Coronary artery bypass graft surgery in the elderly

Indications and outcome

Floyd D. Loop, MD
Bruce W. Lytle, MD
Delos M. Cosgrove, MD
Marlene Goormastic, MPH
Paul C. Taylor, MD
Leonard A. R. Golding, MD
Robert W. Stewart, MD
Carl C. Gill, MD

A total of 5,070 patients 65 years of age or older underwent primary elective coronary bypass surgery at The Cleveland Clinic Foundation from January 1976 through June 1986. These patients were divided by age into two groups, 65–74 years of age and 75 years and older; these groups were compared with each other and with patients younger than 65 years. With advancing age, there was a significantly greater prevalence of women, more severe angina, diabetes, peripheral vascular disease, previous cerebral events, cardiac enlargement, and left main coronary artery disease. Overall mortality during hospitalization was 2.3% and rose progressively with advancing age. Variables predictive of higher operative mortality included age ≥75 years, cigarette smoking, left ventricular impairment, and female gender. Perioperative myocardial infarction and wound complications showed no correlation with age, but other morbidity occurred more frequently in older patients. Stroke was more common over age 65, and postoperative atrial fibrillation rose significantly with advancing age. After a mean follow-up of 91 months, angina relief was better in the elderly than among their younger counterparts ($P = 0.0001$), and vein and arterial graft patency were comparable. The 10-year actuarial survival was 64% for ages 65–74 and the eight-year survival for patients 75 or older was 53%. Successful bypass surgery among the elderly conferred consistent angina relief and longevity that exceeds that of the U.S. population, matched for age and gender.

Index term: Aortocoronary bypass

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Coronary heart disease is the most prevalent form of cardiovascular disease, and chronologic age is the greatest determinant of risk for coronary atherosclerosis.[1] Cur-

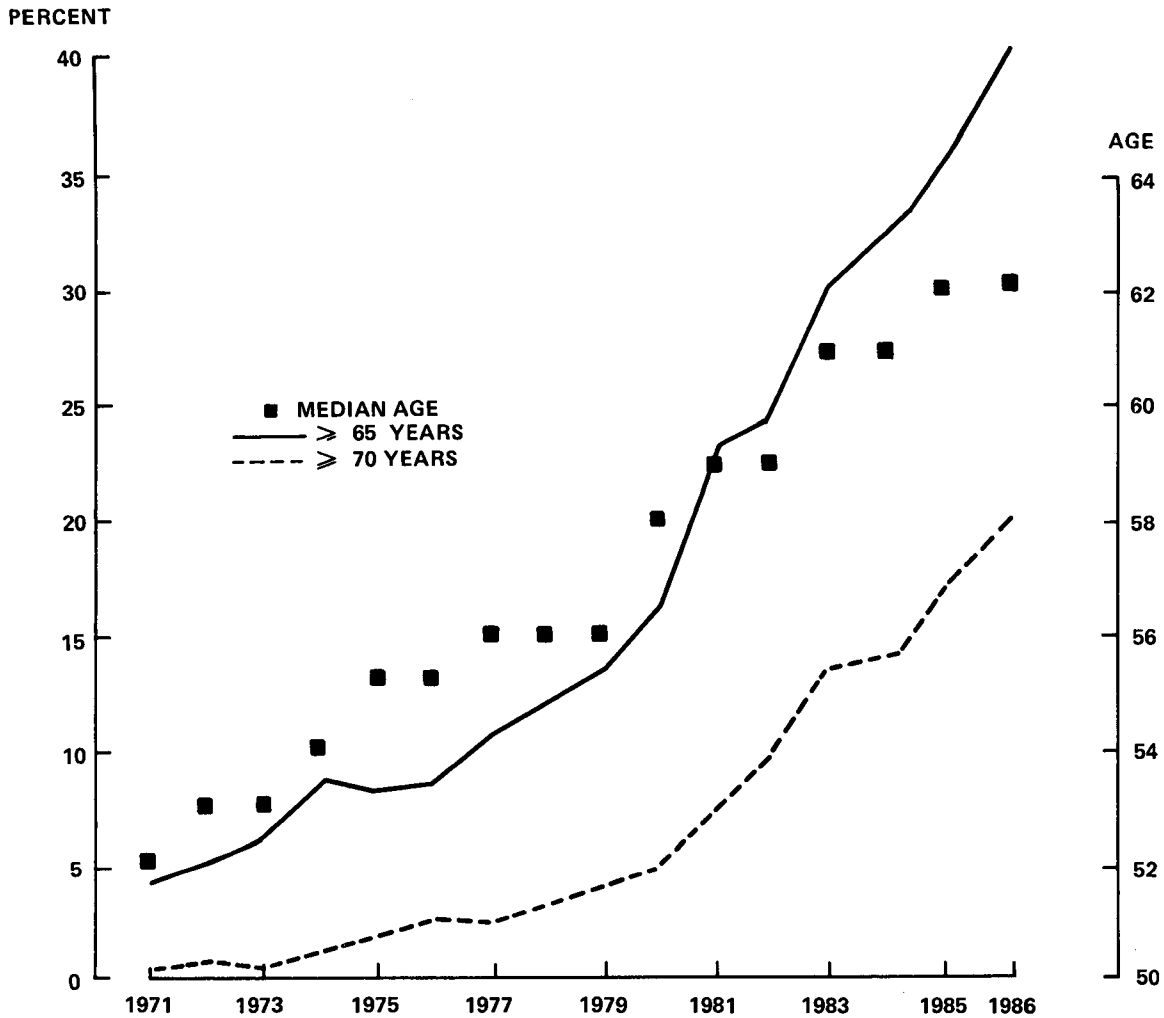

Fig. 1. The median age of patients who underwent isolated bypass surgery in 1986 was 62 years. The rising population of surgical candidates above age 65 now exceeds 40% of our surgical volume. There has been a similar rise in the population above age 70, which now exceeds 20% of our surgical bypass patients.

rently, more than half of all hospitalized acute myocardial infarction patients (approximately 380,000 of a total of 681,000) are age 65 years or older.[2] This age group constitutes about 12% of the entire patient population, but utilizes about 30% of health care funds and resources.[3] Average life expectancy in 1986 reached a high of 74.9 years. The United States Bureau of the Census estimates the number of people age 65 and older will rise from 28.6 million in 1985 to 34.9 million by 2000, and 64.6 million by 2030. The number of people age 85 and older is expected to triple, from 2.7 million in 1985 to 8.6 million in 2030.

Increasingly older patients are referred for bypass surgery. In 1967, the median age of our coronary artery bypass patients was 50 years; in 1986, the median age was 62 years, and 40% of those patients were older than 65 years (*Fig. 1*). Other than the skill of the surgical team, advanced age is the single most determinative risk of operative mortality and morbidity, and figures significantly in the length of hospital stay.[4]

In some patients, successful coronary artery surgery may improve symptoms or alleviate angina altogether, and even extend longevity. In other instances, the elderly and particularly the very elderly may be subjected to impractical and sometimes dangerous investigations and treatment. Indications for and results of surgical treatment must be reviewed to ascertain which patients may benefit. Discriminative application of expensive technologic interventions deserves periodic review.

Table 1. Baseline variables in elderly and nonelderly groups (1976–1986)

	Age groups			
	<65 (%)	65–74 (%)	≥75 (%)	*P* value
Patients	17,996	4,603	467	
Women	2,309 (13)	1,074 (23)	134 (29)	<0.0001
Moderate-severe angina	11,658 (65)	3,086 (67)	329 (71)	<0.0001
Hypertension > 140/90 on admission	4,350 (24)	1,121 (24)	91 (20)	0.06
Diabetes	1,611 (9)	569 (13)	60 (13)	<0.0001
Peripheral vascular disease	2,353 (13)	1,233 (27)	167 (36)	<0.0001
Prior cerebral event	407 (2)	223 (5)	33 (7)	<0.0001
Cigarette smoking	9,269 (53)	1,318 (29)	87 (19)	<0.0001
Cardiac enlargement	1,164 (7)	638 (14)	89 (19)	<0.0001
Multivessel coronary disease (excluding left main coronary artery)	14,182 (79)	3,567 (78)	346 (74)	
Left main coronary artery	1,925 (11)	751 (16)	102 (22)	<0.0001
Abnormal left ventricular performance	9,640 (54)	2,503 (54)	271 (58)	0.11

Table 2. Postoperative complications in elderly and nonelderly (1976–1986)

	Age groups			
Morbidity (%)	<65 (n = 17,996)	65–74 (n = 4,603)	≥75 (n = 467)	*P* value
Death*	132 (0.7)	94 (2.0)	22 (4.7)	<0.001
Stroke	174 (1.0)	126 (2.7)	11 (2.4)	<0.001
Myocardial infarction	237 (1.3)	47 (1.0)	6 (1.3)	0.27
Reopen for bleeding	636 (3.5)	221 (4.8)	30 (6.4)	<0.001
Respiratory distress	188 (1.0)	120 (2.6)	20 (4.3)	<0.001
Wound complication	138 (0.8)	48 (1.0)	5 (1.1)	0.15
Renal failure	44 (0.2)	41 (0.9)	8 (1.7)	<0.001

* Operative (hospital) mortality

The Cleveland Clinic experience

Baseline variables

We surveyed our January 1976 through June 1986 experience with isolated primary elective coronary bypass surgery in 5,070 patients over the age of 65, categorizing elderly patients into two groups: 65–74 years and 75 years and older. Whenever possible, we have compared the elderly patients with patients younger than 65 years. Baseline data obtained from our cardiovascular information registry are shown in *Table 1.* Note that as age advances, women are seen with increasing frequency. Moderate-to-severe angina including acute ischemic syndromes, which corresponds with Canadian Heart Classes II–IV, tends to occur more frequently in older patients than in those younger than 65 years. For the years under survey, hypertension was defined as blood pressure >140/90 mmHg recorded at hospital admission; a history of hypertension or drug treatment for hypertension was not included. Diabetes requiring insulin treatment, peripheral vascular disease, and previous cerebral events were found significantly more often among the elderly than in patients younger than age 65. Cigarette smoking was less prevalent among the elderly. Cardiac enlargement, as observed on a chest radiograph, was significantly more frequent among the elderly than among the younger patients. Although the occurrence of severe multivessel disease was not significantly different among age groups, left main coronary artery disease was found with twice the frequency in patients over age 75, compared with patients younger than age 65. Abnormal left ventricular contraction was found in more than half of patients in all age groups. The mean number of grafts per patient was 3.1.

Mortality and morbidity

The mortality and major complications for patients younger than 65 years, 65–74 years, and ≥75 years are shown in *Table 2.* Overall operative (hospital) mortality was 2.3%. No year-by-year trends emerged except that operative mortality

Table 3. Univariate survival analysis

Variable	*P* value
Left ventricular contraction (LVF) (normal/mild, moderate/severe)	0.0006
LVF (normal, any impairment)	0.0002
Number of vessels narrowed ≥50% (single, double, triple, LMT)	0.07
Left main coronary artery (narrowed ≥50% or narrowed < 50%)	0.03
Age (65–74, ≥75)	0.0001
Gender	0.55
Hypertension (none, systolic > 139 and diastolic >89	0.65
Cigarette smoking (yes, no)	0.0001
Diabetes (yes, no)	0.0002
Documented peripheral vascular disease (yes, no)	0.0001
Preoperative myocardial infarction (MI) by history/EKG (yes, no)	0.0005
Angina (yes, no)	0.03
Cardiac enlargement (yes, no)	0.0001
Internal thoracic (mammary) artery graft (yes, no)	0.0006
Postoperative stroke, MI, or respiratory insufficiency (yes, no)	0.0005
New postoperative atrial fibrillation (yes, no)	0.0001
Number of comorbid diseases (0, 1, 2, 3+)	0.0001

has increased in the ≥75-year-old group during 1984–1986. In the 65–74 age group, operative mortality was 1.8% (62/3,529) for men and 3.0% (32/1,074) for women ($P = 0.01$). For patients ≥75 years, operative mortality was 4.5% (15/333) for men and 5.2% (7/134) for women (NS). Hospital mortality rose progressively with advancing age. Analysis of preoperative variables that potentially influenced the probability of mortality either during the operation or in the subsequent hospital course were reviewed. *Table 3* lists variables examined univariately. The significant variables were analyzed by the logistic regression method for their influence on early and late death. We found that these variables increased operative (hospital) risk: 1) age ≥75 years, 2) current cigarette smoking, 3) any left ventricular impairment, and 4) female gender.

The cause of hospital death changed with advancing age. For patients <65 years, 89 (67%) of the operative deaths resulted from myocardial ischemia/infarction. In the 65–74-year-old group, 53 (56%) of the operative deaths were related to ischemia/infarction, and among patients 75 years or older, ischemia/infarction deaths fell to 11 (50%). As shown previously, multisystem failure was implicated in operative mortality more frequently with advancing age.[5] Stroke occurred more than twice as often in patients over 65 than in those younger than 65 years, but was no greater among the very elderly. Perioperative myocardial infarction, defined as new Q-waves, occurred with about the same incidence regardless of age. Bleeding that required reoperation increased significantly with advancing age, as did respiratory complications. The same was true for renal failure, but not for wound complications.

Postoperative atrial fibrillation was not included in the list of complications because it was not considered a major event, but postoperative atrial fibrillation rose in incidence significantly with advancing age. For 17,996 patients under age 65, transient postoperative atrial fibrillation during the hospitalization occurred in 3,098 (17.2%) patients, compared with 1,540 (33.5%) for the 65–74 age group and 216 (46.3%) for the ≥75 age group.

Atrial fibrillation occurred before coronary bypass surgery in 89 patients (0.5%) age <65 years; 69 (1.5%) of those ages 65–74 years, and 19 (4.1%) of those age ≥75 years. We found that 29 patients (2.4%) who were hypertensive on admission had chronic atrial fibrillation preoperatively compared with 59 (1.5%) normotensive patients with chronic atrial fibrillation preoperatively ($P = 0.05$). There was no significant relationship between preoperative hypertension and postoperative atrial fibrillation, nor was there a correlation between diabetes and pre- or postoperative atrial fibrillation. Patients with atrial fibrillation occurring before bypass surgery were subtracted from those who showed atrial fibrillation at any time during the postoperative course. Of patients ≥65 years who did not have atrial fibrillation preoperatively, 1,693/4,982 (34.0%) experienced atrial fibrillation postoperatively. Although there was no significant difference between men and women in preoperative chronic atrial fibrillation, this supraventricular arrhythmia occurred postoperatively in 2,783 (17.7%) men <65 years compared with 315 (13.6%) women ($P < 0.001$); for ages 65–74, 1,192 (33.8%) men and 297 (27.7%) women ($P < 0.001$); for ≥75 years, 153 (46.0%) men and 51 (38.1%) women (NS). In analyzing patients with atrial fibrillation postoperatively, we find that they had more three-vessel (53.1% vs. 46.4%) and left main coronary artery disease (22.7% vs. 18.4%) ($P = 0.01$), suffered more postoperative strokes (6.2% vs. 2.1%) ($P = 0.003$), and were older (69.5 vs. 68.5) ($P = 0.001$), but did not show any significant difference in left ventricular function, completeness of revascularization, or major postoperative complications.

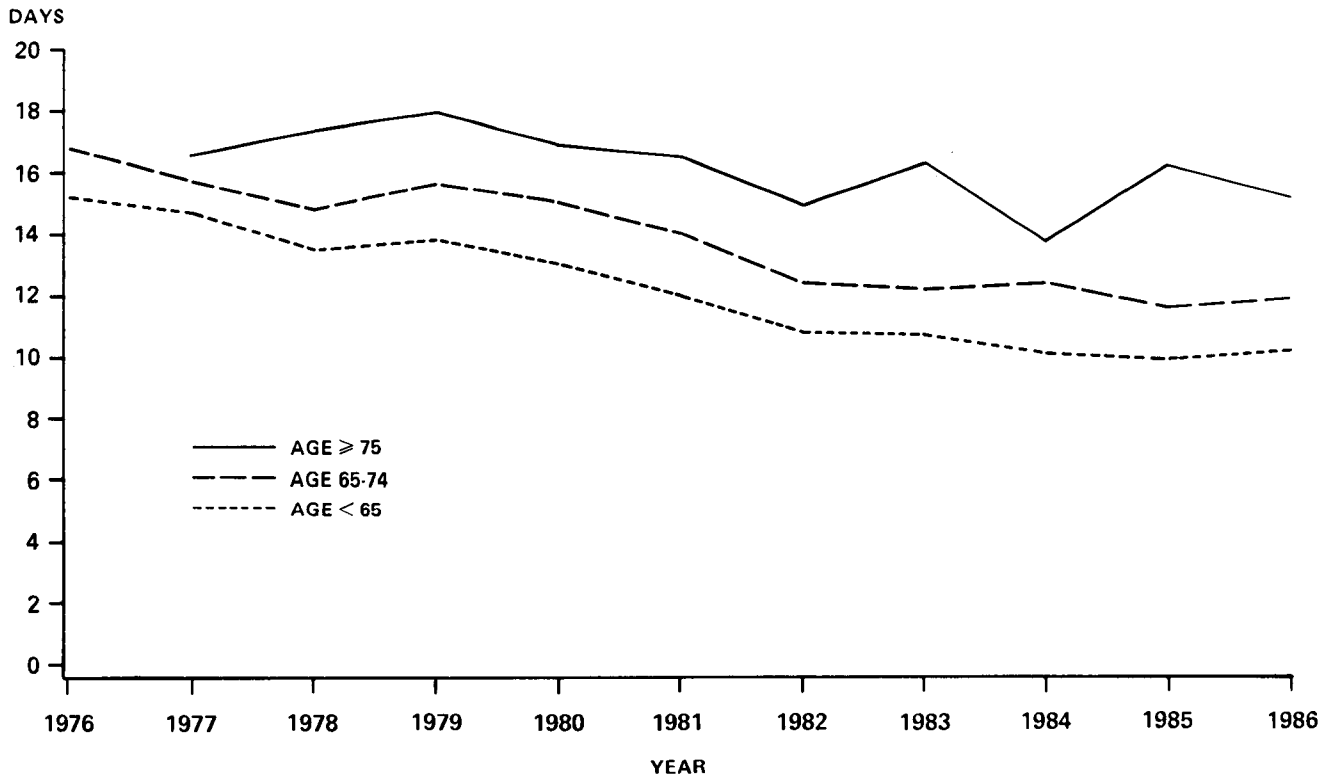

Fig. 2. Length of stay is shown for the three age groups under consideration. In general, length of stay has decreased over the 11 years, but varied widely in the ≥75 age group.

Length of stay

As shown in *Figure 2*, length of stay has decreased during the 11-year period. Geometric mean total length of hospitalization was 12.4 days for patients <65 years (n = 17,904) and 13.5 for those 65 and older (n = 5,045) ($P < 0.001$). (A geometric mean is obtained from the logarithms for the number of days in the hospital by calculating the mean for the logs and then converting the mean back into days through the antilog.) Postoperative length of stay has decreased, currently averaging 10 days for those ≥65, and 8 days for those younger than age 65. The length of stay for women <65 years was 13.2 days; and ≥65 years, 14.0 days. This was longer than for men <65, 12.3 days; ≥65, 13.4 days (all $P <$ 0.001). In the group <65 years old, 505/17,528 (2.9%) were length-of-stay outliers; for those 65–74 years, it was 315/4,580 (6.9%) and for those ≥75 years, 69/465 (14.8%). (A length-of-stay outlier is defined as any patient whose length of stay exceeds the minimum of the geometric mean for length of stay plus 20 days, or the geometric mean plus 1.94 times its standard deviation.)

Figure 3 indicates that all major complications significantly lengthen the period of hospitalization, ranging from a mean of 28 days for wound infection down to 11 days for bleeding requiring reoperation. Also, atrial fibrillation lengthened hospitalization significantly in the <65-year-old group, 13.0 vs. 12.3 days ($P < 0.0001$ because of the large number of patients involved), and in the 65–74-year-old group 14.0 vs. 13.0 days ($P < 0.0001$), but not in the ≥75-year-old category, 16.7 vs. 15.4 ($P = 0.14$). Length-of-stay outliers average about 4.5% for all coronary artery bypass patients (1976–1986).

From the clinical operative and angiographic variables listed in *Table 2*, we performed a logistic regression analysis to determine which variables influenced the probability of being a length-of-stay outlier. In the 65–74-year-old age group, there were 315 (6.9%) length-of-stay outliers. The variables that were found to influence the probability of being an outlier in this age group included: 1) amount of blood transfused, 2) stroke, 3) wound infection, 4) respiratory complications, 5) peripheral vascular disease, 6) hospital death, and 7) atrial fibrillation. In the 465 patients age 75 or older, there were 69 (14.8%) outliers, which were influenced by: 1) amount of blood transfused, 2) peripheral vascular disease, and 3) diabetes.

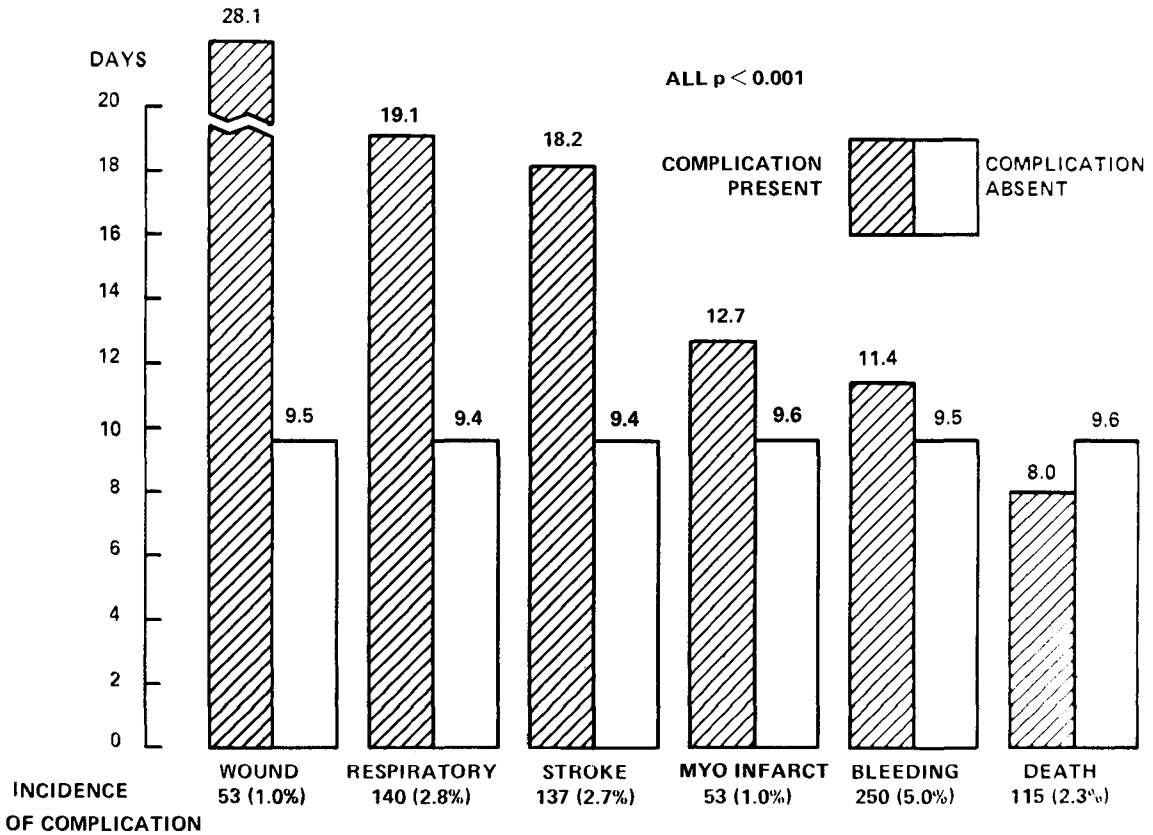

Fig. 3. The effect of complications on length of stay for 5,045 patients ≥65 years is compared with patients who did not sustain these major complications. For every patient who had a major complication except death, the length of hospitalization was significantly longer compared with patients who sustained no complications.

Functional result

Follow-up consisted of an analysis of 1,549 consecutive hospital survivors 65 years or older who had been operated on from 1976 through 1980. Twenty-six (1.7%) had incomplete follow-up. There were 1,439 patients ages 65-74 and 84 patients age 75 or older. This subset was compared with 5,045 patients under age 65. This comparative group consisted of consecutive patients culled from the first 1,000 patients operated on each year from 1976 through 1981. The mean follow-up was 91 months. Angina relief after bypass surgery was better in the elderly than among their younger counterparts ($P = 0.0001$). By questionnaire or telephone call, surviving patients were asked whether they had chest pain, but we did not attempt to grade angina. For the three age groups, no angina was reported by 73.0% (3,230) of the <65-year-old group, 77.4% (780) of the 65–74-year-old group, and 81.0% (34) of the ≥75-year-old group.

Postoperative catheterization was performed in 324 patients over age 65. The mean interval between surgery and postoperative catheterization was 52 months. Of 747 vein grafts restudied in the 65–74-year-old group, 70.4% were patent. Among 91 internal thoracic (mammary) artery grafts in that age group, 78.0% were patent. In the group ≥75 years old, recatheterization of 35 vein grafts showed an 85.7% patency; no internal thoracic artery grafts were restudied. Nearly all postoperative cardiac catheterization was performed because of recurring symptoms.

Longevity

By Cox regression analysis, these variables adversely influenced long-term survival: 1) number of associated diseases, 2) cardiac enlargement, 3) age 75 or older, 4) postoperative atrial fibrillation, 5) preoperative myocardial infarction, and 6) peripheral vascular disease. *Figure 4* demonstrates survival after bypass surgery among the elderly and nonelderly and shows the actuarial survival curves for patients up to 10 years after surgery. The 10-year survival for patients younger than age 65 was 78.8% and for ages 65–

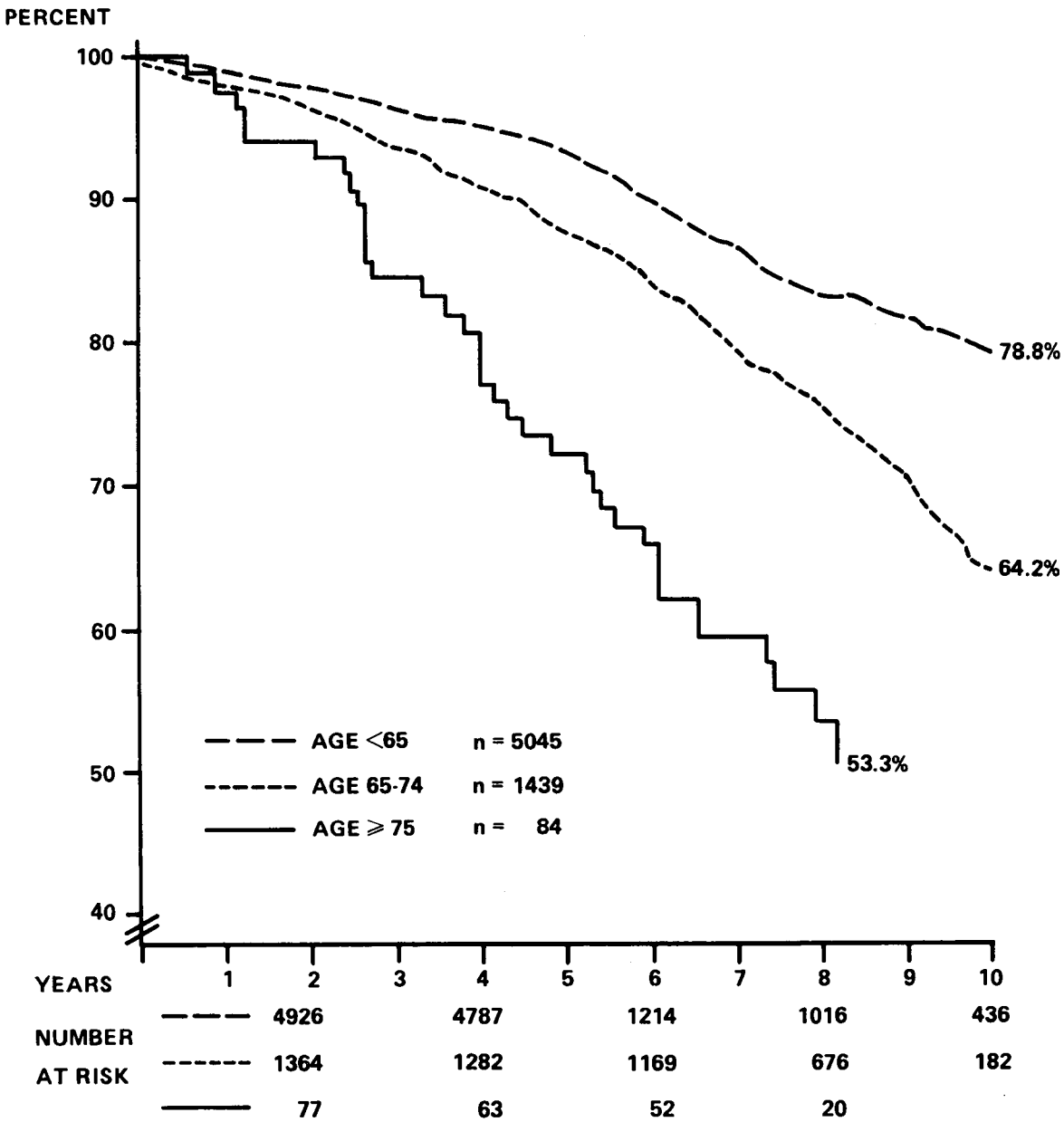

Fig. 4. Actuarial survival for the younger subset was based on follow-up data from the first 1,000 patients operated on each year from 1976 through 1981. For the two older subsets, 1,504 of 1,549 consecutive patients from 1976 through 1980 were followed. Patients in the very elderly subset fared least well but showed 81% four-year and 53% eight-year survival.

74, 64.2%. Eight-year survival for patients 75 or older was 53.3%. There was no significant difference in survival at 10 years for patients ≥65years who were operated on for one-vessel or three-vessel disease. However, patients ≥65 years with normal left ventricular function preoperatively had a significantly higher 10-year survival (68.0%) than patients with preoperative left ventricular dysfunction (58.2%) ($P = 0.0002$). Of the principal comorbid conditions, only the number of associated diseases and peripheral vascular disease adversely affected five- and 10-year survival among the elderly. Patients ≥65 years who experienced new postoperative atrial fibrillation showed decreased survival at five years (83.1% vs. 88.5%), eight years (68.9% vs. 77.0%), and 10 years (54.9% vs. 66.6%) ($P = 0.0001$).

Figure 5 depicts survival for patients in the

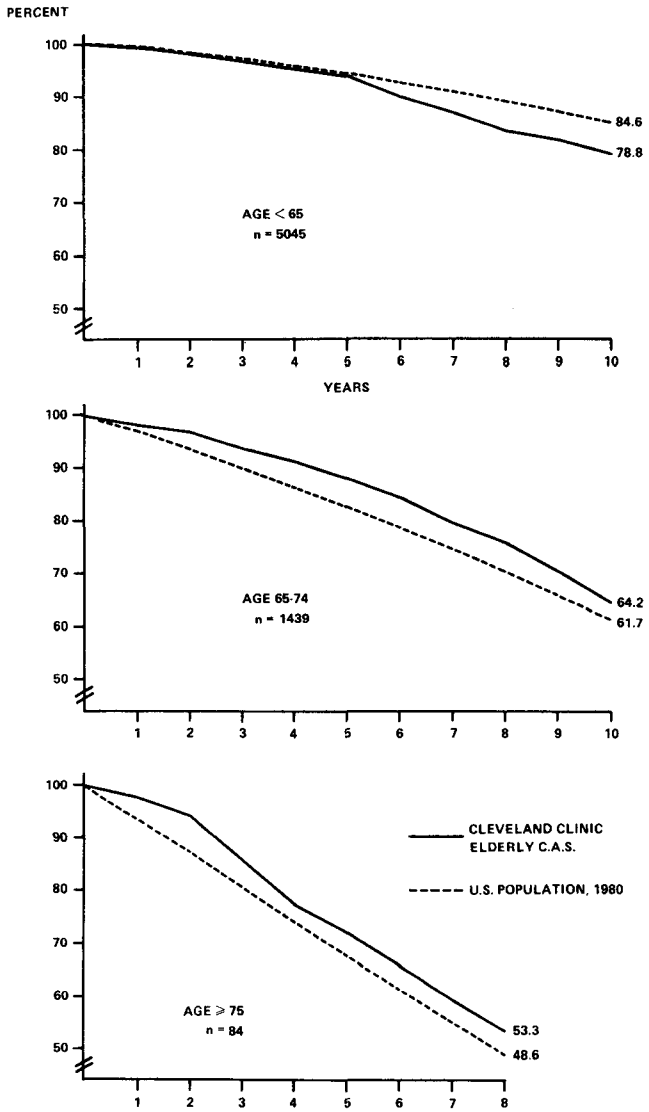

Fig. 5. Survival rates after bypass surgery among the elderly and nonelderly are compared with survival of the U.S. population adjusted for age and gender. Note that for both categories of elderly, i.e., 65–74 and ≥75 years, the surgical survival exceeds that of the normal population.

three age groups under investigation compared with the U.S. population adjusted for age and gender. For patients under age 65, survival of these surgical patients is the same as that of the U.S. population until approximately the fifth postoperative year, when it diverges downward slightly. Interestingly, for the 65–74 age group, the surgically treated patients have a higher survival for the first five years than the U.S. population, although it decreases somewhat with time. The same may be shown for eight-year results from the small group of patients age 75 or older compared with the U.S. population, matched for age and gender.

Discussion

As life expectancy in the 20th century increases, many elderly patients remain fit and may expect to live considerably longer than their ancestors. Average life expectancy is now 72 years, but those who reach age 65 live an average of 15.6 more years; a person who lives to age 75 has an expectation of 9.8 more years; and for those who reach 80, the expectation is nearly seven more years.

The heterogeneity of the elderly involves certain objective variables, among them chronologic age, that are important in deciding surgical candidacy. Although age *per se* is no contraindication to coronary bypass surgery, the issue of advisability of surgery becomes more complex with advancing patient age. The accepted indications for coronary artery surgery in general apply equally well to the elderly: 1) angina interfering with life-style, 2) left main coronary artery stenosis, 3) severe proximal left anterior descending artery stenosis, and 4) three-vessel disease with proximal stenoses, left ventricular dysfunction, or normal left ventricular function at rest with inducible ischemia and poor exercise capacity. Interference with life-style is subjective, and many older inactive patients may be satisfied with occasional angina. Severe left main coronary artery stenosis, especially with >70% narrowing in lumen diameter, accompanied by right coronary lesions deserves consideration for surgery, depending on other biologic variables discussed below. Although most elderly patients with severe proximal anterior descending artery stenosis have multivessel disease, infrequent isolated one-vessel disease may be managed medically or by balloon angioplasty.

In addition to angina, ischemia, and specific angiographic findings, other biologic variables should be assessed in the geriatric patient before recommending therapy. These "four As" may be helpful in appraisal of the elderly for surgical treatment: 1) *Age*, while not necessarily the sole deciding factor, cannot be safely ignored. Advancing age gives rise to increasing mortality and morbidity, as shown in our results and those of others.[6] 2) Appraisal of physiologic age is important. Prior normal *activity* is one sign of relatively good health apart from the present illness. It is

less practical to operate on chronically inactive patients because rehabilitation will be limited. 3) *Attitude* should be conducive to a good result. Motivation includes a good understanding of the risk involved and rational expectations of the functional result. 4) *Associated diseases* affect late results adversely.[6] Independently and collectively, concomitant diseases such as diabetes, hypertension, peripheral atherosclerosis, chronic pulmonary disease, and renal failure are not contraindications to surgery, but their presence should be judged in context. The longevity of patients with documented peripheral atherosclerosis, who frequently have severe coronary atherosclerosis, may be improved by successful coronary bypass surgery performed before peripheral vascular reconstruction.[7] Of the concomitant diseases reviewed in our experience with the elderly, only peripheral vascular disease adversely influenced five- and 10-year longevity. The inveterate cigarette smoker is probably more at risk from postoperative respiratory insufficiency than is the patient with chronic obstructive pulmonary disease. Patients with a history of cancer should be screened carefully to rule out recurrence before any cardiac procedure. Lung cancer discovered during the cardiac evaluation is best treated first, and only in unusual circumstances is the coronary operation performed first or simultaneously.

In our series of 5,070 patients older than 65, we found an increasing frequency of women. Although women have much lower rates of atherosclerosis than men generally, the rates of atherosclerosis become more nearly similar after menopause. We found that elderly patients had significantly more diabetes, peripheral vascular disease, prior cerebral events, and cardiac enlargement than younger patients. Nearly all the patients operated on today have multivessel disease, but left main coronary artery lesions producing greater than an estimated 50% reduction in lumen diameter occur significantly more with advancing age. The incidence of severe left main coronary artery lesions in patients over age 75 was twice that of patients younger than 65.

From selection through management, the approach to the geriatric patient has been refined by experience. In our opinion, the elderly person is selected for surgery less on the perception of myocardial jeopardy and more by overt symptoms. The anesthesiologist, cognizant of the applied pharmacology of aging, designs the anesthetic plan accordingly. For intravenous and inhalation anesthetics, anesthetic requirements decline progressively with age. Age-related peripheral denervation causes neurogenic muscle atrophy, which results in unchanged or even increased requirements for neuromuscular blocking drugs. The loss of large-artery elasticity in the elderly impedes ejection of stroke volume, resulting in left ventricular hypertrophy and a rise in systolic arterial pressure. The older heart tends to be stiffer and may require higher filling pressures. Aging of the cardiovascular system involves reduction of aortic distensibility,[8] progressive left ventricular hypertrophy,[9] and decreased left ventricular compliance.[10] A brief review article by Lakatta and others[11] on changes in cardiac structure and function in senescence is recommended as an overview of the effects of cardiac aging.

There is no evidence to justify discontinuation of blood donation in the population over age 65.[12] Older patients may predeposit one or two units of blood electively, or may arrange for designated donors through the hospital blood bank. Of the technical factors considered by the surgeon, opening and closing the fragile osteoporotic sternum should not be minimized. Peripheral vascular atherosclerosis may require modifications in aortic cannulation, aortic cross-clamping, performance of proximal (aortic) graft anastomoses, and insertion of the intra-aortic balloon pump. Most cardiac surgeons and anesthesiologists would agree that it is safer to keep blood pressure up during the operation in older patients, especially those who have had a prior cerebral event. Veins are more fragile and balloon flotation catheters must be used judiciously. In the very elderly, repeated wedging of that catheter may result in fatal pulmonary hemorrhage.

The operation should be carefully planned and generally conservative. Good myocardial protection is essential and, in addition to good anesthesia, involves crystalloid or blood cardioplegia coupled with core cooling. Unless the pericardium is well insulated, continuous cold saline drips or ice slush in the pericardial cavity should be avoided to protect phrenic nerve function. The very elderly do not easily tolerate extreme normovolemic anemia, and their intraoperative hematocrits should be maintained higher (approximately 30% or higher).

Until recently, the internal thoracic (mam-

mary) artery graft was used infrequently in older patients, but greater experience with this conduit coupled with better myocardial protection has broadened the indications for arterial grafting. In 1986, it was used in 85% of elderly patients. The use of the internal thoracic artery either singly or bilaterally does not cause an increased incidence of sternal complications except in diabetics.[13] Expanded use of this arterial conduit was applied less often among the elderly than among younger patients, but it is still the graft of choice for revascularization of the anterior descending artery system. All anastomoses are best accomplished during one period of aortic cross-clamping to avoid tangential aortic clamping, which may dislodge aortic plaques and contribute to atheroembolism and stroke.

Operative mortality increases with advancing age. For isolated bypass surgery in patients younger than age 65, the hospital mortality was 0.7%. It rose to 2.0% in the 65–74-year-old group and reached 4.7% for patients ≥75 years. Major complications were significantly higher among the elderly, with the exception of perioperative myocardial infarction and wound infection. Reports of operative mortality and complication rates for elderly patients who underwent coronary bypass surgery are reviewed by Dorros et al.[14]

Incidence of postoperative atrial fibrillation rose progressively with advancing age. In the <65-year-old group, it was 17.2%; 65–74, 33.5%; and ≥75, 46.3%. In patients with a mean age of 56 years who underwent coronary artery bypass grafting, Rubin and others[15] found no difference in incidence of atrial fibrillation between patients randomized to receive no drug and those who received digoxin preoperatively. No preoperative, intraoperative, or postoperative characteristics identified a patient population at higher risk for the development of atrial fibrillation. The overall incidence of atrial fibrillation in this largely nonelderly population was 29%. However, pretreatment with propranolol reduced atrial fibrillation to an incidence of 16.2%. Most of these patients had good ventricular function, and these results cannot be extrapolated to patients with depressed left ventricular function.

Our rising incidence of atrial fibrillation in older ages, albeit paroxysmal, assumes greater importance because it figures prominently in variables that influence late survival. Along with age ≥75, comorbidity, preoperative myocardial infarction, and peripheral vascular disease, postoperative atrial fibrillation is a variable that affects late survival. Why would transient atrial fibrillation in the early postoperative period affect late survival? Precursors of atrial fibrillation in the Framingham Study rose sharply with age.[16] Although hypertensive cardiovascular disease was the most powerful precursor (sixfold excess risk), the prevalence of hypertension was not significantly greater in subjects with cardiovascular disease who had atrial fibrillation than in those who did not. The development of chronic atrial fibrillation was associated with double the mortality from cardiovascular disease. Echocardiographic studies have indicated a relationship between atrial fibrillation and diminished left ventricular compliance. Atrial fibrillation is one of the first signs of impaired left ventricular filling, i.e., a more noncompliant left ventricle. Atrial fibrillation is also a marker for degeneration of the conduction system. Unfortunately, we could not analyze the mode of death among the elderly nonsurvivors.

We found a strong correlation between major complications and extended length of stay both for the elderly and nonelderly (*Fig. 3*). A logistic regression analysis of variables that were conducive to a length-of-stay outlier included major complications, atrial fibrillation, poor left ventricular function, and multiple blood transfusions.

Ten-year survival was 78.8% for patients <65 years old, 64.2% for patients 65–74, and for the small group age 75 or older, there was an eight-year survival of 53.3%. The literature is not comparable, but our results are in line with the longevity of 674 patients ≥70 years old from the Milwaukee Cardiovascular Data Registry.[14] They report a seven-year actuarial survival rate of 64.6% and note that there was no difference in survival at four years regardless of extent of coronary disease. After four years the difference between single- and triple-vessel disease became significant. Left ventricular wall motion abnormalities adversely influenced survival (73% with normal and 56% with abnormal left ventricular function).

When our survival curves are compared with those of the U.S. population matched for age and gender, the surgical survival curves are similar, which suggests that bypass surgery has increased survival compared with that of the "normal" pop-

ulation. At 10 years, 64.2% of the 65-74 age group survived compared with 61.7% of the U.S. population. Those 75 or over experienced a 53.3% eight-year survival compared with 48.6% for the U.S. population. Whereas we do not have a similar medical group for comparison, data from the multicenter Coronary Artery Surgery Study (CASS) registry compare medical and surgical treatment groups of patients age 65 or older. Gersh et al[6] surveyed medical and surgical patients treated between July 1974 and November 1980 and found that variables that increase operative risk were more frequent in elderly subgroups. After adjusting for left ventricular performance, congestive heart failure, number of vessels involved, number of associated medical diseases, and age, the six-year survival was significantly better among the surgically treated patients, 79% versus 64% ($P < 0.001$), compared with medical treatment. Their regression analysis also showed an independent beneficial effect of surgery. In patients with essentially normal left ventricular function, five-year survival in surgical patients was 87% compared with 67% for patients who had moderate-to-severe left ventricular dysfunction. The effect of associated medical disease was striking. In patients without associated medical problems apart from their coronary atherosclerosis, the five-year survival was 89% compared with 71% for patients with two or more associated diseases. This CASS study showed relief of angina nearly identical to our experience, with 85% to 100% experiencing reduction in angina and 68% to 85% becoming asymptomatic. Angina is relieved by coronary artery surgery equally well or even better in older patients.

Emory University investigators reported similar mortality and morbidity and confirmed that complications increased with advancing age.[17] The incidence of postoperative stroke changed from 0.9% in patients less than 70 years old but rose to 3.4% among patients age 70 years or older. They found a greater length of hospitalization in older patients, increasing from 11.2 days for patients under age 65 to 13.4 days for patients 65 or older. In patients 70 or older, it increased further to 14.5 days.

It appears from our experience that the age of the bypass candidate is increasing. Advancing age is related to significantly greater mortality and morbidity. Nonetheless, successful bypass surgery among the elderly confers benefit in the form of consistent angina relief and longevity that exceeds that of the U.S. population matched for age and gender. Our experience is confirmed by data from the CASS registry, which shows that longevity is enhanced significantly by surgical rather than medical treatment. The bypass operation, however, is still evolving. During this 11-year period of investigation, we have seen improvements in myocardial protection, greater use of arterial conduits, and improvements in blood conservation. As in younger patients, the skill and success of the operation correlate significantly with the outcome.

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Floyd D. Loop, MD
Department of Thoracic and Cardiovascular Surgery
The Cleveland Clinic Foundation
9500 Euclid Avenue
Cleveland, Ohio 44106