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**Cardiac Surgery**

# Outcomes of Cardiac Surgery in Patients Age ≥80 Years: Results from the National Cardiovascular Network

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**OBJECTIVES** The purpose of this study was to evaluate characteristics and outcomes of patients age ≥80 undergoing cardiac surgery.

**BACKGROUND** Prior single-institution series have found high mortality rates in octogenarians after cardiac surgery. However, the major preoperative risk factors in this age group have not been identified. In addition, the additive risks in the elderly of valve replacement surgery at the time of bypass are unknown.

**METHODS** We report in-hospital morbidity and mortality in 67,764 patients (4,743 octogenarians) undergoing cardiac surgery at 22 centers in the National Cardiovascular Network. We examine the predictors of in-hospital mortality in octogenarians compared with those predictors in younger patients.

**RESULTS** Octogenarians undergoing cardiac surgery had fewer comorbid illnesses but higher disease severity and surgical urgency than younger patients. Octogenarians had significantly higher in-hospital mortality after cardiac surgery than younger patients: coronary artery bypass grafting (CABG) only (8.1% vs. 3.0%), CABG/aortic valve (10.1% vs. 7.9%), CABG/mitral valve (19.6% vs. 12.2%). In addition, they had twice the incidence of postoperative stroke and renal failure. The preoperative clinical factors predicting CABG mortality in the very elderly were quite similar to those for younger patients with age, emergency surgery and prior CABG being the powerful predictors of outcome in both age categories. Of note, elderly patients without significant comorbidity had in-hospital mortality rates of 4.2% after CABG, 7% after CABG with aortic valve replacement (CABG/AVR), and 18.2% after CABG with mitral valve replacement (CABG/MVR).

**CONCLUSIONS** Risks for octogenarians undergoing cardiac surgery are less than previously reported, especially for CABG only or CABG/AVR. In selected octogenarians without significant comorbidity, mortality approaches that seen in younger patients. (J Am Coll Cardiol 2000; 35:731–8) © 2000 by the American College of Cardiology

Thirteen million U.S. citizens are currently over age 75, and this number is expected to quadruple over the next 50 years (1). Because cardiovascular disease is the leading cause of morbidity and mortality in older people (2,3), the aging of the U.S. population has led to an increased number of elderly patients with symptomatic coronary artery disease considered for bypass surgery (4,5). In fact, bypass surgery performed in U.S. octogenarians has increased by 67% from 1987 to 1990 (6,7). A clear understanding of the risks and benefits involved is required for rational decisions regarding cardiac surgery in the elderly. Unfortunately, elderly patients have been significantly underrepresented in the randomized trials of revascularization for coronary disease.

Previous observational series of octogenarians undergoing bypass surgery have reported varied morbidity and mortality rates reflecting small sample sizes and divergent experiences at single institutions. For example, reported postoperative mortality ranges from 8% to 24%, postoperative stroke from 2% to 9%, and postoperative renal insufficiency from 2% to 13% (Table 1). Additionally, prior series were often underpowered to identify the major predictors of mortality after bypass surgery in the elderly and to determine the risk associated with concomitant valve replacement. Finally, as

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**Abbreviations and Acronyms**

| | |
|---|---|
| CABG | = coronary artery bypass grafting |
| CABG/AVR | = coronary artery bypass grafting with aortic valve replacement |
| CABG/MVR | = coronary artery bypass grafting with mitral valve replacement or repair |
| CHF | = congestive heart failure |
| COPD | = chronic obstructive pulmonary disease |
| LVEF | = left ventricular ejection fraction |
| MI | = myocardial infarction |
| NCN | = National Cardiovascular Network |
| NYHA | = New York Heart Association |

cardiac surgery is performed more often in elderly patients, we may see improved outcomes in current practice (4).

The goal of this study was to describe the characteristics and outcomes of the patients age ≥80 undergoing coronary artery bypass grafting (CABG) alone or with an associated valve surgery across 22 high volume centers between 1994 and 1998. We also identified the major clinical predictors of postbypass mortality and determined whether these risk factors varied with age. Finally, we described outcomes in those very elderly patients without comorbidity undergoing cardiac surgery.

## METHODS

**Study population.** The National Cardiovascular Network (NCN) revascularization database is a collaboration among 22 U.S. high volume academic and nonacademic centers that voluntarily submit data on all patients at their centers who undergo coronary angioplasty or cardiac surgery (CABG or CABG with valve surgery; sites are listed in the Appendix). Our population consisted of the 64,467 patients who underwent CABG alone (n = 22 sites) and the 3,297 patients who underwent CABG in conjunction with aortic valve replacement (CABG/AVR) or CABG in conjunction with mitral valve repair or replacement (CABG/MVR) surgery (n = 12 sites) between January 1994 through December 1997. Sites contributed similar numbers of patients to the total population with a median contribution per site of 5% (range 0.6% and 10%). Patients were excluded from the study population if they had missing mortality data (n = 136) or unspecified type of valve surgery (n = 186).

**Data collection.** The NCN database includes administrative data, demographics, risk factors, cardiac history, procedural data and outcome data. Designated personnel familiar with NCN clinical and outcome definitions were responsible for collecting data at each site. Each site then submitted their data semiannually to the NCN Data Coordinating Center at Duke University Medical Center. Personnel in the NCN Coordinating Center confirmed data integrity and variable consistency across sites.

**Data definitions.** Definitions specified in the NCN coding dictionary for postoperative outcomes refer to in-hospital adverse events. Postoperative neurologic complications included stroke, transient ischemic attacks or coma. Postoperative renal failure included acute renal failure (oliguria with a postoperative rise in blood urea nitrogen of >10 mg/dl and creatinine of >1 mg/dl) or the initiation of dialysis. Postoperative myocardial infarction (MI) was defined by new Q-waves in 2 or more precordial leads on the postoperative 12-lead electrocardiogram. Complete revascularization was identified if the number of distal anastomoses were equal to or greater than the number of diseased territories to a maximum of three.

**Data analysis.** The primary analysis determined the relationship between patient age, surgical procedure and in-hospital outcomes. First, we divided our population into two age categories (age <80, age ≥80) and then into three surgical categories (CABG only, CABG/AVR, CABG/MVR). Baseline demographic, clinical and procedural characteristics are presented as means with standard deviations for continuous variables and percentages for dichotomous variables for each of these six groups. All statistical comparisons are made across age category (age <80 or age ≥80) using the chi-square test or $t$ test where appropriate.

We present postoperative in-hospital outcomes (including mortality, all neurologic complications, stroke, renal failure, MI and postprocedural length of stay) in two ways. First, these outcomes were presented for patients undergo-

**Table 1.** Prior Series Reporting Postoperative Mortality and Complications in Octogenarians After CABG

| | Year | n | Stroke | Renal Insufficiency | In-hospital Mortality |
|---|---|---|---|---|---|
| Mayo Clinic—Mullany (5) | 1977–1989 | 159 | 4% | — | 10.7% |
| U Penn—Edmunds (8) | 1976–1987 | 41 | — | — | 24.0%† |
| Emory—Weintraub (9) | 1978–1989 | 154 | 5% | — | 10.4% |
| St. Louis—Naunheim (10) | 1980–1989 | 71 | — | — | 13.0% |
| Duke—Glower (11) | 1983–1991 | 86 | 9% | 5% | 13.9% |
| NY/Cornell—Ko (12) | 1985–1989 | 100 | 3% | 2%* | 12.0% |
| Mt. Sinai—Williams (13) | 1989–1994 | 300 | 2% | 13% | 11.0% |
| Medicare—Peterson (14) | 1987–1990 | 24,461 | — | — | 11.5% |
| NY State—Hannan (15) | 1991–1992 | 1,372 | — | — | 8.3% |

*Incidence of hemodialysis only; †90 day postoperative mortality.

ing CABG only and CABG with associated valve surgery separately by age category. Differences in outcomes across age category were tested for statistical significance. We also clarify the relationship between age and outcome (mortality, neurologic events and renal failure) by displaying outcome plotted by five-year age groups subsequently connected by trend lines for patients undergoing CABG only.

We examined the relationship between clinical risk factors, including age and in-hospital mortality for the CABG only population. Using multivariable logistic regression, we developed a model for the prediction of in-hospital mortality using the entire population undergoing CABG only. We excluded those patients with more than two missing variables leaving 88% of the CABG patients (n = 56,890) for our model development. For patients in the multivariable analysis missing one or two variables, categorical variables were assumed to be absent and continuous variables were imputed to the median. We included variables identified to be major clinical predictors in other models and variables identified as univariate predictors with significance levels of less than 0.01 in our population (3,7,10,12–14). Those variables included in the final model had significance at the level of 0.05. The c-index, or area under the receiver operator characteristic curve, is displayed for this model developed in the overall population and for the model when applied to both the young (age <80) and elderly (age ≥80) age groups. The odds ratios and 95% confidence intervals for the multivariable predictors are displayed by each age category. Finally, in order to determine whether variables in the model predicted differently by age group, we tested the significance of age-interaction terms for each variable. In addition, we tested the significance of a continuous variable for years of age ≥80 in the overall model.

Last, we displayed in-hospital mortality by age for each surgical type (CABG only, CABG/AVR, CABG/MVR) for patients without significant comorbidities. These comorbidities were those identified as independent risk factors for mortality from our model. These included: left ventricular ejection fraction (LVEF) of <35%, prior CABG, history of congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), vascular disease, renal insufficiency, MI within 21 days and emergency surgery. By eliminating patients with these selected comorbidities, we provide actual mortality rates for the 'best case scenario' by age category and surgical type.

## RESULTS

**Demographic and operative characteristics.** Our population was divided into six groups: CABG only (age <80: n = 60,161 and age ≥80: n = 4,306), CABG/AVR (age <80: n = 1,690, age ≥80: n = 345) and CABG/MVR (age <80: n = 1,170, age ≥80: n = 92). The mean age of patients age ≥80 undergoing CABG only was 82.4 years, and the mean age for the younger patients was 63.7 years (Table 2). A large majority (89%) of our elderly population (age ≥80) were at or between the ages of 80 and 85 (n =4,227), 11% were at or between the ages of 86 and 89 (n = 501) and exactly 15 patients were 90 years old. There were no patients older than age 90 in our population.

The octogenarians were more frequently female and typically smaller. They also had more renal insufficiency and vascular disease than younger patients but a similar rate of hypertension. Octogenarians had more Canadian Cardiovascular class III or IV angina and New York Heart Association (NYHA) class III or IV heart failure at the time of their surgery. In addition, octogenarians had more extensive coronary artery disease at the time of their bypass than younger patients but did not differ significantly from younger patients in their preoperative LVEF. In contrast, octogenarians were less likely to have COPD, diabetes or prior revascularizations than younger patients. Similar age-related differences in baseline characteristics were seen for patients undergoing CABG with valve surgery (Table 2).

As expected, there were also significant differences in procedural characteristics across age category (Table 3). Within our population, patients age ≥80 were twice as likely to have combined CABG/valve surgery compared with the younger patients in our population (9% combined CABG/valve vs. 4.5% combined CABG/valve, p = 0.001). They more frequently had preoperative shock, required preoperative left ventricular assist devices and had their surgery under emergency circumstances.

Octogenarians had shorter cross clamp and bypass times regardless of whether CABG was performed with or without valve surgery, which may reflect less frequent use of internal mammary artery grafts in octogenarians (58.7% vs. 80%, p = 0.001). We compared the number of distal anastomoses to the number of diseased vessels to determine the completeness of revascularization and found only a slight trend toward less complete revascularization in octogenarians undergoing combined CABG/valve surgery. We found no differences in the absolute number of distal anastomoses although patients undergoing combined CABG/valve surgery had fewer anastomoses than did patients undergoing CABG alone, regardless of age.

**Operative mortality and morbidity.** After CABG, octogenarians had a significantly higher operative mortality than did younger patients did (8.1% vs. 3%, p < 0.001, Table 4). For descriptive purposes, we present mortality divided by categorical age (age <80 and age ≥80) although mortality after cardiac surgery rises in a linear fashion with advancing age as shown in Figure 1. Combined CABG/valve surgery is associated with higher mortality and complications than CABG only (Table 4), with octogenarians continuing to have a higher mortality rate than younger patients with either procedure: CABG/AVR (10.1% vs. 7.9%, p < 0.001), CABG/MVR (19.6% vs. 12.2%, p < 0.001). Although combining AVR with CABG surgery increased mortality by about 3% across all ages, combining MVR with

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**Table 2.** Baseline Characteristics of Patients Undergoing Cardiac Surgery by Age Category

| | CABG | | CABG/AVR | | CABG/MVR | |
|---|---|---|---|---|---|---|
| | Age <80 n = 60,161 | Age ≥80 n = 4,306 | Age <80 n = 1,690 | Age ≥80 n = 345 | Age <80 n = 1,170 | Age ≥80 n = 92 |
| Age (yrs)† | 63.7 ± 9.9 | 82.4 ± 2.3 | 68.2 ± 9.1 | 82.7 ± 2.3 | 67.7 ± 8.6 | 82.4 ± 2.0 |
| Gender (% female) | 28.2% | 44.1%* | 30.7% | 43.8%* | 48% | 43.5% |
| BMI < 22 kg/m$^2$ | 7.0% | 15.8%* | 10.3% | 19.1%* | 16.2% | 27.3%* |
| Hypertension | 61.5% | 62.6% | 62.0% | 62.1% | 60.2% | 65.2% |
| COPD | 16.0% | 14.1%* | 18.2% | 15.0% | 20.8% | 21.4% |
| Diabetes | 29.5% | 23.0%* | 24.4% | 15.9%* | 27.6% | 15.4%* |
| Renal insufficiency | 4.8% | 8.0%* | 7.4% | 8.5% | 10.9% | 10.3% |
| Dialysis | 0.7% | 0.5% | 1.2% | 0.6% | 2.1% | 1.2% |
| History of CHF | 11.7% | 19.4%* | 38.6% | 48.7%* | 60.8% | 68.4% |
| Cerebrovascular disease | 10.4% | 18.7%* | 13.9% | 17.6% | 16.3% | 17.7% |
| Peripheral vascular disease | 13.7% | 16.4%* | 13.2% | 15.2% | 14.3% | 8.6% |
| Prior PTCA | 22.1% | 15.6%* | 11.5% | 8.4% | 14.6% | 5.3%* |
| Prior CABG | 9.3% | 6.8%* | 10.2% | 8.7% | 11.5% | 12.1% |
| CCS angina III–IV | 83.4% | 86.3%* | 77.4% | 75.7% | 81.1% | 85.3% |
| NYHA class III–IV | 9.8% | 16.6%* | 27.4% | 33.7%* | 48.7% | 54.4% |
| MI ≤ 21 days | 24.1% | 25.3% | 13.3% | 14.2% | 34.4% | 33.7% |
| Left main stenosis | 32.7% | 43.8%* | 18.7% | 32.9%* | 23.5% | 28.9%* |
| 3 vessel CAD | 64.3% | 70.4%* | 32.4% | 40.5%* | 46.9% | 47.8% |
| Moderate–severe MR | 2.2% | 4.8%* | 4.5% | 5.6% | 61.5% | 69.8% |
| LVEF† | 48.6 ± 13.1 | 48.3 ± 13.0 | 47. ± 13.1 | 49. ± 13.4* | 41.9 ± 13.7 | 43.2 ± 14.3 |

*$p < 0.05$ for comparison by age; †mean ± SD.
AVR = aortic valve replacement; CABG = coronary artery bypass grafting; CAD = coronary artery disease; CCS = Canadian Cardiovascular Society; COPD = chronic obstructive pulmonary disease; LVEF = left ventricular ejection fraction; MI = myocardial infarction; MR = mitral regurgitation; MVR = mitral valve repair or replacement; NYHA = New York Heart Association; PTCA = percutaneous transluminal coronary angioplasty.

CABG more significantly increases mortality compared with CABG alone, especially in octogenarians (Fig. 1).

Among octogenarians selected for the absence of significant comorbidity undergoing cardiac surgery, mortality was close to that of the general population of younger patients. To provide clinicians with an estimate of the 'best case scenario' for these procedures in octogenarians, we present the actual mortality rates in our population for elective procedures without significant comorbidity. This selected subset of octogenarians had a 4.2% mortality with CABG only, 7% mortality with CABG/AVR and 18.2% mortality with CABG/MVR. The number of octogenarians without significant comorbidity having CABG/MVR was quite small (n = 11) and few conclusions can be made regarding their outcomes. The mortality rates for CABG only and CABG/AVR, however, are comparable with outcomes in younger patients overall.

Postoperative neurologic and renal complications occur twice as often in octogenarians as in younger patients, and elderly patients also have more postoperative MIs although these were infrequent (Table 4). As shown in Figure 2, postoperative neurologic events and postoperative renal

**Table 3.** Procedural Characteristics of Cardiac Surgery by Age Category

| | CABG Only | | CABG/AVR | | CABG/MVR | |
|---|---|---|---|---|---|---|
| | Age <80 n = 60,161 | Age ≥80 n = 4,306 | Age <80 n = 1,690 | Age ≥80 n = 345 | Age <80 n = 1,170 | Age ≥80 n = 92 |
| Shock/emerg/assist† | 10.3% | 11.7%* | 6.6% | 6.1% | 15.9% | 19.6% |
| IMA grafts | 80.0% | 58.7%* | 44.0% | 25.9%* | 41.5% | 20.3%* |
| Cross clamp (min)‡ | 57.9 ± 27.0 | 55.4 ± 26.0* | 100.4 ± 39.4 | 95.9 ± 37.6* | 105.6 ± 42.2 | 91.1 ± 39.1* |
| Bypass time (min)‡ | 95.9 ± 95.6 | 93.6 ± 38.7* | 147.6 ± 55.0 | 142.4 ± 48.1 | 160.9 ± 58.1 | 146.7 ± 47.3* |
| Distal anastomoses | 3.4 ± 1.3 | 3.5 ± 1.2 | 2.3 ± 1.2 | 2.4 ± 1.2 | 2.7 ± 1.4 | 2.7 ± 1.3 |
| Complete revasc§ | 93.6% | 93.6% | 92.2% | 89.6%* | 93.3% | 88.6% |
| Mechanical support | 4.9% | 6.8%* | 9.0% | 10.9% | 17.0% | 19.1% |

*$p < 0.05$; †Shock/emerg/assist = preoperative shock, preoperative hemodynamic assist device or emergency procedure; ‡mean ± SD; §complete revascularization includes patients without prior CABG who have number of distal anastomoses equal to number of diseased vessels to a maximum of three.
AVR = aortic valve replacement; CABG = coronary artery bypass grafting; IMA = internal mammary artery; LV = left ventricular; MVR = mitral valve repair or replacement.

**Table 4.** Outcomes of Cardiac Surgery by Age Category

| | CABG Only | | CABG/AVR | | CABG/MVR | |
|---|---|---|---|---|---|---|
| **All Patients** | **Age <80 n = 60,161** | **Age ≥80 n = 4,306** | **Age <80 n = 1,690** | **Age ≥80 n = 345** | **Age <80 n = 1,170** | **Age ≥80 n = 92** |
| In-hospital mortality | 3.0% | 8.1%* | 7.9% | 10.1% | 12.2% | 19.6%* |
| (95% CI) | (2.9–3.2) | (7.3–8.9) | (6.6–9.2) | (6.9–13.4) | (10.3–14.1) | (3.5–10.8) |
| All neurologic events (stroke, TIA, coma) | 4.2% | 10.2%* | 9.1% | 15.2%* | 11.2% | 22.5%* |
| Stroke only | 1.8% | 3.9%* | 3.2% | 4.9% | 4.7% | 8.8% |
| Renal failure | 2.9% | 6.9%* | 6.8% | 12.1%* | 11.4% | 25.0%* |
| Perioperative MI | 1.7% | 2.5%* | 2.0% | 3.0% | 2.7% | 1.5% |
| PLOS days‡ | 6 (5,8) | 7 (6,11)* | 7 (5,10) | 9 (6,15)* | 9 (6,14) | 11 (7,19) |
| **Patients w/o Comorbidity† (% of population)** | **n = 24,811 (41.2%)** | **n = 1,588 (36.9%)** | **n = 571 (33.8%)** | **n = 100 (29.0%)** | **n = 196 (16.8%)** | **n = 11 (12.0%)** |
| In-hospital mortality | 1.1% | 4.2%* | 4.0% | 7.0% | 7.1% | 18.2% |
| (95% CI) | (1.0–1.3) | (3.2–5.2) | (2.4–5.7) | (1.9–12.1) | (3.5–10.8) | n/a |

*$p < 0.05$ for comparison by age category; †subset of patients without significant comorbidity: EF <35%, prior CABG, Hx CHF, COPD, vascular disease, renal insufficiency, MI within 21 days or emergency surgery (see Methods section); ‡median and 25th and 75th quartiles.

AVR = aortic valve repair; CABG = coronary artery bypass grafting; MI = myocardial infarction; MVR = mitral valve repair or replacement; PLOS = postprocedural length of stay.

failure both increase with advancing age in a similar fashion to in-hospital mortality, with the greatest rise occurring after age 75. The rate of postoperative stroke in octogenarians after CABG was 3.9%, after CABG/AVR was 4.9% but increased to 8.8% after CABG/MVR. Likewise, the rate of postoperative renal failure in octogenarians after CABG was 6.9% and increased to 12.1% after CABG/AVR and 25% after CABG/MVR.

Finally, postprocedural length of stay increased slightly with age and associated valve surgery. Octogenarians had a median postoperative length of stay of seven days after CABG compared with six days in younger patients ($p < 0.001$).

**Predictors of in-hospital mortality.** We performed multivariate logistic regression to identify the major variables with independent prediction for in-hospital mortality. These variables are listed in Table 5 in order of descending chi-square (overall model c-index = 0.77). We found that young and old patients share many predictors of mortality following CABG. Variables that were similarly predictive in both age groups included gender, hypertension, emergency procedure, recent MI and ejection fraction. Although octogenarians with prior CABG and COPD less frequently undergo cardiac surgery, these variables carry higher odds of death in those who do. Younger patients had higher odds

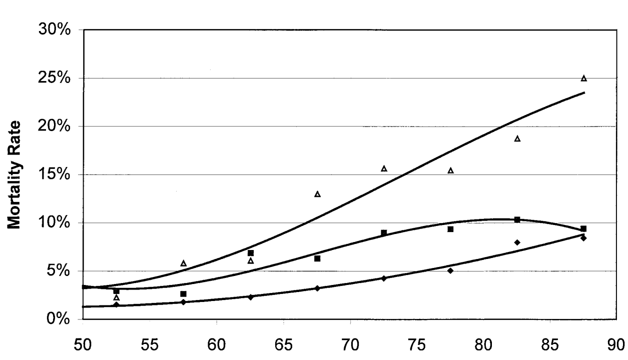


**Figure 1.** Observed in-hospital mortality after cardiac surgery among all patients. **Diamond** = CABG; **solid square** = CABG/AVR; **triangle** = CABG/MVR. AVR = aortic valve replacement; CABG = coronary artery bypass grafting; MVR = mitral valve repair or replacement.

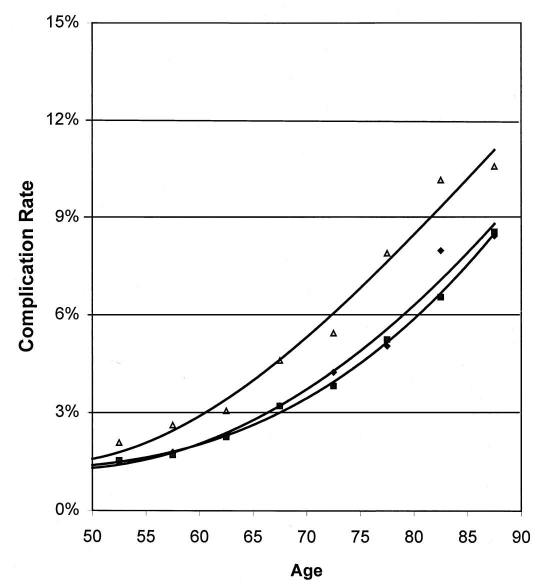


**Figure 2.** In-hospital mortality, postoperative neurologic complications and postoperative renal failure after CABG by age. **Diamond** = mortality; **square** = renal failure; **triangle** = Neurologic events.

**Table 5.** Multivariate Logistic Regression Model for the Prediction of In-Hospital Mortality After CABG in Order of Descending Chi-Square

| | Age <80 | | Age ≥80 | |
|---|---|---|---|---|
| | **Odds Ratio** | **95% CI** | **Odds Ratio** | **95% CI** |
| Shock/emerg/assist† | 3.5 | 3.1–3.9 | 3.6 | 2.8–4.8 |
| Age (per 5 yrs) | 1.2 | 1.2–1.3 | 1.2 | 0.9–1.6 |
| Prior CABG | 2.9 | 2.5–3.3 | 3.3 | 2.1–4.5 |
| Vascular disease | 1.8 | 1.6–2.0 | 1.5 | 1.2–1.9 |
| History of CHF | 1.8 | 1.6–2.1 | 1.4 | 1.0–1.9 |
| Renal insufficiency | 2.1 | 1.8–2.5 | 1.4 | 0.9–2.1 |
| Women | 1.5 | 1.4–1.7 | 1.5 | 1.2–1.9 |
| Renal dialysis | 3.8 | 2.7–5.3 | 1.5 | 0.2–1.7 |
| LVEF (per 10% decline) | 1.2 | 1.1–1.2 | 1.1 | 1.0–1.3 |
| COPD | 1.3 | 1.2–1.5 | 1.7 | 1.2–2.3 |
| MI ≤ 21 days | 1.3 | 1.1–1.4 | 1.3 | 1.0–1.7 |
| C-Index | 0.77 | | 0.71 | |

*All p values <0.01; †shock/emerg/assist = preoperative shock, preoperative hemodynamic assist device or emergency procedure.
CABG = coronary artery bypass grafting; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; LVEF = left ventricular ejection fraction; MI = myocardial infarction.

ratios for heart failure class and renal insufficiency. Although not in the final model, placement of an internal mammary artery graft was a univariate predictor for lower short-term mortality in both young and old (odds ratio 0.5 vs. 0.7). It is important to note, however, that the qualitative predictive importance of all variables was similar in both age groups.

We added a continuous age variable (years of age ≥80) to the model shown in Table 5 to determine whether the effect of age accelerated after 80 and found that it did not have independent predictive ability after accounting for the other variables (years of age ≥80; chi-square = 2.0, p = 0.16). Finally, we tested each variable in the model for interaction with age to determine whether these variables predicted differently across the range of age. We found no significant age interaction with the variables listed in Table 5.

## DISCUSSION

This study represents the largest contemporary multicenter clinical series of octogenarians undergoing cardiac surgery, either CABG or combined CABG/valve surgery. Because of its size, we have been able to examine the risks associated with cardiac surgery in the very elderly and to identify the clinical predictors of mortality following CABG. Most importantly, we found that predictors of in-hospital mortality are very similar in both the young and old. In addition, we found that while octogenarians continue to have higher morbidity and mortality after cardiac surgery than younger patients, compared with prior series, the gap in mortality between young and old appears to be more narrow than previously reported.

**Comparison with prior series.** Mortality in octogenarians after CABG has been reported to range from 8% to 24%, but these reports were frequently limited to the experience of a small numbers of patients at a single institution. The largest prior series used Medicare data and reported a mortality of 11.5% for the years 1987 to 1990 for CABG only patients (4). Our population of octogenarians undergoing surgery from 1994 to 1997 had a lower mortality (8.1%) compared with this and most other series.

Combined CABG/valve surgery adds to mortality risk. One prior report of CABG/AVR in 149 octogenarians showed a mortality of 11.4% (16). The 345 octogenarians undergoing CABG/AVR in our study had a mortality of 10.1%, and those 100 without significant comorbidity had a mortality of 7%. Whereas AVR appears to increase mortality by the same amount across age category, MVR adds increasingly to operative mortality risk with advancing age. However, a relatively small number of octogenarians undergo CABG/MVR, so our conclusions about outcomes in this group must be considered preliminary. This worse outcome may reflect the fact that patients with mitral valve disease have depressed ventricular function that is an additive insult to the lower physiologic reserve of elderly patients. Thus, although bypass surgery in elderly patients is associated with favorable outcomes, combined CABG/valve surgery is associated with significantly higher risks.

Postoperative morbidity such as renal failure and neurologic complications were somewhat lower in our series than reported earlier. For example, we found a 6.9% incidence of renal failure in octogenarians after bypass surgery compared with previously reported rates of 2% to 13% (17). Prior reports indicated that the rate of postoperative stroke in patients of all ages is 3.1% and in octogenarians ranged from 2% to 9% (18). Our 3.9% incidence of stroke in octogenarians is comparable with previous studies.

The overall improvement in outcomes may be due to better selection of very elderly patients undergoing surgery or to the increased experience and skill acquired by operating on more octogenarians over time. In terms of patient selection, consistent with prior series, the octogenarians in our study had less diabetes, COPD and prior revascularization but higher disease acuteness and severity than younger patients (19). This selection appears to be evidence-based, given the higher risk of mortality associated with COPD and prior CABG in octogenarians. However, in general, our octogenarians appear to be at least as sick as those in earlier series. For example, compared with other series, our population had more diabetes, hypertension, three-vessel disease and left main disease, renal failure and prior bypass surgery (13,20). Therefore, although octogenarians undergoing cardiac surgery continue to be a carefully selected group, it seems unlikely that the lower mortality seen in our population is explained solely by improved selection.

In terms of process of care, our octogenarians received more internal mammary artery grafts than in prior reports (58.7% vs. 33%), which may be evidence of a trend towards more aggressive operative strategies in older patients (21). The use of IMA grafts was associated with better short-term outcome in our series and others and may partly explain the improved outcomes seen (7). Octogenarians had a similar number of distal anastomoses and complete revascularization as younger patients.

**Clinical predictors of mortality.** For patients of any age, the variables that were independent predictors of mortality in patients following CABG were age, gender, prior CABG, vascular disease, COPD, history of CHF, shock or emergency procedure, ejection fraction, renal insufficiency or dialysis and preoperative MI. We compared the predictors of in-hospital mortality after CABG in the young and old. We found some variability in the odds ratios associated with these variables but no differences in their overall prognostic significance. Consistent with prior series, major risk factors that were predictive across age were measures of disease acuity and left ventricular function (recent MI, shock, NYHA class III to IV, LVEF, prior CABG). However, unlike other series, measures of coronary disease severity (three-vessel disease, left main disease), and comorbid illness (diabetes, hypertension, vascular disease) were less predictive of mortality in our octogenarians (8,9,12,18,22). Finally, age was among the most powerful predictors of outcome in both young and old after adjusting for other known risk factors. Overall, the model was less able to distinguish which elderly patients were likely to die after surgery, perhaps because there are other factors besides those included in our model that explain this outcome in octogenarians.

**Study limitations.** While the NCN data have the advantage of having a significant amount of detail, data are submitted voluntarily. The outcomes were limited to in-hospital events and do not reflect the morbidity or mortality after hospital discharge. In addition, the explanatory power of risk factors may be affected by treatment selection bias that is inherent in any observational study. For example, older patients with severe comorbidity may not undergo bypass surgery. This may diminish the power of risk factors in the elderly. The categorical nature of the variables does not take into account variation in disease severity that may vary by age. Also, although the variables in our model are similar to those in other CABG mortality models, there may be other variables that explain some of the additional variation in elderly mortality. Although every clinician realizes the important contribution of "physiologic age" to patient outcome, this can not be quantified or included in a model. Finally, since the NCN data represent the experience in 22 high volume medical centers, the extrapolation of these outcomes to those at lower volume centers must be done with caution.

**Conclusions.** This large clinical series provides a profile of octogenarians currently undergoing cardiac surgery and their associated outcomes. We found that the major clinical predictors of mortality were largely the same in octogenarians as in younger patients. In addition, while the relationship between age and in-hospital mortality appears to be nearly linear, the gap between mortality in the young and old after CABG is smaller than previously thought, especially for CABG and CABG/AVR. Because these data are observational, we cannot answer the question of which elderly patients have the most to gain and should be referred for bypass surgery. The physician and the octogenarian patient must continue to answer this question on an individual basis.

## APPENDIX

*NCN Participating Centers:*

Albany Medical Center, Albany, NY; Abbott-Northwestern, Minneapolis, MN; Bryan Memorial Hospital, Lincoln, NE; Duke University Medical Center, Durham, NC; EHS Good Samaritan, Downers Grove, IL; Emory Heart Center, Atlanta, GA; Florida Hospital Medical Center, Orlando, FL; Hillcrest Medical Center, Tulsa, OK; Indiana Heart Institute, Indianapolis, IN; Jewish Hospital, Louisville, KY; Jersey Shore Medical Center, Neptune, NJ; Methodist Heart Institute, Memphis, TN; New England Medical, Boston, MA; Ohio State University, Columbus, OH; Shadyside Hospital, Pittsburgh, PA; St. Dominic's Hospital, Jackson, MS; St. John's Hospital, Springfield, IL; St. Louis University, St. Louis, MO; St. Luke's Medical, Milwaukee, WI; St. Vincent Infirmary, Little Rock, AR; Maine Medical Center, Portland, ME; William Beaumont, Royal Oak, MI.

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