 (19)	.23
Intraoperative complications	20 (4)	287 (4)	.82
Length of hospitalization, mean ± SD, d	8.74 ± 9.10	6.72 ± 6.52	<.01

*Data are given as the number (percentage) of cases and control subjects unless otherwise indicated.

Table 4. Adjusted Relative Risks and 95% Confidence Intervals Comparing Octogenarians and Nonoctogenarians for 9 Hospitalization Outcomes*

Hospitalization Outcome	Relative Risk† (95% CI)	*P* Value
Length of hospitalization	1.03 (1.01-1.04)	<.01
Mortality	1.72 (1.52-1.83)	<.01
Neurologic complications	1.51 (1.26-1.67)	<.01
Reoperation to treat bleeding	1.49 (1.09-1.72)	.02
Pulmonary complications	1.31 (1.00-1.53)	.06
Renal complications	1.29 (1.81-0.58)	.20
Intraoperative complications	1.33 (0.51-1.70)	.33
Return to intensive care unit	1.24 (0.50-1.62)	.44
Gastrointestinal tract complications	1.03 (0.71-1.27)	.86

Abbreviation: CI, confidence interval.

*Adjusted for race, sex, diabetes mellitus, body surface area, urgency of surgical procedure, hypertension, New York Heart Association functional class, previous myocardial infarction, interval since last myocardial infarction, cerebrovascular history, tobacco use history, chronic obstructive pulmonary disease, pump time, left ventricular hypertrophy, number of grafts used, and surgery type.

†Octogenarians vs nonoctogenarians.

There was no significant difference between cases and controls for diabetes mellitus, urgency of surgical procedure, previous MI, time since last MI, cerebrovascular history, chronic obstructive pulmonary disease, or pump time. Octogenarians had significantly higher NYHA functional class, incidence of hypertension, and greater number of CABGs plus valve surgical procedures ($P<.05$); this group also had significantly fewer nonwhite patients and fewer men ($P<.05$). Furthermore, octogenarians had significantly less body surface area and tobacco use history, fewer instances of abnormal left ventricular hypertrophy, and fewer total number of grafts used ($P<.05$). Specifically, octogenarians averaged significantly fewer (mean±SD, 0.7±0.7) arterial grafts used than did nonoctogenarians (mean±SD, 0.8±0.7; $P<.001$).

Multivariate analysis revealed no significant difference between octogenarians and nonoctogenarians for gastrointestinal tract complications, pulmonary complications, renal complications, return to the intensive care unit, or intraoperative complications. However, octogenarians were found to have a higher risk for death (rela-

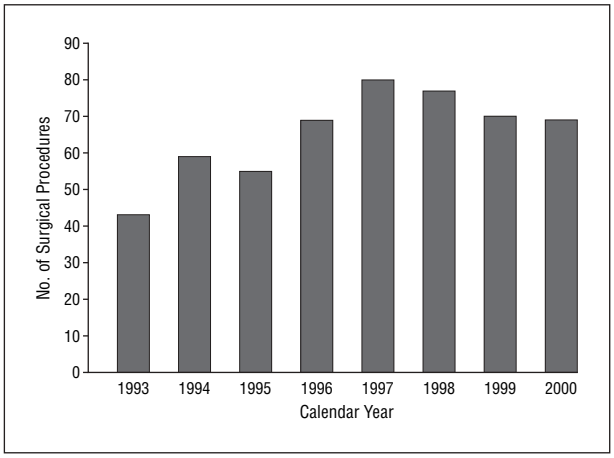

Figure 1. Number of octogenarian surgical procedures by calendar year.

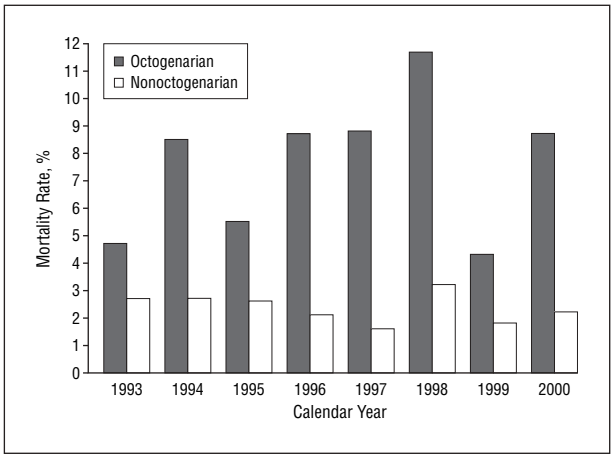

Figure 2. Mortality rate by calendar year.

tive risk [RR], 1.72; 95% confidence interval [CI], 1.52-1.83), longer length of hospitalization (RR, 1.03; 95% CI, 1.01-1.04), and a higher risk for neurologic complications (RR, 1.51; 95% CI, 1.26-1.67); they were also more likely to undergo reoperation to treat bleeding (RR, 1.49; 95% CI, 1.09-1.72; Table 4). **Figure 2** shows the mortality each year in octogenarians and nonoctogenarians.

COMMENT

Open heart surgery in octogenarians has risen steadily since the 1980s. A number of factors justify this increase. Cane et al[8] have shown actuarial survival for octogenarians undergoing CABG that is comparable to that of the age-matched population. They concluded that octogenarians should be offered the opportunity for CABG "with the expectation of reasonable results and late survival that parallels their demographic group."[8(p1037)] Other investigators have noted that octogenarians enjoy a higher quality of life after undergoing CABG or valve surgery. For example, in their review of 68 octogenarians undergoing CABG or valve surgery, Kumar et al[9] found that approximately 85% of patients reported that, in retrospect, they definitely would have made the decision to undergo open heart surgery. This population also had postoperative improvement in NYHA functional class.

In a trial comparing invasive vs medical therapy in elderly patients with chronic symptomatic coronary artery disease, investigators found that those older than 75 years benefit more from revascularization than from medical therapy.[10] Their findings showed a significant reduction in major adverse cardiac events with revascularization; although patients had an immediate higher mortality, they subsequently had improved short-term survival. Similarly, Graham et al[11] found revascularization to be superior to optimal medical treatment: patients aged 80 years and older undergoing CABG had a 4-year survival rate of 77.4% compared with 60.3% in patients treated medically. In particular, these researchers noted improved 1-year survival in the subset of patients with left main coronary artery disease undergoing revascularization.

Because of ongoing evidence supporting revascularization in patients aged 80 years or older with coronary artery disease, it was our intent to evaluate the differences between octogenarians and nonoctogenarians undergoing CABG or valve replacement. In our experience, octogenarians had significantly higher NYHA functional class, prevalence of hypertension, and less body surface area. Octogenarians also had fewer instances of abnormal left ventricular hypertrophy and averaged fewer total number of grafts used than did nonoctogenarians. Although similar predictors of postoperative morbidity and mortality have been reported by some centers, no physiologic variables have been found to be universally predictive. Like other investigators, we found that octogenarians were at higher risk for postoperative death.[5,6,12] However, our results show that after controlling for differences between octogenarians and nonoctogenarians, age is an independent risk factor for morbidity and mortality.

Our finding raises some interesting questions. As previously reported, chronologic and physiologic age may not always match.[12] However, it is logical to assume that a person's overall health is a summation of his or her physiologic status. It would be reasonable to suggest that in our study we may have failed to recognize a physiologic variable predictive of postoperative outcome. Although Akins et al[5] did not show statistical significance, they noted improved survival in patients undergoing CABG when at least 1 internal mammary artery graft was used rather than only venous grafts. In our analysis, we did not include the type of graft used in calculating outcome differences. Certainly other physiologic variables that have not become manifest could explain outcome differences between the 2 age groups; alternatively, intangible characteristics might enable an octogenarian to do well after open heart surgery. Nevertheless, after controlling for known physiologic differences between the 2 groups in our study, age alone is clearly a predictor of postoperative morbidity and mortality.

As the younger population ages and life expectancy rises, an estimated 12 million Americans will swell the ranks of octogenarians by the year 2010.[13] An increasing number of octogenarians undergoing coronary revascularization or valve surgery are certain to strain an already burdened health care system. It is, therefore, incumbent on researchers to develop more refined algo-

rithms to predict postoperative outcomes. As this study indicates, age should be considered a component of any such algorithm.

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