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GERIATRIC CARDIAC SURGERY

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Cardiovascular disease is the leading cause of death in the United States; 84% of deaths from cardiovascular disease occur in people aged 65 and older. [1] The health care of the geriatric patient population includes a growing number of cardiothoracic surgical interventions intended to improve the quality of life of older persons, and the challenges of providing surgical therapy for coronary and valvular diseases in older patients are increasing.

METHODS

To identify issues that will affect decisions about the role and potential benefits of surgery for heart disease, we reviewed the current body of knowledge in the field of cardiac surgery for the geriatric patient. We searched the National Library of Medicine's PubMed database for the period from 1994 to April 6, 2001. The time frame was narrower than for many other of the topics covered by this project because examination of initial search results indicated that only the more recent references were relevant. The search strategy combined terms for specified cardiac surgical procedures with terms for complications, and it was further qualified by adding the various terms for risk factors, age factors, outcomes, quality of life, and rehabilitation. The search resulted in 1799 references. From among the relevant papers, we chose those that emphasize the management of such issues as perioperative care, postoperative complications, and quality of life for the elderly cardiac surgical patient. Age as a risk factor for specific cardiac surgical procedures was also examined.

THE CHANGING PATTERN OF PATIENTS UNDERGOING HEART SURGERY

The characteristics of patients undergoing heart surgery have changed over time. The patients undergoing operations for coronary artery disease (CAD) and valve replacement or repair are now older, with more comorbid conditions. Warner et al prospectively studied and compared 23,512 patients undergoing coronary artery bypass grafting (CABG) during three time periods from 1981 to 1995. [2] The mean age and the percentage of patients aged 65 years or older were significantly higher in the later time periods. In a multivariate analysis for predictors of mortality, these researchers found that patients aged 65 and older in the more recent cohort of patients had an odds ratio of 2.7 for mortality. Patients aged 80 and over were found to have a significantly higher risk of any complication with surgery, including neurologic events, pneumonia, arrhythmias, or wound infection. Other researchers reviewed aortic and mitral valve replacements in 2898 patients over two separate 4-year periods. [3] The later group had significantly more patients with preoperative

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risk factors for mortality and low cardiac output syndrome. Patients in the later group were more likely to be aged 70 or older. A prospective analysis of 4839 CABG procedures over three time periods by Abramov et al showed a time-related increase in severity of preoperative risk profile. [4] Age, urgent surgery, chronic renal failure, peripheral vascular disease, and prior CABG were found to be independent predictors of operative morbidity and mortality. These authors suggest the revision and expansion of criteria for CABG referral.

The mortality rate for patients aged 65 and over was shown to be higher than that for younger patients (6.1% versus 3.5%). [5] Risk factors for in-hospital death after heart surgery among elderly patients include diabetes mellitus, hypertension, myocardial infarction, and congestive heart failure. Retrospective multivariate analysis of 436 patients aged 75 or older who underwent cardiac surgery at a single institution showed that emergency operation, renal dysfunction, and cardiomegaly negatively influence hospital survival. [6]

Decisions regarding resource allocation for future health care delivery to older people must acknowledge the impact of heart disease on cost. Patients with multivessel CAD and diabetes mellitus have higher costs of care with greater length of stay. In a retrospective analysis, Culler et al demonstrated this effect, with age being one of eight important factors that contribute to these costs. [7]

A common misconception among clinicians treating elderly patients is that advanced age alone precludes aggressive interventions, including surgical therapies. An older patient with myocardial ischemia may receive either less aggressive or delayed intervention wherever this bias persists. Bearden et al demonstrated this when they observed that when patients enrolled in a multicenter hypertension study developed CAD, the elderly patients, regardless of comorbid conditions, socioeconomic status, and social support, are offered cardiac interventions that are less intensive than those offered to younger patients. [8] Similarly, according to a study by Paul et al, [9] elderly patients who sustain acute myocardial infarctions are often treated less aggressively. These researchers noted that, despite higher rates of mortality among elderly patients (19% versus 5%), younger patients are three times as likely to undergo percutaneous transluminal coronary angioplasty (PTCA) or CABG.

The treatment of cardiovascular diseases in elderly persons consists largely of the management of symptoms and sequelae of atherosclerotic disease. Initial management at the primary care level consists of risk reduction to minimize onset and progression of atheromatous disease. When surgical intervention is required, atheromatous disease of the aorta may be encountered, a condition that may increase the risk of emboli and stroke. Protruding atheromas have a higher incidence in patients aged 60 and over. [10] Trehan et al examined 6138 patients undergoing CABG and formulated specific surgical approaches for patients with evidence of carotid and aortic atheromatous disease to attain low rates of stroke. [11] Detection of atheromatous disease by carotid screening and intraoperative transesophageal echocardiography may contribute to risk adjustment and surgical planning for a growing number of elderly patients with extensive vascular disease.

The medical community has appropriately emphasized the need for improved treatment of congestive heart failure in elderly patients. The best surgical option for end-stage heart failure, however, after correction of ischemic states or repair of valvular dysfunction, consists of cardiac transplantation. The limitations of this therapy, particularly for elderly patients, are well known; older age negatively influences candidacy for transplantation, as

demand for suitable organs far outweighs supply. Pennington et al note that older age affects transplant candidacy, noting that only 3.2% of patients listed for cardiac transplantation in 1995 were 65 years or older. [12] An aging population will potentially increase the demand for donor organs if the upper age limit for candidacy for transplantation is increased. Therefore, one additional surgical strategy to be considered is implantation of permanent ventricular assist devices into the growing number of patients who will present with end-stage congestive heart failure with little or no option of undergoing cardiac transplantation. This approach will require further experience in the use of cardiac assist devices in the elderly patient population to identify those who have potential for improvement in quality of life with the ultimate cardiac therapy—permanent cardiac replacement with a mechanical device.

An important component of providing surgical therapy to all elderly patients with cardiac disease is acknowledgment of age-specific changes in cardiac response to ischemia or stress. Clinical studies show that elderly patients with CAD have lower left ventricular pump performance and efficiency than do younger patients. [13] Patients aged 70 and over have also been shown to have a reduction in myocardial perfusion reserve. [14] The presence of angina before an acute myocardial infarction does not appear to confer the protection against in-hospital death in patients aged 65 and over that it has been shown to offer for younger patients, which suggests the possible loss of ischemic preconditioning in the senescent myocardium. [15] Animal studies that demonstrate variance between adult and senescent myocardial response to blood cardioplegia, which is commonly used for clinical heart surgery, suggest that strategies for myocardial protection may need to be reexamined if the less contractile hearts of elderly patients are to be accommodated. [16] The understanding of aging as a physiologic response has profound ramifications in cardiac surgery as it relates to varied clinical presentation of disease, recovery from reperfused states, and maintenance of perioperative hemodynamic stability.

Further research in geriatric cardiac surgery is needed to accurately define the populations at risk for heart disease and the indications for surgical evaluation. This will require institutional and multicenter databases that allow cardiac surgeons to monitor outcomes. Specific areas of investigation include the following:

CardiacSurg 1 (Level B): **Risk profiles must be revised to accurately reflect current medical and surgical practices with regard to advanced age and heart surgery. Existing databases must be expanded to include functional outcomes in elderly patients and to monitor cardiac care patterns for elderly patients. This will yield important outcome data to guide clinical decision making for the aging population.**

CardiacSurg 2 (Level A): **Intervention studies (clinical trials) of specific geriatric clinical pathways in cardiac surgery are needed to identify possible beneficial effects on outcomes.**

CardiacSurg 3 (Level D): **Methods for estimating future total costs of cardiac surgery in elderly patients, including the perioperative and rehabilitative periods, need to be developed.**

CardiacSurg 4 (Level A): **Multicenter randomized controlled trials comparing catheter-based interventions and coronary artery bypass**

grafting for the treatment of coronary artery disease in geriatric cardiac patients is needed.

CardiacSurg 5 (Level D): **Studies are needed to review resources that accommodate potentially longer hospital stays by elderly heart surgery patients who present with greater acuity and complications following surgery.**

CardiacSurg 6 (Level B): **Predictive models are needed to estimate the numbers of patients with risk factors for heart disease who may ultimately require surgical care (eg, the current diabetic population that will require surgery in their 60s through their 80s).**

CardiacSurg 7 (Level B): **Prospective cohort studies are needed that investigate the potential role of cardiac assist devices in the treatment of congestive heart failure in elderly patients deemed unlikely to undergo heart transplantation.**

CardiacSurg 8 (Level B): **Further investigation of the senescent myocardium and age-specific physiologic response to stress is needed to identify reasons for pump failure or for low-output syndrome.**

CORONARY ARTERY DISEASE

Advances in the treatment of CAD, including early intervention, prevention, risk modification, and general public awareness, have resulted in improved clinical outcomes in myocardial ischemia. For patients who present with acute coronary syndromes, early reperfusion to myocardium at risk is considered the standard of care. The benefit of reperfusion in elderly patients (aged 75 or older) was shown by Gottlieb et al in a comparison of two cohorts (1981–1983, 1992–1994) of patients who had sustained acute myocardial infarction. [17] The more recent cohort of elderly patients who received thrombolysis, angioplasty, or CABG were found to have fewer in-hospital complications and mortality rates approximately 30% lower than those of the earlier cohort of patients. The treatment of CAD for all patient populations, however, has dramatically changed over time. The availability of new interventional techniques and drug therapies necessitate a re-evaluation of the care of elderly cardiac patients to determine the benefit that is specific to this group at risk.

Stouffer et al noted in a comparison of older and younger patients that age influences the risk factors but not the clinical signs and symptoms of left main CAD. [18] The older CABG patients (N = 798, mean age 59) were found to have significantly greater incidence of hypertension, obesity, and prior myocardial infarction than did the younger CABG patients (N = 112, mean age 40). [19]

Surgical revascularization continues to play an important role in treating older people with CAD. CABG is the operation performed most frequently by most cardiac surgeons. The typical CABG patient, however, may have already exhausted other medical options for symptomatic angina or heart failure. Aldea et al examined patients undergoing CABG or percutaneous intervention and noted that the CABG patients generally are older. [20] Harris et al retrospectively studied 7099 patients at Mayo Clinic treated with CABG and

4937 who underwent coronary angioplasty over a 10-year period (divided into three equal intervals). [21] Operative mortality rates for both procedures changed little over the study period despite the significantly greater number of patients aged 65 and over undergoing both procedures in the later time periods. These researchers noted an increase from 23% to 84% in the use of the internal mammary artery as a bypass conduit in the latest period. They also noted the trend for CABG to be performed more often following acute myocardial infarction or as an emergency operation for unstable angina. In a retrospective analysis, O'Keefe et al compared two concurrent cohorts of patients aged 70 and over who underwent either coronary angioplasty or CABG. [22] The groups were found to have similar rates of survival over 5 years; however, patients undergoing angioplasty were found to have significantly greater numbers of cardiac events, including Q-wave myocardial infarction, repeat revascularization, CABG, or angioplasty than did those treated by CABG initially. This suggests that this older group of patients had greater freedom from repeated revascularization when treated with CABG.

In a retrospective analysis over a 2-year period of 109 patients aged 70 and over who presented with refractory angina, Vassilikos et al showed that the patients who were revascularized by CABG had better long-term outcomes than did those treated by angioplasty. [23] The patients who underwent CABG had fewer events, such as the need for repeat revascularization or the development of myocardial infarctions. The study confirms and strengthens the earlier findings by O'Keefe. In the more recent study, the selection of procedure, however, was determined by the cardiologist; at the time of the study, coronary stents were not routinely used in conjunction with angioplasty.

In the Bypass Angioplasty Revascularization Investigation (BARI) trial where 1829 patients were randomly assigned to either undergo CABG or PTCA, 39% of patients were aged 65 and over at the start of the trial. [24] Cardiac mortality was shown to be greater at 5 years in the patients undergoing PTCA, although there was no difference when nondiabetic patients were excluded from the analysis. For older patients in that trial, stroke was more common after CABG than for younger patients (1.7% versus 0.2%). Older patients in the trial were found to have less recurrent angina and to be less likely to undergo repeat procedures if they initially underwent CABG.

As percutaneous coronary interventional techniques have improved with the development of intracoronary stents, studies to compare CABG and angioplasty with stent placement have become necessary to appropriately compare current treatment modalities for CAD. In a study of 1200 patients randomized to undergo either CABG or stent placement for multivessel CAD, Serruys et al noted no significant difference between the rates of death, stroke, or myocardial infarction between the two treatment groups. [25] At 1 year, however, a second revascularization was required by 16.8% of those in the stenting group but only by 3.5% of those who underwent CABG. The two groups were similar with respect to age (mean age = 61 years in both groups). Patients in the CABG group showed greater freedom from angina at 1 year than the stenting group. In a study of 200 patients with normal left ventricular function, Kim et al showed similar results in CABG and multivessel coronary stenting. [26] Angina returned in 19% of the stenting group but only 8% of the CABG group. Repeat revascularization was required in 19% of the stenting group and 2% of the CABG group at mean follow-up of 21 $\pm$ 10 months, despite the fact that ventricular function was normal in all patients upon enrollment.

The use of coronary stents in elderly patients has also been studied. Ritchie et al examined the impact of stents on the management of CAD in the Medicare population over time periods when stent use became more widespread. [27] The study showed that patients who have stents have lower hospital mortality and less same-admission CABG than patients having angioplasty alone. Munoz et al compared coronary stenting in patients older than 75 years to that in a younger cohort of patients. [28] A similar incidence of major adverse cardiac events (27.7% versus 28.2%) was observed in the two groups of patients. Long-term event-free survival rates also showed no differences at 5 years between the two groups. The older group of patients, however, were found to present more often with multivessel coronary disease and lower ejection fractions, and more frequently to have unstable angina. The older patient group showed a significantly higher in-hospital mortality rate (6.6% versus 2.4%) and rate of myocardial infarction (5.3% versus 1.7%) than did the stented patients aged 75 or younger.

In another study, patients undergoing isolated CABG between 1970 and 1989 demonstrated stable perioperative mortality rates. [29] However, temporal trends showed an increased number of patients older than 65 and a greater number of emergency operations. In this study, the leading cause of death was found to be cardiac pump failure and postoperative myocardial infarction, both occurring more commonly in older patients. Elderly patients undergoing CABG present with a higher frequency of hypertension, hyperlipidemia, prior myocardial infarction, and diabetes mellitus. These patients more often present with unstable angina and diffuse coronary artery disease. [30] The operative mortality for CABG among elderly patients has declined, however. Ivanov et al showed in examination of 3330 consecutive patients aged 70 and over that the prevalence of high-risk elderly patients rises over time and that poor ventricular function, diabetes, female sex, prior CABG, and peripheral vascular disease are independent predictors for poor outcome among elderly patients. [31]

Hannan and Burke demonstrated increased in-hospital mortality for elderly patients by reviewing the 30,972 CABG procedures performed in New York State in 1991 and 1992. [32] Patients aged 80 and over had mortality of 8.31%. The group aged 75 to 79 had mortality of 5.28%. These data were compared with the mortality rates of 1.10%, 1.65%, 2.17%, 2.76%, and 3.36% for ages 40–49, 50–59, 60–64, 65–69, and 70–74, respectively. The mortality rates for 33 risk factors were found to be higher in patients aged 75 and over than in younger patients. These factors include emergency surgery (14.08% versus 5.73% mortality), hemodynamic instability (23.45% versus 9.52% mortality), and renal failure (21.34% versus 10.35% mortality).

Peigh et al examined the records of 250 patients undergoing isolated CABG who were divided into five age groups and found that the elderly patients had more complications, a longer length of hospital stay, and a higher mortality rate than did the younger patients. [33] In addition, the older patients had a reduced performance status measured by the Karnofsky scale. However, in a retrospective analysis by Ott et al of patients undergoing CABG, the mortality rates and postoperative complications were not found to be significantly different in a group of patients aged 70 or over and in a younger group. [34] This study emphasized the application of a rapid recovery protocol. Such protocols feature rapid extubation, aggressive fluid management, and early patient mobilization. Using data collected prospectively from 20,614 patients undergoing isolated CABG from 1982 to 1997, Yau et al showed that age, reoperation, ventricular dysfunction, operative urgency,

and left main coronary artery disease are predictors of mortality for coronary artery bypass. [35] The prevalence of patients with moderate ventricular dysfunction (left ventricular ejection fraction 20% to 40%) increased from 18.4% in 1982–1986 to 21.7% in 1992–1997. Mortality decreased from the 1982–1986 cohort to the 1987–1991 cohort; the reduction in mortality was most marked in patients with ejection fraction of under 40%.

Other studies have shown some specific increased risk profiles in elderly patients undergoing surgical revascularization. CABG following acute myocardial infarction carries added risk for mortality. Kaul et al observed that age above 70 years is an independent predictor of early mortality for patients who undergo CABG within 30 days of an acute myocardial infarction. [36] In a study of over 4500 patients undergoing CABG at the Toronto Hospital, patients who had low-output syndrome were found to have a greater mortality (16.9% versus 0.9%). Importantly, one of the nine independent predictors of developing low-output syndrome was found to be age above 70 years, resulting in an odds ratio increase of 1.5. [37] This suggests that efforts to reduce myocardial ischemia, a known precipitating factor for low-output syndrome, should be investigated, with particular emphasis on the aging myocardium. In multivariate analysis of 2264 patients undergoing CABG, Del Rizzo et al noted that age above 70, re-do surgery, poor left ventricular function, renal impairment, and the presence of preoperative intra-aortic balloon pump are predictors of mortality. [38]

In a retrospective study of 1127 patients aged 70 years and over who underwent CABG between 1985 and 1996, Busch et al noted that, despite a decreased number of emergent operations, the incidence of respiratory failure and neurologic disorders rose over that period. [39] They also observed that the percentage of septuagenarians operated upon rose from 6.4% in 1985 to 21.5% in 1996.

Technical aspects of the operation have been investigated in an attempt to identify strategies that would improve outcome and long-term survival or minimize morbidity for CABG. The use of bilateral grafting with skeletonized internal thoracic arteries in elderly patients was found to result in low morbidity and mortality. [40] Elderly patients undergoing CABG who received internal mammary artery grafting were found to have fewer postoperative complications. [41] Among elderly patients who receive internal mammary artery grafting, other factors such as smoking, reoperation, or left main coronary artery disease are risk factors for mortality. [42] In a study to improve outcomes in an elderly high-risk CABG patient population, Gutfinger et al showed that liberal use of preoperative intra-aortic balloon pump could be performed safely with no significant increase in complication or mortality rates. [43]

For elderly patients undergoing CABG, time to recovery may determine needs for postoperative resources and rehospitalization. Paone et al studied 146 patients aged 70 and over with the expectation that these patients would progress through the postoperative clinical pathway in much the same way as a younger comparison group. [44] Although age was one significant factor in contributing to increased length of stay, the study suggests that extraordinary modifications of the clinical pathways are not necessary for success with elderly patients. Advanced age was not found to be significantly associated with 30-day hospital readmission following CABG. [45]

Samuels et al identified a group of older patients at particularly high risk for mortality following CABG. [46] In patients aged 75 and older with chronic obstructive pulmonary disease (COPD) who are receiving corticosteroid therapy, mortality was 50%. Older pa-

tients with COPD not receiving steroids had a mortality rate of 17%. These data support investigation into nonsurgical therapy for elderly patients with severe COPD.

Recently, cardiac surgeons have used minimally invasive techniques to perform cardiac operations in an effort to reduce morbidity and decrease hospital stay and postoperative recovery period. These novel methods include coronary artery bypass performed on a beating heart and without the use of cardiopulmonary bypass (off-pump coronary artery bypass). The avoidance of cardiopulmonary bypass may reduce morbidity that has been attributed to inflammatory responses and fluid shifts known to occur with extracorporeal circulation.

Two cohorts of elderly CABG patients were compared by Boyd et al.[47] Off-pump patients were found to have significantly shorter hospital stay, intensive care unit stay, and rates of postoperative atrial fibrillation than did conventional CABG patients. Koutlas et al showed that two groups of patients aged 75 or over, those who underwent beating-heart coronary artery bypass surgery and those who underwent conventional CABG, had similar neurologic complications, renal failure, rates of atrial fibrillation, and rates of postoperative myocardial infarction.[48] These researchers noted significantly shorter postoperative length of stay, lower transfusion rates, and a lower mortality rate in the beating-heart surgery group.

Yokoyama et al studied high-risk groups undergoing off-pump and on-pump CABG.[49] They found that off-pump and on-pump CABG have comparable results in the high-risk group consisting of patients 80 years of age or older. They noted that off-pump CABG reduces but does not eliminate neurologic events in elderly patients. Other methods for adapting conventional operations are being performed, including port-access operations where percutaneous cannulation techniques and limited incisions are used in an attempt to limit surgical trauma. Such adaptations do not eliminate the use of cardiopulmonary bypass, but these techniques are rapidly evolving as tools that potentially reduce the morbidity of open cardiac procedures.

Research in coronary artery surgery should continue to focus on technical aspects of the operations that allow safer perioperative management of the elderly CABG patient. Recent studies indicate that coronary revascularization can often be safely performed by novel techniques that may avoid use of cardiopulmonary bypass. Cardiac surgical specialists are also active in the investigation of other therapies intended to ameliorate the symptoms of coronary artery disease. This includes transmyocardial laser revascularization and gene therapy for inoperable CAD. As medical and surgical options for the treatment of coronary artery disease expand, treatments that benefit elderly patients should be investigated to determine suitability on the basis of outcomes in this patient population. Potential areas of investigation for cardiac surgery include the following:

CardiacSurg 9 (Level B): **Prospective studies of young and elderly patients are needed to investigate lung function as a risk for coronary artery bypass grafting by determining the degree of pulmonary compromise that would shift risk from surgical to medical management of coronary artery disease.**

CardiacSurg 10 (Level B): **Cohort studies on various cardiopulmonary bypass techniques are needed, with morbidity in elderly patients as the chief outcome measure.**

CardiacSurg 11 (Level A): **Randomized controlled trials are needed that select the most promising cardiopulmonary bypass techniques and compare them, again with morbidity in elderly patients as the chief outcome measure.**

CardiacSurg 12 (Level B): **Cohort studies are needed to identify risk factors and benefit predictors of myocardial protective techniques for both on- and off-pump coronary artery bypass in elderly patients. This includes myocardial protective strategies aimed specifically at the aged myocardium and mechanical or chemical protective techniques when off-pump procedures are used.**

CardiacSurg 13 (Level A): **Randomized controlled trials are needed that select the most promising myocardial protective techniques and compare them with each other and with traditional bypass techniques; morbidity, need for reintervention, and relief of symptoms in elderly patients should be the main outcome measures. The best on-pump method could also be compared with the best off-pump method.**

CardiacSurg 14 (Level B): **Cohort studies are needed of innovative and emerging therapies for coronary artery disease (eg, gene therapy, transmyocardial laser revascularization), as well as of other complementary treatments in the elderly patient population.**

CardiacSurg 15 (Level B): **Cohort studies are needed to investigate the profiles and clinical course of elderly patients who undergo angioplasty and to establish future risks of reintervention or need for coronary artery bypass grafting.**

CardiacSurg 16 (Level B): **Outcome studies are needed of conduit use (mammary artery, radial artery, saphenous vein graft) in elderly patients, specifically to analyze a possible selection bias by surgeon in the choice of conduit.**

CardiacSurg 17 (Level B): **Studies are needed that apply and test minimally invasive techniques that may reduce cost, decrease length of stay, and yield good long-term outcome in elderly coronary artery bypass grafting patients.**

VALVE SURGERY

Valvular surgery in the elderly patient is performed as an intervention for stenotic or insufficient native valves. The aortic and mitral valves are most often involved; aortic stenosis is the most common indication for cardiac valve surgery. The aortic valve is typically replaced with either a mechanical or bioprosthetic prosthesis, or, alternatively, a homograft may be used. For mitral valvular disease, reparative procedures including annular supportive operations are preferred, although replacement with mechanical or bioprosthetic valves is also performed. Cardiac valvular procedures become more complex when they need to be combined with procedures such as CABG.

For patients with mild symptoms, Stahle et al noted that postoperative survival rates for those aged 70 and over who were undergoing aortic valve (AVR) or mitral valve replacement are comparable to those for the general population without valvular disease. The study therefore recommends early identification and surgical intervention for valvular heart disease. [50] Hannan et al showed that the number of years in excess of age 55 is a significant multivariate predictor of mortality for patients undergoing cardiac valve replacement. [51] This was found to be consistent across multiple groups when other risk factors are controlled.

For mitral valve surgery, Lee et al compared 190 elderly patients with 424 younger patients and noted that late surgery contributes far more than age to poor outcome, as the elderly group typically presented with advanced heart failure and poor ventricular function. [52] Survival was studied in 2359 patients undergoing AVR, showing excellent relative survival at 15 years of 74.9. [53] In these studies, old age was not consistently shown to be a risk factor for excess mortality after AVR.

In another study on elderly patients (aged 75 years and over) undergoing AVR for aortic stenosis, the independent predictive factors for mortality were found to be left ventricular failure, lack of sinus rhythm, and emergency operation. [54] The presence of severe preoperative symptoms due to advanced aortic stenosis also translates into longer intensive care stay for elderly patients. [55]

Mitral valve repair in the elderly patient may be compatible with acceptable mortality and outcomes. Grossi et al showed that mitral valve reconstruction in 278 patients aged 70 or greater had 6.5% mortality, rising to 17.0% when CABG was added. [56] The 5-year rate of freedom from reoperation in this patient population was 91.2%. However, advanced age was found in another study to be a predictor of long-term mortality in patients with pulmonary hypertension who were undergoing mitral valve surgery for mitral stenosis. [57]

The choice of valve prosthesis in the elderly patient has been investigated extensively. The excellent durability of mechanical prosthetic valves when compared with tissue or bioprosthetic valves is weighed against the need for long-term anticoagulation, which in an elderly population may lead to bleeding complications. In the Veterans Affairs randomized study comparing mechanical and bioprosthetic valves in valve replacement, the rate of primary valve failure after AVR was not found to be significantly different between the valve types in patients aged 65 and over. [58] In long-term follow-up of patients aged 65 and over, Helft et al showed that bioprosthetic valve replacement has low structural deterioration rates and low mortality rates but ultimately has high mortality rates attributable to causes not related to valves. [59] In patients aged 70 and over, a bioprosthetic valve offers lower risk of thromboembolic complications and acceptable rates of structural deterioration. [60] Banbury et al concluded that the Carpentier-Edwards pericardial aortic valve, with low incidence of structural deterioration and acceptable rates of freedom from hemorrhage (91%), endocarditis (93%), and thromboembolism (87%) at 12 years, is an appropriate choice of prosthesis in patients aged 65 and older. [61]

In a prospective randomized study of AVR in patients aged 75 years and over, Santini et al noted that stentless valves (ie, biologic valves with nonrigid sewing rings) carry no advantage over conventional bioprosthetic valves with respect to mortality rates, transvalvular gradients, or regression of left ventricular mass. [62] The stentless valves typically require longer operative times for implantation. Elderly patients were found to have satisfactory survival after AVR with stentless xenografts at 3 years. [63] Schmidtke et al also

showed that the Ross procedure (AVR with pulmonary autograft) can be safely performed in selected patients aged 60 and over. [64]

Milano et al showed that elderly patients who receive mechanical valves in the aortic position have significantly increased risk of anticoagulant-related hemorrhages during the next 10 years in comparison with patients who receive bioprosthetic valve replacements. [65] Jamieson et al compared older patients with a younger cohort and noted that older patients undergoing AVR with bileaflet mechanical prosthesis have a significantly greater rate of thromboembolic and hemorrhagic complications than do the younger group of patients. [66] Masters et al, however, found no difference in thromboembolism when comparing mechanical valve replacement in an elderly group (aged 65 and over) and a younger group of patients. [67] These studies indicate that anticoagulation risks in elderly patients are not firmly established. The degree to which thrombotic or hemorrhagic complications occur in elderly patients as a consequence of ineffective monitoring, drug interactions, or noncompliance requires further study. For elderly patients with known coronary artery disease, the shorter survival expectations may justify the use of bioprosthetic valve replacement. [68]

Excellent quality of life after isolated valvular surgery was shown in a study of 147 patients aged 75 and over. The study found that 59.2% of patients are able to perform moderate to vigorous activities and 88.5% are able to climb at least one flight of stairs. [69]

Efforts to intervene early in the course of valvular heart disease in elderly patients have the potential for improving outcomes. Continued research in the technical aspects of valve surgery is warranted. Minimally invasive techniques with their potential for reduced morbidity following valvular surgery are currently being employed with increasing frequency. The minimally invasive procedures include those that limit incisions and surgical trauma. Minimal-access surgery for aortic valvular procedures has focused on parasternal incisions or mini-sternotomy. Mitral valve operations have also been developed to allow endoscopic or robotic manipulations of instruments placed through the right chest via small incisions. Methods to establish cardiopulmonary bypass have been devised to allow percutaneous arterial and venous access coupled with tissue-sparing incisions. These techniques are in rapid developmental stages and will require data collection to demonstrate their efficacy and the durability of repair. Early data suggest reduced hospital stay and good patient tolerance. Data that are specific to the elderly patient undergoing operations with the new techniques are needed. The choice of valvular prosthesis continues to evolve. Thrombotic or hemorrhagic complications in elderly patients need to be examined. Anticoagulant monitoring by newly developing home-based tests have the potential for reducing dosage errors that lead to those complications. An important question to be answered is whether a patient with a mechanical valve device requires any anticoagulation other than antiplatelet therapy. Specific studies that should be performed include the following:

CardiacSurg 18 (Level A): **Prospective randomized trials are needed to compare regimens of anticoagulant therapy for elderly patients with a mechanical prosthesis to minimize valvular complications and thromboembolic complications. Such studies may require cost-benefit analysis of decreasing anticoagulation as a function of age in patients with valvular prostheses.**

CardiacSurg 19 (Level A): **Prospective randomized trials comparing minimally invasive aortic valve replacement with conventional**

methods in elderly patients are needed to assess the benefits of improved morbidity and decreased hospitalization.

CardiacSurg 20 (Level A): **Randomized prospective trials comparing minimally invasive with conventional mitral valve operations in elderly patients are needed. These studies should include the efficacy and duration of repair and outcomes with respect to operative and perioperative morbidity when thoracoscopic and robotic techniques are employed.**

REOPERATIVE CARDIAC SURGERY

Reoperative surgery in elderly patients carries a high risk for morbidity and mortality. In a comparison of younger and older (aged 70 and above) patients undergoing reoperative CABG, Christenson et al noted that the older patients had poorer New York Heart Association (NYHA) functional classification and more generalized atherosclerosis. [70] These older patients had a higher occurrence of low cardiac output syndrome, a higher incidence of gastrointestinal and renal complications, and longer cardiopulmonary bypass times. Hospital mortality rates for the older patients were 17.9% and 7.1% for younger patients; however, the 5-year survival rates and cardiac event-free survival rates for the older and younger patients were 76.2% and 69.9%, respectively. In an analysis comparing reoperative CABG and primary CABG, Christenson also noted that age above 80 years, urgent operation, poor ventricular function, and generalized atherosclerosis are among the independent risk factors for postoperative death in both the primary and reoperative CABG patients. [71] Weintraub et al reviewed the course of 2030 patients who underwent reoperative CABG and noted that hospital mortality increases from 5.7% for patients less than age 50 to 10% for patients aged 70 and older. [72] In that study, older age was found to be a marker for increased mortality by multivariate analysis. Neurologic events also were found to be significantly greater for the older patients undergoing reoperative surgery, with an occurrence of 4.1% for those aged 70 and over. Pellegrini et al noted significantly greater mortality, occurrence of low-output syndrome, renal failure, and sepsis in reoperative CABG patients aged 70 to 79 than in those 60 to 69 years of age. [73]

Reoperation carries increased risk for the elderly patient. Technical aspects of re-do procedures must be investigated to identify potential areas of improvement. These include myocardial protective schemes, modifications of cardiopulmonary bypass techniques, and minimally invasive operative strategies where possible. Topics for research include the following:

CardiacSurg 21 (Level B): **Cohort studies are needed that focus on patency and outcomes related to conduit choice in elderly patients who have had prior coronary artery bypass grafting and who require reoperation.**

CardiacSurg 22 (Level A): **Randomized trials of myocardial protective strategies in reoperative heart surgery in the elderly patient are needed to identify the optimal approach in recurrent coronary disease.**

CardiacSurg 23 (Level B): **Feasibility and outcomes analyses of off-pump techniques in elderly patients are needed to define morbidity and mortality in repeat revascularization procedures.**

CardiacSurg 24 (Level B): **Cohort studies are needed of outcomes in elderly patients who have undergone reoperative coronary artery bypass grafting with arterial grafts after venous conduits developed stenosis or other flow-limiting changes occurred.**

CardiacSurg 25 (Level B): **Longitudinal studies are needed to determine outcomes in valvular repair or replacement operations in elderly patients who have had prior coronary revascularization procedures.**

AORTIC DISSECTION

Surgery for aortic dissection often presents as an acute syndrome with hemodynamic compromise, ischemia, and multi-organ dysfunction. This condition is poorly tolerated by elderly patients with poor cardiac reserve and other comorbid conditions. An emergency surgical procedure is commonly required early in the course of ascending aortic dissection for survival benefit. In reviewing the course of 124 consecutive patients who underwent operation for acute ascending aortic dissection, Ehrlich et al showed in multivariate analysis that age above 60, hemodynamic compromise, and the absence of hypertension are predictors for hospital death. [74] In a similar study Ehrlich et al found that older age, hemodynamic instability, preoperative cardiopulmonary resuscitation, and lack of retrograde cerebral perfusion are significant predictors of death from operation for acute ascending aortic dissection. [75]

To improve outcome and reduce perioperative morbidity in elderly patients with acute dissection, it is necessary to identify the problem expediently and attempt to control factors that lead to hemodynamic instability. Intraoperative measures to improve reconstructive techniques include the use of glue-type substances for aortic repair. [76] Further research on methods to preserve cerebral perfusion and prevent accumulation of metabolites during periods of circulatory arrest is also indicated, as elderly patients fare poorly from neurologic complications often associated with major aortic procedures.

The technical aspects of surgery for aortic dissection require ongoing refinement. Techniques that improve cerebral protection and reduce visceral injury are being investigated. Further understanding of circulatory arrest physiology, with particular emphasis on the geriatric patient, may elicit the development of maneuvers and medications that minimize the morbidity and mortality of the operations. Studies comparing medical and surgical treatment for aortic dissection in older patients need to be performed to establish survival benefit and refine indications for either rapid operation or stabilization and medical treatment. Potential topics for investigation include the following:

CardiacSurg 26 (Level B): **Longitudinal studies of elderly patients treated nonoperatively for aortic dissection are needed to determine the profile of patients at greatest risk of early death that is related to initial dissection.**

CardiacSurg 27 (Level B): **Outcome analyses of operative treatment for ascending and descending aortic dissection in elderly patients are**

needed to further clarify risk profiles. Emphasis should be on comparison of acute and chronic presentation.

CardiacSurg 28 (Levels B, A): **Cohort studies and ultimately randomized clinical trials of cerebral protection techniques in elderly patients are needed to identify surgical techniques that lead to fewer neurologic complications, transfusion requirements, and other perioperative complications.**

COMPLICATIONS OF CARDIAC SURGERY

Complications following cardiac surgery result in increased mortality, longer hospital and intensive care unit stays, and greater costs. Stroke, arrhythmias, postoperative bleeding, wound infections, and renal failure are among the most common complications. These complications have been shown to be particularly prevalent in elderly patients, as demonstrated by some of the studies discussed here and in the next section. Stroke is also considered in Chapters 4 (General Surgery) and 12 (Rehabilitation), as it is known to have increased occurrence with worse outcomes in elderly patients as both a disease entity and a surgical complication.

The occurrence of atrial fibrillation following cardiac surgical procedures is approximately 20% to 30%. This arrhythmia has been shown to increase the length of both intensive care unit and hospital stay. In their study of 570 patients undergoing CABG, Aranki et al showed that atrial fibrillation occurs more commonly in older patients, with the median age being 71 years; 66 years was the median age for those patients who did not have postoperative arrhythmias. [77]

Postoperative bleeding following CABG which requires re-exploration may be associated with increased mortality and length of hospital stay. In a multicenter regional cohort study of 8586 patients undergoing CABG, increased age and prolonged cardiopulmonary bypass time were found to be among the factors associated with increased bleeding risk. [78]

Gastrointestinal complications after cardiac surgery may occur in approximately 1% to 3% of patients; mortality from these events may be high. Christenson et al noted a 16.4% overall mortality from gastrointestinal complications following CABG. Cholecystitis and mesenteric ischemia were the most common events noted in that study. [79] In addition to poor ventricular function, cardiac reoperation, urgency of operation, and poor preoperative NYHA functional classification, age greater than 70 years was also found to be independently associated with post-CABG gastrointestinal complications. [80,81] Visser et al concluded that advanced age, valve replacement, emergency procedures, and prolonged bypass or clamp times are risk factors for the development of colorectal complications following cardiac surgery. [82] No independent risk factors for mortality associated with these complications could be established.

In a study of changing patterns among patients undergoing cardiopulmonary bypass between 1990 and 1997–98, Ostermann et al observed not only that the patient population became older and more severely ill, but also that the incidence of patients requiring perioperative continuous veno-venous hemofiltration for acute renal failure actually declined slightly (2.0 versus 2.7%). [83]

Wound complications following any surgical procedure may significantly increase the length of hospital stay, overall costs, and even mortality rates. In a retrospective study of 12,267 consecutive cardiac surgical patients over a 5-year period with 100% follow-up, Borger et al noted that advanced age is an independent risk factor for the development of serious sternal wound infections. [84]

In another study, in multivariate analysis advanced age also proved to be an independent risk factor for mortality after development of postsurgical mediastinitis. [85] For patients who develop sepsis following cardiac surgery, an increased mortality was found to be associated with advanced age or the development of low cardiac output syndrome. [86]

In a case-control retrospective analysis of post-CABG patients, silent aspiration, a severe form of pharyngeal dysfunction where oral contents spill into the tracheobronchial tree without elicitation of gagging or coughing, was studied. Advanced age was identified as a significant predictor of this entity. The study suggested that intraoperative cerebral injury might contribute to its development. [87]

Delirium in elderly patients following heart surgery is often attributable to multiple causes, including acute illness, prolonged pre- and postoperative intensive care unit stay, and drug interactions. [88] The chapter on cross-cutting issues addresses this common geriatric surgical complication (see the section on delirium in Chapter 13).

Complications are an expected part of surgical procedures and have a great impact on the outcomes in an elderly population. Potential areas for research include the following:

CardiacSurg 29 (Levels B, A): **Exploratory cohort studies are needed to seek evidence of success with treatments designed to reduce perioperative arrhythmias associated with a large percentage of cardiac operations. It would be important to establish whether postoperative atrial arrhythmias in elderly patients lead to lessened mobility and subsequent added risk for pneumonia, deep-vein thrombosis, and other complications. Subsequently, randomized controlled trials might be carried out to compare success rates and possible benefits from the treatments that show promise.**

CardiacSurg 30 (Level B): **Outcome studies of specific technical aspects of operations are needed to identify potential means of reducing wound complications in elderly patients. The use of minimally invasive techniques for both cardiac exposure and vein harvest to reduce surgical trauma in elderly patients should be evaluated.**

CardiacSurg 31 (Level B): **Cohort studies are needed to establish the incidence of and risk factors for complications in the geriatric cardiac patient, including delirium, bowel dysfunction, and swallowing difficulties.**

CardiacSurg 32 (Level B): **Studies of the susceptibility to hospital-acquired infections of elderly cardiac patients are needed. This should include efforts to determine if wound complications in the older patient are a result of prolonged hospital stay, lessened mobility, or age-related depression of the immune system.**

STROKE, NEUROLOGIC DEFICITS, AND CARDIAC SURGERY

Stroke is a leading cause of serious, long-term disability in the United States. About 88% of stroke deaths occur in people aged 65 and older.[1] Studies of patients undergoing cardiac surgical procedures have attempted to identify technical and patient-related factors contributing to risk of stroke.

Most strokes after cardiac surgery occur after an initial uneventful recovery, and atrial fibrillation has not been found to impact postoperative stroke rate unless it is accompanied by low cardiac output syndrome.[89] In a multicenter prospective study of 2108 patients undergoing CABG, Roach et al showed that independent predictors of focal-injury stroke, coma, or stupor are proximal aortic atherosclerosis, a history of neurologic disease, age above 70, and history of pulmonary disease.[90] Older age is an important predictor of more subtle neurologic injury, such as deterioration in intellectual function, memory deficit, or seizures. The strongest independent predictor for focal stroke was found to be proximal aortic atherosclerosis (judged by the surgeon's intraoperative palpation), which was associated with a fourfold increase in risk. Janssen et al observed that age greater than 75 years is a risk factor for the development of all neurologic complications (mild or major) after CABG.[91] Notably, the preoperative neurologic deficits, including the presence of mild dementia and delirium with acute illness in the elderly patient with heart disease, may not be recognized or fully documented, resulting in inaccurate risk assessment and misinterpretation of the patient's postoperative neurologic recovery.

In a prospective study of consecutive CABG patients, D'Agostino et al noted that age is a significant predictor of carotid stenosis, with stenosis $> 50\%$ resulting in significantly increased risk of postoperative neurologic event.[92] The role of preoperative carotid screening of elderly patients undergoing cardiac procedures should be investigated. In elderly patients (aged 70 and over) undergoing CABG, Morino et al found that calcification of the ascending aorta is associated with cerebral complications.[93]

Five factors were identified by McKhann et al as being correlated with post-CABG stroke: increased age, prior stroke, presence of carotid bruit, hypertension, and diabetes mellitus.[94] The only intraoperative factor showing correlation with stroke was cardiopulmonary bypass time. Mickleborough et al studied 1631 consecutive patients undergoing CABG and noted that age above 60 years has an odds ratio 2.9 for developing stroke of by multivariate analysis of preoperative, intraoperative, and postoperative variables.[95] Carotid scanning to identify high-risk groups was advocated. Another study reported that age above 70 years predisposes patients to stroke after CABG (N = 3910, multivariate odds ratio 3.88).[96] Almassi et al studied stroke in the setting of cardiac surgery.[97] Their database consisted of 4941 patients, 72% of whom were aged 60 and over. Stroke predictors were found to include age, renal insufficiency, use of inotropic agents in the postoperative period, total cardiopulmonary bypass time, and surgical priority. They found that stroke results in increased intensive care unit and hospital stay as well as increased mortality. In a multicenter review of preoperative risk factors for stroke after CABG, the independent factors found to be significantly associated with stroke include increased age, prior stroke, increased duration of cardiopulmonary bypass period, renal dysfunction, and carotid and peripheral vascular disease.[98]

Hammon et al studied neurobehavioral changes after CABG and noted that increasing patient age, multiple emboli detected by cranial Doppler, and palpable aortic plaque are associated with increased neurologic deficits. [99] They suggested that technical maneuvers to reduce embolic production (such as minimal aortic clamping) might result in fewer adverse neurobehavioral events. Such studies to correlate specific aortic manipulations with resultant postoperative neurologic events warrant further investigation. In a retrospective analysis of 2480 younger and older (aged 70 and over) patients undergoing coronary or valvular heart surgery, Ahlgren and Aren showed that the older patients have increased cerebral complication rates (4.1% versus 2.5%). [100] The nature of the complications ranged from coma and hemiparesis to confusion and visual deficits. Nearly one half of the noted cerebral symptoms were recorded in the period beyond immediate anesthetic recovery. Higher incidence rates of cerebral complications were found in patients who had combined valve and coronary procedures.

Reducing the stroke rate among elderly cardiac surgical patients warrants investigation into the technical aspects of cardiac procedures and the refinement of preoperative assessment and risk reduction. Carotid duplex scanning may identify patients at risk. Minimally invasive operative techniques have the potential for decreasing stroke rates, if indeed cardiopulmonary bypass is contributory to higher rates of cerebral complications. Risk modification, including improved diabetic management and control of hypertension, also deserves investigative attention, with emphasis on the elderly patient at risk. Future research should include the following:

CardiacSurg 33 (Level A): **Randomized clinical trials are needed to compare the neurologic results of coronary artery bypass grafting alone with the results of this procedure preceded by carotid endarterectomy when carotid stenosis $>$ 50% is present.**

CardiacSurg 34 (Level A): **More randomized clinical trials should be conducted to investigate the occurrence of stroke and neurocognitive behavioral symptoms in elderly patients on whom coronary artery bypass grafting is performed with or without the use of cardiopulmonary bypass. This would include the development of widely acceptable neurobehavioral assessment tools (eg, cognitive tests) to be used as benchmarks in the evaluation of elderly patients before and after cardiac surgery.**

CardiacSurg 35 (Level B): **To identify possible modifiable risk factors for stroke in elderly patients undergoing cardiac surgery, investigation is needed of available and novel techniques (eg, epi-aortic ultrasound, cerebral oximetry, and transesophageal echocardiography) in elderly patients. Studies of the role of pharmacologic agents as risk factors are also needed.**

THE OCTOGENARIAN AS CARDIAC SURGICAL PATIENT

Octogenarians (and even nonagenarians) are commonly being treated for advanced cardiac disease. Surgical intervention may be considered in this high-risk group of patients to

relieve symptoms or improve quality of life. As few as 3% of octogenarians who ultimately require treatment for coronary artery disease may present with typical angina. [101] The elderly patients may present with low energy level or heart failure, and cardiac workup is initiated. Ricou et al reported that of 115 octogenarians with angina who underwent coronary angiography between 1988 and 1992, 54% underwent revascularization by angioplasty or CABG. [102]

The benefits of myocardial revascularization in this specific group of patients have been demonstrated by several studies. Kaul et al noted that among octogenarians, a significantly greater actuarial survival at 5 years was achieved after CABG than after angioplasty (66% versus 55%). [103] Craver et al compared 601 octogenarians undergoing cardiac surgery with two younger cohorts of patients who received similar operative intervention. [104] The octogenarians in this study, however, did demonstrate a higher incidence of NYHA class IV angina and congestive heart failure. In-hospital death rates and stroke rates were significantly higher for these elderly patients than for the younger groups (9.1% versus 3.4% and 5.7% versus 2.6%, respectively).

In one of the largest studies of octogenarians undergoing cardiac surgery, Alexander et al analyzed results from 22 centers in the National Cardiovascular Network. [105] They found that preoperative predictors for mortality in the older patients are similar to factors in younger patients and that, when comorbidities are not present in the elderly patients, mortality rates are acceptable (4.2% CABG, 7% CABG with AVR, and 18.2% CABG with mitral valve replacement). The mortality rates reported are varied, however, with a typical recent study showing 14.7% mortality rate among 76 octogenarians undergoing cardiac surgery. [106]

Among predictors of hospital death for patients 80 years and older undergoing cardiac operations, Akins et al identified chronic lung disease, postoperative stroke, preoperative use of intra-aortic balloon pump, and congestive heart failure. [107] Risk factors for poor outcome in octogenarians undergoing CABG include pre- or postoperative renal dysfunction, postoperative pulmonary insufficiency, and sternal wound infection, [108] and still another research group found that the only independent predictor of operative mortality is preoperative intensive care unit stay. [109]

In a study of 140 octogenarians undergoing AVR, Bessou et al noted a 56.5% probability of surviving 5 years after operation. [110] Gehlot et al studied early and long-term results of AVR in 322 octogenarians and observed that significant risk factors for mortality include female gender, renal impairment, concomitant bypass grafting, poor ventricular function, and chronic obstructive pulmonary disease. [111] The use of the internal mammary artery as a conduit in octogenarians undergoing CABG was found to have slightly beneficial effects on survival in comparison with the use of saphenous veins alone. [112]

In a comparison of octogenarians and a younger cohort of patients undergoing beating-heart coronary surgery, the older patients were found to have significantly higher complication rates for pneumonia (6% versus 0.8%), atrial fibrillation (47% versus 26%), and need for inotropic support (21% versus 7%). [113] However, in a study of 269 patients by Ricci et al, stroke incidence among octogenarians undergoing off-pump coronary bypass operations was found to be significantly lower than it was among octogenarians undergoing conventional CABG with cardiopulmonary bypass. [114]

The issue of specific surgical management of the octogenarian undergoing CABG is as yet unresolved. The selection criteria for patients who would benefit from beating-heart

surgery need further clarification, particularly as the newer operative techniques become more widely used by cardiac surgeons. Furthermore, randomized controlled trials comparing beating-heart and conventional CABG in octogenarians may elicit data to identify indications for specific techniques in this group of patients. The potential for reduced length of hospital stay and fewer complications may be resolved by trials that address operative strategies in this patient group.

Octogenarians undergoing CABG have been shown to perform well under rapid-recovery protocols. Ott et al noted that 71% of these patients could be discharged in under 10 days following surgery and that other factors such as obesity, vascular disease, and prior ambulatory difficulties delay patient recovery and rehabilitation. [115]

Significant improvements in quality of life were observed in octogenarians undergoing cardiac operations by Kumar et al. [116] They showed in a retrospective analysis of two cohorts (1986 and 1991) that both groups demonstrated clinical and quality-of-life improvements and that over 70% of both patient groups had no regret over the decision to undergo surgery. Tsai et al studied 528 consecutive patients aged 80 and over who underwent cardiac operations; at a mean follow-up of 2 years, 70% of the patients reported improvement in their health status. [117]

Cardiac treatment protocols for angina, acute myocardial infarction, and congestive heart failure must be developed to encompass patients greater than 80 years of age. Trials need to begin at the earliest stages of evaluation. For coronary disease, this would involve randomized clinical trials comparing medical and surgical treatment among patients aged 80 and over. The purpose of the trials would be to negate selection criteria, which may have excluded patients for CABG on the basis of age alone. Similarly, randomized trials of conventional versus beating-heart surgery need to be performed in this patient group. Currently, beating-heart surgery is selected on the basis of the surgeon's familiarity with techniques and patients' cardiac anatomy. The outcomes may, therefore, be related to learning curve in this rapidly evolving method. Does selection for beating-heart surgery indicate the surgeon's perception of increased risk for morbidity or simply a preference for the technique? Multicenter trials should be clear in their selection criteria as well as relative uniformity of operative methods.

The long-term outcomes of patients aged 80 years and over who undergo cardiac surgery should also be investigated. Studies to identify rates and reasons for hospital readmission, deterioration in neurologic status, and objective functional recovery of patients after heart surgery should be performed. Age-matched cohort studies to compare neurologic and functional studies between patients who undergo heart surgery and those who are treated medically may be useful in determining the utility of operation for elderly patients. Future investigations should include the following:

CardiacSurg 36 (Level A): **Randomized clinical trials comparing percutaneous coronary intervention techniques (angioplasty plus stenting) and coronary artery bypass grafting in patients aged 80 and over are needed, with emphasis on the presentation of acute myocardial infarction or congestive heart failure, or both, to clarify selection criteria for this patient group.**

CardiacSurg 37 (Level A): **Randomized clinical trials are needed that compare outcomes with conventional and beating-heart coronary artery bypass grafting in patients aged 80 and over.**

CardiacSurg 38 (Level B): **Longitudinal outcome studies are needed of octogenarians who are treated by surgery, percutaneous interventions, or medically only to suggest the functional and neurologic long-term results and the need for reintervention.**

CardiacSurg 39 (Level B): **Follow-up studies should be performed to determine the need for readmission, repeat intervention, and functional outcomes in patients aged 80 and over who have undergone cardiac surgery.**

CardiacSurg 40 (Level B): **The development of cardiac treatment protocols specifically aimed at patients aged 80 and over is a critical need. This might include prospective trials to allow earlier surgical intervention when risk profile is favorable for good outcomes, particularly for coronary artery bypass grafting.**

QUALITY OF LIFE AFTER CARDIAC SURGERY

An important goal of any surgical intervention in the elderly person is to improve the quality of life. Cardiac surgical procedures are commonly performed under acute circumstances, with immediate survival as the near-term goal of therapy. With increased risk of morbidity and mortality for major operations in the elderly population, the decision to undergo a cardiac operation may be predicated on the perception of long-term issues of quality, and not just duration of life. Chocron et al used the Nottingham Health profile questionnaire to study patients aged 70 and over before and after open-heart operations. [118] The scores showed improvement in health perception by the elderly patients after heart surgery. In the area of physical mobility, diabetes mellitus was the only predictor for worsening scores after surgery. These researchers noted that elderly patients undergoing aortic valve operations showed greater improvement in health perception than patients undergoing CABG.

Melo et al also used the Nottingham Health Profile, as well as the Medical Outcomes Study 36-item Short Form (SF-36) health survey, to study quality of life after coronary artery bypass in 150 patients, 81% of whom were older than 50 years. [119] Surgery proved to be beneficial in improving quality of life, according to patient surveys given before and 6 months following coronary revascularization. Hunt et al in a similar analysis of 123 CABG patients (mean age = 64) used the SF-36 questionnaire at 12 months postoperatively and found improvement in perception of quality of life. [120] They noted an association between poor quality of life and patients who reported severe pain or poor quality sleep.

The Sickness Impact Profile and the Psychological Well-Being Schedule were used to study a small number of elderly patients undergoing CABG. [121] The patients were noted to have improvements in physical, social, and psychological functioning following CABG. In a study by MacDonald et al, [122] which used the SF-36 health survey and the Seattle Angina Questionnaire, quality of life at 3 months following CABG in elderly patients was shown to be improved.

In an analysis of patients aged 80 and older who underwent AVR, Sundt et al found that quality of life, as measured by a postoperative SF-36 survey, was comparable to that predicted for the elderly general population, thereby emphasizing that operative therapy should not be withheld from older patients on the basis of age alone. [123] Although the study did not include matched preoperative data, the surgically treated patients demonstrated higher scores in five of eight health concepts than did the general population.

In addition to physiologic variables that may contribute to mortality, Oxman et al found by multivariate regression analysis in a study of elderly patients following elective cardiac operations that lack of participation in social groups and absence of comfort from religion were significant predictors of mortality. [124] Using the Duke Activity Status Index, Jaeger et al studied functional capacity in cardiac surgery patients aged 70 and over and noted that smoking, female gender, older age, and prior cardiac operation are among the predictors for less improvement at 1 year after operation. [125] Yun et al prospectively studied 604 patients aged 65 and over following nonemergent cardiac operations with 100% follow-up at 2 years. [126] They observed that perception of physical health peaked at 12 months; however, measurements for mental attributes (limitations attributed to emotional problems) continued to improve with time.

For patients who develop complications following cardiac surgical procedures, Wahl et al noted that 67% of patients who required prolonged intensive care unit stay ultimately survived and that approximately 50% of these survivors progressed to functional independence. [127] The study noted that patients who develop severe cardiac or neurologic dysfunction, however, have worse outcomes, with little chance for independent recovery.

Older patients who undergo mitral valve surgery typically present with clinical deterioration as a consequence of advanced heart failure; however, despite higher morbidity and mortality in this group, survivors show significant improvement in symptoms and quality of life following surgery. [128]

Further efforts to improve quality of life after heart surgery may be aided by continued refinement of postoperative survey tools for elderly patients. Comparisons with cohorts treated medically should be performed. Quality-of-life assessment should include measures of older patients' perception of health and objective measurement of their physical and mental capabilities. These data are often lacking in retrospective analyses. The older patients who require cardiac surgery may be divided into urgent and elective groups. An older patient with stable angina who ultimately requires CABG may represent a group with the greatest potential for improvement in quality of life. Urgent operation or operations performed for advanced heart failure may predict lesser degree of functional recovery. To study these issues, surveys should compare outcomes of elective with outcomes of urgent operations. Follow-up is crucial in assessing elderly patient groups, as rehospitalization rates, requirement for nursing-home admissions, and repeat cardiac intervention may determine the need to reassess earlier decision making.

Also needed are improved means of preoperative assessment of elderly patients, to accurately describe their physical and mental capabilities. Ultimately, the surgical refinements may decrease postoperative debilities, but this can be confirmed only if more detailed information about preclinical condition is available. Future investigations should include the following:

CardiacSurg 41 (Level B): **Survey tools to assess quality of life after cardiac surgery in elderly patients need to be refined, to determine the contribution of surgical intervention to long-term disability. This should include cohort studies to clarify the impact of surgical treatment on caregivers.**

CardiacSurg 42 (Level B): **Long-term study of elderly cardiac surgical patients who had prolonged perioperative course is needed to determine the degree to which functional and symptomatic improvement occurs when operative therapy is complicated by stroke, infection, or other medical condition commonly associated with surgery in elderly patients.**

CardiacSurg 43 (Level B): **Comparison studies of outcomes of acute and elective cardiac surgery in elderly patients are needed to identify high-risk groups of elderly patients and to develop potential exclusion criteria for operative therapy.**

SUMMARY

The current trends in cardiac surgery show that more operations are being performed on elderly patients. This has coincided with advances in the medical management of CAD and heart failure. Operative interventions are nevertheless an integral part of advanced cardiac therapy with our aging population. Technical improvements in the operations continue to be investigated. Coronary artery bypass and valvular operations are performed routinely on older patients with excellent results.

Accurate data are needed to determine the population at risk for heart disease and those who benefit from surgical intervention. At the primary care level, surveys to identify age bias or aberration from cardiac protocols must be performed to determine that cardiac surgical candidates are appropriately referred. At the next level, the cardiologist and cardiac surgeon must collaborate on the management of advanced heart disease. Medical versus surgical intervention trials are warranted across multiple disease entities. For CAD, further randomized prospective trials specific to the elderly population are indicated. Trials in the area of angioplasty or stent versus CABG, medical versus laser therapy or gene therapy for inoperable CAD, or angioplasty versus beating-heart surgery for single or double vessel CAD are examples of other needed trials. In the surgically treated elderly patients, further trials to define long-term results of beating-heart and minimal access valve surgery are recommended. Randomized trials are especially important for CAD in the area of beating-heart surgery to identify the potential advantages of performing CABG without the use of cardiopulmonary bypass. The degree to which these techniques may decrease stroke rate, reduce hospital stay, and improve functional recovery is still undetermined.

Older patients undergoing operations require more advanced techniques to reduce morbidity. Safer anesthetic techniques, better myocardial protection methods, and perhaps greater use of minimally invasive operations may yield better outcomes. The postoperative phase, which includes intensive care, in-hospital stay, and rehabilitation periods, require refinement in protocols and procedures to afford the best results. Cardiac surgeons require the latest data and educational support to be able to treat their older patients optimally.

KEY RESEARCH QUESTIONS IN GERIATRIC CARDIAC SURGERY

The three most important research areas identified in the specialty of geriatric cardiac surgery are the analysis and investigation of functional outcomes among geriatric cardiac surgical patients, the impact of stroke and neurocognitive deterioration among elderly surgically treated patients, and the design and assessment of geriatric clinical management programs to accommodate the increasingly older and sicker patients who may require cardiac operations. Studies to address these needs include clinical trials, observational studies, subgroup analyses, and expansion of databases to address key questions about the care of elderly cardiac surgical patients.

CardiacSurg KQ1: **To what extent do cardiac surgical operations improve functional outcomes in an elderly patient population?**

Hypothesis-generating research should include the expansion of current clinical databases to include long-term and functional outcomes of elderly cardiac surgical patients. The ability to satisfactorily gauge the success of cardiac operations in improving quality of life for elderly patients depends heavily on the accurate measure of preoperative and perioperative functional capabilities. Observational studies and database analysis should focus on refinement of risk factors for poor outcome in elderly surgically treated patients.

Hypothesis-testing research studies to address this question would be aimed at defining the benefits of surgical over medical therapy for coronary and valvular disease in older patients. Randomized trials of elderly patients treated for specific disease entities (eg, advanced CAD, mitral insufficiency with significant heart failure) are needed to clarify the role of operative therapy in improving survival and quality of life.

CardiacSurg KQ2: **How can stroke and neurocognitive deterioration following cardiac surgical procedures be reduced among elderly patients?**

Hypothesis-generating research studies should focus on the technical aspects of specific cardiac operations. Database analyses and observational studies of specific technical maneuvers currently used in operations on elderly patients should elucidate risk factors and technical contributions to cognitive impairment. Further hypothesis-generating research should focus on the development of widely acceptable neurobehavioral assessment tools (eg, cognitive tests) to be used as benchmarks in the evaluation of elderly patients before and after cardiac surgery. The newer methods of assessment may ultimately shape management decisions in cardiac surgery for the elderly patient, as they may alter technical practices of heart surgeons, revise risk stratification, and further clarify the expectations of postoperative recovery from heart surgery in the geriatric patient.

Hypothesis-testing research may include randomized trials of CABG performed with or without the use of cardiopulmonary bypass in elderly patients. Cohort studies to describe neurocognitive deterioration among nonsurgically treated elderly patients with cardiac disease are needed. Multivariate analyses for such studies may clarify the role of operative

characteristics versus the presence of specific diseases in predicting cognitive decline in older patients.

***CardiacSurg KQ3*: What changes in perioperative care are needed to improve outcomes in the elderly cardiac surgical patient?**

Hypothesis-generating research should include methodologic studies to identify high-risk elderly patients and devise clinical pathways for their care. Database analyses of the pre-hospital, in-hospital, and rehabilitative periods of elderly surgically treated patients should be performed to identify clinical management strategies that result in decreased morbidity and improved functional recovery.

Hypothesis-testing research studies include randomized trials of CABG with and without the use of cardiopulmonary bypass, with emphasis on reduction in morbidity. Prospective cohort studies of surgically and nonsurgically treated cardiac patients aged 75 and over are needed to clarify the potential beneficial effects of nonoperative therapy. Case-control or randomized studies of elder-specific pathways to elucidate the benefit of pathways in obtaining better functional outcomes and reducing in-hospital adverse events are needed. The aim of these studies would also be to identify treatment strategies that reduce the incidence of perioperative pulmonary complications, wound-related problems, and arrhythmias, which have been shown to be especially prevalent in elderly cardiac patients.

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