6

GERIATRIC CARDIAC SURGERY

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Cardiovascular disease remains the leading cause of death among adults aged 65 and over in the United States and other Western populations. As the older age group continues to increase rapidly, the treatment of cardiovascular disease will become an increasingly important factor in the health of older persons. In fact, of the over 6 million cardiovascular procedures performed during 2002 in the United States, more than half were carried out in patients aged 65 or over.[1,2] Cardiovascular surgical interventions are offered to older patients to improve both length and quality of life. The challenges of thoracic aortic procedures and of providing surgical therapy for coronary artery disease (CAD) and valvular disease in older patients are increasing. The field of cardiac surgery faces a demand for continual improvement in the processes and structures of care to address the unique problems encountered in older patients undergoing cardiac surgery.

This chapter updates the research agenda for cardiac surgery for the older adult that was presented in *New Frontiers in Geriatrics Research.*[3] Discussion of the more recent research for each cluster of agenda items from *New Frontiers* is found in the section Progress in Geriatric Cardiac Surgery. The Key Questions for research in geriatric cardiac surgery remain as stated in that publication, with one addition. For the new Key Question and discussion, see the section New Horizons in Geriatric Cardiac Surgery at the end of the chapter.

Elderly patients still require greater resources and are more likely to suffer stroke and a prolonged length of stay following cardiac surgery. Improvement in anesthesia, postoperative care, better myocardial protection, and perhaps preoperative prehabilitation require continual refinement to yield better outcomes. The care of elderly patients will best be delivered by continual close collaboration between cardiac surgeons and geriatricians to synergistically offer different perspectives and skill sets, with the goal of optimizing outcomes for elders who undergo cardiac surgery.

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

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

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

METHODS

To update the review of issues that affect decisions about the role and potential benefits of surgery for heart disease in older adults, we searched the National Library of Medicine's

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PubMed database for the period from April 2000 to December 2005. This time frame covers the period from the end of the searches for *New Frontiers* to the writing of this update. The search strategy combined terms for specified cardiac surgery 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 10,742 references. From among the relevant papers, we chose those that emphasize the management of such issues as peri-operative 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.

PROGRESS IN GERIATRIC CARDIAC SURGERY

The Changing Pattern of Patients Undergoing Heart Surgery

See *New Frontiers*, pp. 147–149.

***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 peri-operative 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 potential longer length of 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.**

New Research Addressing These Questions: The characteristics of patients undergoing cardiac surgery have continued to change over the past five decades. Succinctly stated, the profiles of patients who are referred for cardiac surgery indicate that they are older and have more comorbid conditions. Ferguson et al reviewed the Society of Thoracic Surgeons National Adult Cardiac Surgical Database during the period 1990 through 1999 for patients undergoing coronary artery bypass grafting (CABG) procedure. Several important findings emerged from this observational analysis of over 1.1 million patient records. The mean age of patients undergoing CABG increased from 63.7 years in 1990 to 65.1 years in 1999. Other comorbidities, such as diabetes mellitus and prior stroke, also increased during this study period. Interestingly, although the predicted operative risk increased from 2.6% in 1990 to 3.4% in 1999, the observed operative mortality decreased from 3.4% in 1990 to 3.0% in 1999. There was, however, no analysis of the cohort of patients aged 65 or older to determine whether the improvement in operative mortality was also enjoyed by the geriatric patients. Similarly, if one examines the Coronary Artery Surgery Study registry of patients undergoing CABG from 1975 to 1979, only 12.2% were 65 years of age and older. Two decades later, over half (56%) of the patients undergoing CABG were aged 65 years and older. [2]

Analysis of valvular heart surgery trends reveal similar patterns to those observed for CABG. Nowicki et al examined data from the Northern New England Cardiovascular Disease Study Group data registry from the period of 1990 to 1999. In patients undergoing mitral valve surgery, the mean age increased from 64.7 years of age in 1990 to 67.0 in 1999. More striking was the proportion of patients aged 80 years or older undergoing mitral valve surgery. The data show that mitral valve operations were infrequently performed in octogenarians prior to 1990, but by 1999 that age group represented 12.4% of all patients undergoing this surgery. Over the course of this study, the majority of patients underwent surgery for mitral regurgitation rather than stenosis. This report demonstrates the shifting patient population who receive cardiac surgery and highlights that older patients with poorer left ventricular function are increasingly offered mitral valve surgery. [4]

Though one can question whether this phenomenon is observed only in New England, other reports substantiate this trend toward increasingly offering older patients valve surgery. Collart et al from France describe a similar pattern of referring patients aged 80 and older for valvular surgery. [5]

Modification of These Questions in Light of New Research: No changes or additions to the research agenda are recommended.

CORONARY ARTERY DISEASE

See *New Frontiers*, pp. 150–154.

***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.**

New Research Addressing These Questions: 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. Patients presenting with acute coronary syndromes (ACS) deserve prompt reperfusion for myocardium at risk. The entire scope of defining practice patterns for elderly patients presenting with ACS is outside the scope of this chapter; however, a brief consideration of this topic seems warranted. The overarching theme in the management of elderly patients with ACS is presented in an analysis of the Global Registry of Acute Coronary Events (GRACE) data. Avezum et al examined over 200,000 patients reported to this observational registry and found that seemingly standard therapies such as aspirin, β-blockers, thrombolytic therapy, statins, and glycoprotein IIb/IIIa inhibitors were prescribed less in patients aged 65 or older, whereas calcium channel antagonists were not. Coronary angiography and percutaneous coronary intervention rates also significantly decreased with age.[6] In summary, elderly ACS patients do not receive evidence-based therapies, and the inconsistent utilization of standard invasive therapies argues strongly for the need for clinical trials that examine the use of these therapies in elderly patients. (See the new Key Question, CardiacSurg KQ4, in the section New Horizons in Geriatric Cardiac Surgery at the end of the chapter.)

The treatment paradigm for CAD has changed dramatically during the past decade. In essence, a shift toward increasing utilization of percutaneous coronary intervention (PCI) has occurred, particularly for multivessel CAD. Concurrently, the number of CABG procedures has decreased, particularly in the past 3 years. Mack et al reviewed the HCA Casemix Database for the years 1999 to 2002. This database is utilized by the 76 HCA hospitals performing cardiac surgery. During this period, PCI accounted for 65% of all coronary revascularization, with an annual growth rate of nearly 7%, whereas CABG volume declined at 2% annually.[7] If one examines these trends over a longer period, even greater differences emerge. Ulrich et al queried the rate of PCI versus CABG in Washington State from 1987 to 2001. While CABG rates remained stable until 1997 and then declined by 20%, PCI rates demonstrated an explosion—with an increase of PCI rates by 128%.[8] In summary, multiple reports substantiate the relatively rapid growth and acceptance of PCI for multivessel coronary revascularization, with a concomitant decline in the utilization of CABG in the treatment of CAD.

Three randomized controlled trials have been conducted and are widely cited to support PCI as an equivalent therapy to CABG for the treatment of multivessel CAD. When reading these trials, one must realize that the term *multivessel* does not necessarily mean three-vessel CAD, as a great proportion of these patients in these trials have single- or double-vessel disease with preserved left ventricular function. The Arterial Revascularization Therapies Studies (ARTS) group randomized 1205 patients to either CABG or PCI; the primary clinical endpoint of this study examined freedom from major adverse cardiac or cerebrovascular events at 1 year. Assessment at 1 year showed no difference in rates of death, myocardial infarction, or stroke between the two groups. However, the PCI group was more likely to have undergone another intervention (16.8 % PCI versus 3.5% CABG). Although not cited as an endpoint, relief of angina was substantially greater in the CABG group (89.5%) than in the PCI group (78.9%) at 1 year. It is noteworthy, however, that the mean age of patients in this study was 61 years for both groups, and the mean ejection fraction was 61% in both groups—suggesting that patients were carefully selected for enrollment in the study. The 5-year follow-up of the ARTS study revealed that there was no difference in mortality between stenting and surgery. However, the disparity in revascularization rates widened further, with a 30.3% re-intervention rate in the stent group versus 8.8% in the CABG group.[9] The SoS (Stent or Surgery) trial similarly randomized 988 patients with symptomatic multivessel CAD to PCI or to CABG. Again, like other randomized trials, the population studied was relatively young (mean age 61 years) and predominantly male (79%). In this study, a mortality difference favoring CABG was observed, with a 2% death rate in CABG patients compared with 5% in the PCI group. Also, the rate of repeat revascularization for PCI, although lower than other studies, remained at 21%, compared with 6% in the CABG group. All patients were followed for a minimum of 1 year, and the median follow-up was 2 years. [10] Lastly, the ERACI II study examined both 30-day and 1-year outcomes in 450 patients randomized to receive either stenting (PCI) or CABG. Although the mean age of both groups was approximately 62 years, 38% of the patients were older than 65 years. At 30 days' follow-up the composite major adverse rate (death, myocardial infarction, repeat revascularization, and stroke) favored PCI with a 3.6% rate versus 12.3% for the CABG patients. At 1 year, the mortality advantage enjoyed by the PCI group remained, with a 96.9% survival in PCI group versus 92.5% in the CABG group. In concert with the other two studies, the rate of repeat revascularization was 16.8% for PCI but 4.8% for CABG. [11]

Though multicenter randomized trials are considered the gold standard for comparing therapies, these trials must be considered in the perspective of other investigations and for the populations of patients in these trials. When one considers the population used in these randomized trials, concerns arise regarding the applicability of their findings to "real world" practice patterns for PCI and CABG. This statement is supported by the reporting of the ERACI II trial—in which nearly 2800 patients were screened to obtain 500 for study (roughly 20% eligibility). Two other retrospective studies add further controversy to the role of PCI versus CABG for the treatment of multivessel CAD. Brener et al at the Cleveland Clinic examined 6603 patients undergoing revascularization at their center in the 1990s; 872 underwent PCI and 5161 underwent CABG. Nearly half the patients had significant left ventricular dysfunction or diabetes mellitus. This group of investigators utilized propensity analysis to attempt to control for selection bias and match the groups as evenly as possible. At 5 years, the unadjusted mortality rate for CABG was 14% versus 16% for PCI. However, when PCI was adjusted for mortality with the propensity model, PCI was found to be associated with an increased risk of death (hazard ratio 2.3, 95% confidence interval [CI] 1.9 to 2.9, $P < .0001$). Thus, in this group of patients with multivessel CAD and many high-risk characteristics, CABG was associated with better survival than PCI. [12] Again, one must also consider the clinical setting of this study to appropriately frame these results. The Cleveland Clinic is a large-volume center with a very low operative mortality rate for CABG.

Perhaps the most intriguing and controversial study to fuel this controversy was conducted by Hannan et al. This retrospective study examined the two mandatory reporting registries for cardiac intervention in New York State. The Cardiac Surgery Reporting System and the Percutaneous Coronary Intervention Reporting System were examined for the endpoint of death or the composite endpoint of death or revascularization over a 3-year period from January 1997 to December 2000. It is remarkable that the median age of PCI patients was 65 versus 67 for CABG patients, and that 38.1% of the PCI patients were aged 70 or older and 42.4% of CABG patients were aged 70 or older. Again, the older age of patients examined reflected the "real world" practice in New York State, unlike the younger patients selected for the randomized studies. The analysis of the survival in both cohorts yielded an advantage for CABG over PCI. For three-vessel disease involving the proximal left anterior descending artery, the adjusted hazard ratio favoring CABG was

0.64. Also, 3-year rates of revascularization were considerably higher for PCI patients than for CABG patients. In the stenting group, 7.8% underwent CABG and 27.3% underwent a subsequent PCI, compared with 0.3% of the CABG group undergoing another CABG and 4.6 % of the CABG group undergoing PCI. [13] These studies will not settle the controversy that continues in the management of the patient with multivessel CAD. The advent of drug-eluting stents has not been fully evaluated yet, but preliminary analyses suggest a much lower rate of need of subsequent revascularization.

The surgical management of CAD has undergone a significant paradigm shift with the advent and development of “beating-heart” or “off-pump” coronary artery bypass (CAB) surgery. On the basis principally of descriptions by Benetti et al [14] and Buffolo et al, [15] surgeons began exploring techniques for conducting multivessel revascularization without the use of cardiopulmonary bypass—so called off-pump CAB. Even though advocates of this technology firmly believe that off-pump CAB is associated with superior outcomes, available data suggest that the avoidance of cardiopulmonary bypass does not necessarily improve outcomes. [16] The use of off-pump CAB has not been extensively studied in elderly patients, although advocates of off-pump surgery often state that this group of patients may benefit from off-pump CAB.

Athanasiou et al published a meta-analysis of nine studies which examined off-pump CAB in patients aged 70 years or older. All nine studies were observational and were published between 1999 and 2002. Noteworthy was the fact that the total number of subjects included was 4475, of which 1253 (28%) underwent off-pump CAB and 3222 (72%) underwent CAB with cardiopulmonary bypass. The overall analysis focused upon neurologic outcomes; stroke was chosen as the primary endpoint. This analysis documented a lower incidence of stroke in elderly patients who had off-pump CAB (1%) versus CAB performed with cardiopulmonary bypass (3%). Several limitations of this study bear comment. Unfortunately, because of the observational nature of this study, it was impossible to match the groups for baseline neurologic function. Second, bias in selection of patients for off-pump CAB is also a potential confounding variable. Last, rigorous definition of stroke varied between studies. [17]

Other studies have shown some specific increased risk profiles in elderly patients undergoing surgical revascularization. CAB following acute myocardial infarction carries added risk for mortality. Kaul et al observed that age 70 years is an independent predictor of early mortality for patients who undergo CAB within 30 days of an acute myocardial infarction. [18] In a study of over 4500 patients undergoing CAB at the Toronto Hospital, patients who had low-output syndrome were found to be aged 70 years or older, resulting in an odds ratio increase of 1.5. [19] 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 CAB, 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. [20]

For elderly patients undergoing CAB, 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. Although age was found to be 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 CAB.[21] With regard to the health status of elderly patients following CAB, Conaway et al examined the symptoms, function, and quality of life in elderly patients and younger patients following CAB. This group administered the Seattle Angina Questionnaire to 690 patients (156 were aged 75 years or older, 534 were younger than 75 years) at baseline and at 1 year post-CAB. The first 224 patients were given the questionnaire monthly for 1 year; the remainder had the questionnaire only at baseline and at 1 year. Of interest, although initial peri-operative mortality was similar (2.6% versus 2.2%) at 1 year, the elderly cohort had a mortality of 11.5% versus 5.4% for the younger group. Recovery of physical function was slower in the elderly group, and a significant age-time interaction existed in the elderly patients, showing a slower time to recovery. At 1 year post-CAB, however, angina relief and quality of life did not differ by age.[22] Hedeshian et al examined whether increasing age has impacts on 6-month functional outcome after CAB. They utilized the Duke Activity Status Index (DASI) and analyzed age-specific cohorts for functional outcomes following CAB. Although the mean baseline DASI score was lower in patients undergoing CAB who were 70 years or older, the 6-month change in DASI scores did not differ between the patients aged 70 or older and those who were younger. Further, when three separate terciles of age were analyzed (age 31–60, age 61–70, and age 71–90), the 6-month changes in DASI did not differ. The authors concluded that patients older than 70 present for CAB with a lower functional level, and they remain at a lower functional level at 6 months post-CAB. The change in functional improvement following CAB, however, does not appear to be affected by age.[23]

Cognitive decline after CAB constitutes a great source of concern for both physicians and patients who undergo the procedure. Indeed, a recent report by van Dijk et al[24] estimated the incidence to be 22.5% of patients following CAB; however, others have estimated the incidence to approach nearly 50%. Ho et al identified several predictors of cognitive decline following CAB. They utilized 994 patients in the VA Processes Structures and Outcomes of Care in Cardiac Surgery study. These patients completed a short battery of cognitive tests at baseline and 6 months following CAB surgery. In this multivariate analysis, patient characteristics associated with cognitive decline included cerebrovascular disease, peripheral vascular disease, history of chronic disabling neurologic illness, and living alone. Years of education and cardiopulmonary bypass time were found to be inversely associated with the risk of cognitive decline. Age did not emerge in the risk model to predict cognitive decline.[25] In contrast, Tuman et al have noted age to be an important risk factor for cognitive decline after CAB.[26]

Another entity that consumes great resources and prolongs hospital length of stay is postoperative atrial fibrillation. Mathew et al examined risk factors for the development of atrial fibrillation after CAB surgery. This study was a prospective observational study involving 4657 patients at multiple centers. The endpoint studied was new-onset atrial fibrillation after CAB. Overall, 1503 patients (32.3%) developed atrial fibrillation after CAB. Risk factors for the development of atrial fibrillation after CAB in this study included a history of atrial fibrillation, chronic obstructive pulmonary disease, postoperative withdrawal of either a β-blocker or angiotensin-converting enzyme inhibitor, and advanced age. Advanced age was quantified by a 10-year increase, with an odds ratio of 1.75

for each 10-year increase.[27] On the basis of this study, anyone older that 70 years of age would be considered to be at high risk of developing atrial fibrillation. When all other preoperative risk factors are considered, advanced age is the most consistent predictor for the development of atrial fibrillation after CAB.[28–30] Multiple hypotheses are offered to explain this increased risk, including structural changes in the atria that occur with age, as well as nonuniform anisotropic conduction in the atria of elderly patients.[31] It bears comment, however, that advanced age alone is a risk factor for the development of atrial fibrillation independently of cardiac surgery, as observed in the Framingham population.

Modification of These Questions in Light of New Research: Research in coronary artery surgery should continue to focus on technical aspects of the operations that allow safer peri-operative management of the elderly CAB patient. In addition, future research should focus specifically on the processes of peri-operative management of sedation, analgesia, arrhythmias, physical and occupational therapies, and cardiac rehabilitation strategies that optimize the physiologic recovery of aged patients undergoing CAB.

VALVE SURGERY

See *New Frontiers*, pp. 155–157.

***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)*: Prospective randomized 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 peri-operative morbidity when thoracoscopic and robotic techniques are employed.**

New Research Addressing These Questions: Aortic stenosis is the most common adult heart valve condition in the Western world. Although the pathophysiology of the development of aortic stenosis is incompletely understood, the pathologic findings include the deposition of calcium about the aortic valve leaflets, in the aortic annulus, and with extension into the aortic sinuses. It is very likely that aortic sclerosis precedes stenosis, with stenosis marking the end stage of this process. Epidemiologic data suggest that aortic sclerosis is present in 20% to 30% of persons aged 65 years or older and 48% of those aged 85 and older. Aortic stenosis is present in 2% and 4%, respectively.[32] Clinical risk factors for aortic stenosis include age, male sex, smoking, diabetes mellitus, hypertension, CAD, and chronic renal failure. Once a patient is diagnosed with aortic stenosis, progression in gradients and velocities are 7 to 8 mm Hg per year and 0.3 meters per second.

These gradients correspond to a decrease in aortic valve area by approximately 0.2 cm^2 per year.[33] The natural history for patients with asymptomatic aortic stenosis closely parallels age- and sex-matched controls. However, with the onset of symptoms of angina, dyspnea, or heart failure, the prognosis changes dramatically without surgery; survival without surgery is only 50% at 2 years. Data regarding elderly patients who progress to symptoms with aortic stenosis are scarce; however, it is suggested that patients aged 70 or over have a worse prognosis without surgery of 2-year survival of only 37%.[34]

The decision process regarding referral of elderly patients for aortic valve replacement (AVR) remains clouded with controversy. Bouma et al surveyed 530 cardiologists in the Netherlands with a six-point scale questionnaire to determine patterns of referral for AVR in elderly patients. This survey with 32 case vignettes contained a scale from 1 to 6 regarding recommendation for AVR (1 = certainly no and 6 = certainly yes) in symptomatic aortic stenosis patients 70 years of age. Of 530 cardiologists, 275 (52%) responded to the survey. A wide variability was observed in the advice scores given. However, by the use of latent class regression analysis, six groups of cardiologists could be identified who within each group arrived at similar recommendations regarding valve replacement. Of these groups, 41% of the cardiologists were principally influenced by age of the patient rather than other clinical variables (valve area, left ventricular function, and comorbidities). Interestingly, comorbid conditions had very little effect on the decision to refer elderly patients for surgery across all cardiologists who participated in this study. The authors concluded that prospective observational studies are needed to appropriately characterize elderly patients who should undergo AVR for aortic stenosis.[35]

Several observational studies regarding outcomes for AVR in elderly patients have been reported. Collart et al sought to assess the pre- and postoperative mortality and morbidity factors in octogenarian patients undergoing AVR in Marseilles, France, during the period 1993 to 2003. They prospectively created a database that yielded 215 patients for study; the average age of patients operated on was 83 years. They further calculated the EuroSCORE for the patients and divided them into three groups—low risk, medium risk, and high risk—on the basis of the scores. Overall, operative mortality for this group was 8.8%; cardiogenic shock with low cardiac output compromising was the principal cause of death. The only preoperative factor that emerged as significant in a multivariate analysis was moderate depression in left ventricular function. Postoperative complications were experienced by 63% of patients; the onset of atrial fibrillation in 31% of patients was the most common complication. From the standpoint of quality-of-life indicators, 65% of patients had an Outcomes Management System (OMS) scale of 0 or 1 (0 = normal life without restriction, 4 = bedridden). Importantly, 77% of patients returned home, and 38% were able to live independently. The 5-year survival curve for this group was similar to the age-matched population without aortic valve surgery.[36]

Chiappini et al retrospectively analyzed outcomes after AVR in octogenarians in Italy. This series consisted of 115 patients treated between 1983 and April 2003 with AVR or AVR with concomitant CAB. The operative mortality was 8.5%, similar to Collart's findings, and the majority of peri-operative deaths occurred secondarily to low cardiac output with peri-operative myocardial infarction. Of interest, mechanical bioprostheses were implanted in 28% of these 115 patients. The 5-year actuarial survival in this group was strongly affected by the choice of prosthesis—it was a relatively robust 82% at 5 years in the bioprosthesis group versus 57% in the mechanical valve group. Among patients undergoing mechanical valve implantation, 22% experienced valve-related complications such as thromboembolic or bleeding events. In their analysis of their outcomes, the researchers identified preoperative ejection fraction, preoperative heart failure, and type of implanted prosthesis (bioprosthetic versus mechanical) as predictors of late death. This group did not undertake a systematic, rigorous analysis of quality-of-life indicators but reported that in telephone follow-up 98% of patients who underwent AVR were satisfied with this decision. [37]

Proponents of minimally invasive cardiac surgical procedures advocate the avoidance of sternotomy in performing AVR to potentially reduce morbidity. Sharony et al reported their experience with minimally invasive AVR in elderly patients. They performed a case-control study analyzing 515 patients aged 65 years or older. Their study cohort included patients who underwent isolated AVR from 1995 to 2002 at their institution. They matched 189 patients who had minimally invasive AVR with 189 patients undergoing AVR with conventional sternotomy. The minimally invasive group had either a small third intercostal space thoracotomy or a mini-sternotomy. Overall in-hospital mortality was identical in both groups—6.9%. Similar to other investigations, this analysis, by the use of multivariate analysis, showed that preoperative congestive heart failure, urgent or emergent status of operation, ejection fraction, and increasing age are risk factors for mortality. Complication rates also were similar in the two groups; however, the hospital length of stay was lower in the minimally invasive group—11 days versus 14 days in the conventional sternotomy group. A greater percentage of patients with minimally invasive AVR were discharged home—53% versus 38% in the group receiving conventional treatment. Acknowledging the limitations in retrospective case-control studies, these researchers concluded that minimally invasive techniques can be safely applied to AVR patients aged 65 and older. [38]

Mitral valve surgery in the elderly patient is much less well characterized than AVR. The natural history of mitral valve disease does not seem to have the same proclivity for aging-related changes with sclerosis and stenosis as is seen in the aortic valve. Kolh et al describe peri-operative outcomes and long-term results in patients undergoing cardiac surgery operations. Of the 182 patients reviewed who had cardiac operations from 1992 to 1998, only 12 patients had mitral valve surgery. Of this subgroup of 12 patients, mitral valve replacement was performed in 9 (75%) of these patients. This group could not offer any statistical insights into mitral valve surgery in the elderly age group with this small number of patients. However, peri-operative mortality was substantial: 25% of patients died. Despite the low number of patients, the authors conclude that mitral valve surgery should be offered only to patients without any other therapeutic option who remain without any other significant comorbid conditions. [39]

Mitral valve repair has become the preferred method of cardiac surgeons for addressing mitral valve regurgitation. Lee et al examined the feasibility and outcomes for mitral repair in elderly patients by reviewing their experience with 140 patients operated upon for mitral regurgitation, 44 of whom who were aged 70 years or older. Multivariate analysis indicated that preoperative cardiogenic shock but not age was a risk factor for death. The older patients in this group suffered more atrial fibrillation, prolonged ventilation, and hospital stay. The overall mortality approached 9.1% in those aged 70 or over versus 5.2% in the younger group. The researchers concluded that mitral valve surgery should not be denied to appropriate candidates on the basis of age alone. [40] (See also the new Key

Question in the section New Horizons in Geriatric Cardiac Surgery at the end of the chapter.)

Modification of These Questions in Light of New Research: Valvular heart surgery can be safely conducted in the elderly patient. No change in the research agenda is recommended.

REOPERATIVE CARDIAC SURGERY

See *New Frontiers*, pp. 158–159.

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.**

New Research Addressing These Questions: Reoperative surgery in elderly patients carries a profound 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 functional classification and more generalized atherosclerosis. 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.[41] In an analysis comparing reoperative CABG and primary CABG, Christenson et al 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.[42] Weintraub et al reviewed the course of 2030 patients who underwent CABG and noted that in-hospital mortality increases from 5.7% for patients younger than 50 years to 10% for patients aged 70 and older. Neurologic events were found to occur at a significantly higher rate in older patients undergoing reoperative surgery, with an incidence of 4.1% for those patients aged 70 and older.[43] Pellegrini et al noted higher 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.[44] With regard to long-term survival, Noyez and van Eck studied 541 patients with reoperative CABG. They found age lower than 65 years to be associated with greater cardiac survival, but impaired left ventricular function to be the only independent variable predicting late cardiac-related mortality.[45]

Modification of These Questions in Light of New Research: Reoperation carries increased risk for the elderly patient, and research in this area remains very important. No change in the research agenda is recommended.

AORTIC DISSECTION

See *New Frontiers*, p. 159.

> ***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 peri-operative complications.**

New Research Addressing These Questions: Type A aortic dissection constitutes a true surgical emergency with an extremely poor prognosis for patients who do not undergo operative management with replacement of the ascending aorta. Many studies have evaluated both CAB and AVR in the elderly patient, but aortic dissection has not been examined in great detail. Indeed, Mehta et al were the first to examine the International Registry of Acute Aortic Dissection (IRAD) to compare the outcomes in patients younger than 70 with patients aged 70 years or older. This retrospective study covered the period of January 1996 to December 1999. A total of 550 patients were reviewed, 174 (32%) of whom constituted the older cohort. With regard to the presentation, the older patients with type A dissection are much less likely than their younger counterparts to present with abrupt onset of chest or back pain and lower systolic blood pressure. Relatively fewer elderly patients were managed surgically (64% versus 87%), and comorbid conditions were listed as the principal reason that surgical therapy was deferred. Peri-operative complications (coma, myocardial infarction, acute renal failure, and cardiac tamponade) were similar in the two groups. Mortality for the younger patients undergoing surgical repair was 38% versus 27% for the older patients. Logistic regression analysis identified age above 70 as an independent risk factor for death with type A aortic dissection. The limitations of this analysis are consistent with those of most retrospective studies; however, this investigation provides multicenter data regarding higher mortality in patients aged 70 and older with type A aortic dissection.[46]

Contrasting findings were reported by Chiappini et al in their retrospective analysis of single-center experience with type A aortic dissection. This group analyzed 315 patients who underwent surgery for type A dissection between 1976 and 2001; of this sample, 245 patients were younger than 70, and 70 were aged 70 years or older. The data show that in-hospital mortality did not differ between the two groups—20.5% in those younger than 70 and 17.6% in those 70 and older. Longer term actuarial survival did not differ between groups—77.1% in the younger patients and 80% in the older patients. These researchers concluded that surgery for type A aortic dissection can be performed with acceptable results in patients aged 70 and older. Furthermore, they concluded that surgery should not be withheld in this group of patients solely because of age. [47]

Type B aortic dissections traditionally include older patients with comorbid conditions. The management of type B aortic dissections usually involves medical therapy unless specific complications develop to mandate operative intervention. Mehta et al investigated the outcomes of elderly patients with type B aortic dissection in the IRAD registry. They examined 383 patients with type B aortic dissection and compared a group of 161 patients (42%) who were aged 70 or older with 222 patients (58%) who were younger than 70. This analysis was retrospective, as well. The comorbid conditions of hypertension, diabetes mellitus, prior aneurysms, and arteriosclerosis were more common in elderly patients. Overall, in-hospital mortality was higher in the elderly cohort—16% versus 10% in the younger group. Multivariate logistic regression analysis identified three risk factors that greatly increase mortality in the elderly cohort. The presence of shock with hypotension, the involvement of a branch vessel in the dissection, or the presence of a periaortic hematoma places the patient aged 70 or older in a high-risk category, in which mortality is 35%. Without one of these three adverse predictors, the mortality was found to be less than 2%. It is also noteworthy that the older group with an operation fared least well, which is in agreement with other investigations regarding the surgical results with type B aortic dissection. [48]

Another increasingly common clinical scenario for type A aortic dissection involves patients with prior cardiac surgical procedures presenting with acute type A dissection. Collins et al retrospectively examined a group of 100 patients in the IRAD registry with acute type A dissection and prior cardiac surgery. This group was more likely to be male and elderly. Multivariate analysis revealed that age above 70 years, previous AVR, shock, and acute renal failure were all independent predictors of in-hospital mortality. [49]

Modifications of These Questions in Light of New Research: The treatment of aortic dissection in the elderly patient remains an important issue, and more studies of the types described here are needed. No change in the research agenda is recommended.

COMPLICATIONS OF CARDIAC SURGERY

See *New Frontiers*, pp. 160–161.

***CardiacSurg 29 (Levels B, A)*: Exploratory cohort studies are needed to seek evidence of success with treatments designed to reduce peri-operative 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.**

New Research Addressing These Questions: Atrial fibrillation after cardiac surgery is arguably the most common complication following cardiac surgery. The exact incidence of postoperative atrial fibrillation varies, as different studies document a rate from as low as 20% to over 60%. The reasons for this wide variation principally include differing methods of diagnosis in studies, lack of a consistent definition for postoperative atrial fibrillation, differing rates with type of cardiac surgery, and patient demographics. The onset of atrial fibrillation is generally between the second and fourth postoperative days; however, this complication can occur at any time during the peri-operative period. In fact, this complication is also the leading cause of readmission following cardiac surgery. [50]

Mechanisms of atrial fibrillation are not universally agreed upon and are incompletely understood. A unifying hypothesis suggests that re-entry is the central mechanism whereby the atria become chaotic, and there is a lack of uniformity to dispersion of the atrial impulse. Multiple factors may promote atrial fibrillation, including operative trauma during manipulation of the heart, pericardial inflammation, endogenous and exogenous heightened levels of circulating catecholamines (epinephrine), anemia, pain, local atrial stretch with volume changes, and alteration of sympathetic or vagal tone.

Risk factors for atrial fibrillation have been extensively investigated. Overall, the literature is somewhat inconsistent because of a lack of uniformity in patient monitoring for atrial fibrillation, differing definitions of what constitutes atrial fibrillation, and heterogeneous patient populations. However, accepting these limitations, the variable that most consistently appears as an independent risk for atrial fibrillation following cardiac surgery is increasing patient age. A common hypothesis for relating patient age to the development of postoperative atrial fibrillation is age-associated changes in the atria of elderly patients. As patients age, the deposition of lipofuscin increases greatly in the atria, and this phenomenon may be related to alterations in atrial electrophysiology. Another potent risk factor that is modifiable is the withdrawal of β-blockers. Ali et al noted that withholding β-blockers after cardiac surgery doubles the incidence of atrial fibrillation from 17% to 38%. [51]Though atrial enlargement is noted in population-based studies to be a risk factor for the development of atrial fibrillation, its role as a causative factor for atrial fibrillation following cardiac surgery is less clear. Shore-Lesserson et al measured left atrial dimensions with transesophageal echocardiography during cardiac surgery and found that size of left atrial chamber was not predictive of postoperative atrial fibrillation.[52] Last, speculation abounds that postoperative atrial fibrillation occurs in patients who are prone to develop atrial arrhythmias. Steinberg et al analyzed signal-averaged electrocardiograms in patients undergoing cardiac surgery. They established that a p-wave duration > 140 ms identified risk for atrial fibrillation.[53] Others have also reported that a history of atrial fibrillation predisposes a patient to postoperative atrial fibrillation.

A paradigm shift in cardiac surgery has recently included the realization that atrial fibrillation is not a “benign” condition. Mathew et al[27] analyzed outcomes in patients developing atrial fibrillation after cardiac surgery and found a nearly threefold increase in peri-operative stroke. Lahtinen et al also documented that 36% of postoperative strokes result from the development of atrial fibrillation. Their data suggested, on average, 2.5 episodes of atrial fibrillation that preceded the stroke.[54] In addition to contributing to poor outcomes, the postoperative atrial fibrillation entails the use of considerable extra resources. Aranki et al provided a very thorough analysis of 570 patients undergoing CAB and investigated postoperative length of stay and hospital charges associated with the development of atrial fibrillation. They noted that the development of postoperative atrial fibrillation increases the length of stay by 4.9 days. In addition, the excess charges incurred by a patient who develops atrial fibrillation were approximately $11,000.[55] When one considers the large number of patients who develop postoperative atrial fibrillation, the enormous societal costs of this arrhythmia become apparent.

Pharmacologic prophylaxis against atrial fibrillation has proven difficult. In total, 91 randomized controlled trials have examined a variety of agents, including β-blockers (propranolol, atenolol), antiarrhythmic drugs with β-adrenergic receptor blocking effects (sotalol, amiodarone), digitalis, magnesium, and various other agents. On the basis of a review of these trials, the American College of Chest Physicians released guidelines for pharmacologic prophylaxis. Essentially, the use of Vaughn-Williams β-blockers is recommended, with consideration being given to sotalol and amiodarone if therapy with Vaughn-Williams Class II β-blockers is contraindicated. Digitalis, magnesium, and calcium channel antagonists (diltiazem and verapamil) were not recommended as prophylactic agents to prevent postoperative atrial fibrillation.[56]

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 patients over a 5-year period, Borger et al noted that advanced age is an independent risk factor for the development of serious sternal wound infection.[57]

Delirium in elderly patients following heart surgery is often attributable to multiple causes. The chapter on cross-cutting issues addresses this common geriatric surgical complication. (See *New Frontiers,* pp. 401–402.)

Modification of These Questions in Light of New Research: Complications associated with cardiac surgical procedures unfortunately are far too prevalent, and they have a profoundly negative impact upon outcomes in the elderly population. Further research in this area is needed and no modification of the research agenda is recommended.

STROKE, NEUROLOGIC DEFICITS, AND CARDIAC SURGERY

See *New Frontiers*, pp. 162–163.

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.**

New Research Addressing These Questions: Stroke is a leading cause in the United States of serious long-term disability. The vast majority of strokes occur in people aged 65 and older. With the increasing age of patients undergoing cardiac surgical operations, the aged population is certainly at higher risk for age-related adverse cerebrovascular events.

Determining the incidence of stroke after cardiac surgical procedures remains imprecise because of the different methods used to calculate neurologic events after cardiac surgery. McKhann et al reviewed this subject and illustrate the variance in reported rates of stroke. They note that, depending on whether stroke incidence is obtained prospectively or retrospectively, the incidence following CAB can vary considerably. Prospective risk of stroke is estimated at 1.5% to 5.2%, whereas the retrospective incidence is estimated at 0.8% to 3.2%. Further, the timing of postoperative stroke is quite difficult to estimate when retrospective methods are applied. These researchers have found, however, that the 65% to 85% of strokes following CAB or CAB with valve or valve surgery appear within the first 2 days of surgery. [58]

Identifying patient groups at higher risk for cerebrovascular accident following cardiac surgery has inherent advantages. Patients can be adequately informed of their risk in discussions regarding surgery, and other intraoperative and postoperative maneuvers can be undertaken to mitigate this risk. Nearly all studies uniformly confirm that a history of prior stroke remains as one of the most robust risk factors for stroke after cardiac surgery. Baker et al reviewed a large experience with 4380 patients undergoing CABG in their center. They identified seven predictors of postoperative stroke: previous stroke, diabetes mellitus, age, hypertension, the presence of cerebrovascular disease, elevated creatinine, and preoperative atrial fibrillation. Of these risk factors, the odds ratio for prior stroke was 6.3, and it far outweighed the other factors with regard to predictive ability. Increasing age had a modest odds ratio of 1.1. Noteworthy in this report was the excess in resources that patients who developed stroke consumed. A postoperative stroke increased the intensive care unit (ICU) length of stay by 4 times, doubled the overall length of hospital stay, and increased the mortality at 30 days by a factor of 10. [59]

If a patient does incur a stroke following cardiac surgery, the short- and long-term outcomes are poor. Salazar et al analyzed the Johns Hopkins Cardiac Surgery Stroke Database and determined what the early and late outcomes were for patients with stroke. Their overall incidence of stroke following CAB was 3.2%, with combined CAB–carotid endarterectomy having the highest incidence of 17.3% of peri-operative stroke. The impact of stroke upon early outcomes was impressive. Stroke doubled the ICU length of stay from 3.6 to 7.3 days, nearly tripled the overall hospital length of stay from 10 to 25 days, doubled the hospital charges from $30,000 to $60,000, and more than quadrupled the mortality from 4% to 19%. These researchers were able to follow up via telephone interview with 99% of the stroke patients, at a mean of 1.89 years following cardiac surgery. Overall survival after stroke was 67% at 1 year and 47% at 5 years; this survival was not compared with an age-matched population cohort, but it would appear that the occurrence of stroke significantly compromised long-term survival. Functional status was assessed at the time of telephone interview by Rankin Scale. Of the 81% of patients who survived to discharge following stroke, only 39% lead a life with minimal disability. Stated differently, nearly two thirds of patients who sustain a stroke after cardiac surgery will die early or be significantly disabled. [60]

The cause of stroke following cardiac surgery is usually multifactorial and not likely to be pinpointed on one specific factor. The leading culprits include embolic debris, hypoperfusion during cardiopulmonary bypass, and perhaps the early postoperative development of atrial fibrillation. Although large embolic events during cardiac surgery are much less common, the persistence of microembolic debris remains problematic. Embolic debris can include gaseous or particulate matter. Particulate matter includes microscopic thrombi (despite anticoagulation with heparin), lipid material, and atherosclerotic material from the ascending or transverse aorta. Indeed, Djaiani et al performed TEE, transcranial Doppler (TCD), and epiaortic scanning during the conduct of CAB in their institution. Patients then underwent postoperative brain magnetic resonance imaging (MRI) on days 3 to 7 after their CAB. These researchers divided the patients into those at low risk (intimal thickness on TEE and epiaortic scan $\leq$ 2 mm) and at high risk ($>$ 2 mm) for cerebral events. A strong correlation was observed between the high-risk group and number of embolic episodes by TCD, and only the high-risk group had changes seen on MRI consistent with ischemic injury. The researchers concluded that at least mild to moderate atheromatous burden in the thoracic aorta correlates with brain injury following CAB. With regard to when embolic events occur, they are most likely to occur during manipulation of the aorta for cannulation for cardiopulmonary bypass or cross-clamping or unclamping the aorta. [61]

Cerebral hypoperfusion during cardiopulmonary bypass (CPB) invariably occurs; however, firm evidence is still lacking to determine the level of hypoperfusion necessary to produce reversible injury. It is widely theorized that risk factors such as diabetes mellitus and hypertension contribute to a microvascular dysautoregulation in the brain during CPB that can produce ischemic brain injury. However, investigative efforts to either affirm or disprove this hypothesis remain inconclusive. In fact, the optimal mean arterial pressure that should be maintained during CPB is still unknown. Gold et al actually randomized

124 patients to a low mean arterial pressure (50 to 60 mm Hg) and compared them with a group with high mean arterial pressure (80 to 100 mm Hg) during CPB. These researchers observed a lower incidence of combined cardiac and neurologic complications—4.8% versus 13% in the higher mean arterial pressure group.[62] Further investigation of this area, however, is needed to more clearly refine the relationship between risk factors for cerebral hypoperfusion and ischemic brain injury after cardiac surgery.

Encephalopathy or diffuse brain injury following cardiac surgery remains an equally vexing and troublesome complication. This complication is variably known as confusion, delirium, coma, seizures, prolonged alteration in mental status, combativeness, and agitation. The incidence of encephalopathy varies widely; reports range from 8% to over 30% following cardiac surgery. McKhann et al prospectively examined the impact and risk factors for encephalopathy in patients undergoing CAB. They identified five risk factors for the development of encephalopathy: prior stroke, the presence of a carotid bruit, diabetes mellitus, hypertension, and incremental age > 65 and age > 75. The development of encephalopathy after CAB, in a similar manner to stroke, doubled hospital stay from 6 days (no encephalopathy) to 15 days, and increased mortality from 1.7% (no encephalopathy) to 7.5%.[58] The mechanisms underlying the development of encephalopathy remain largely unknown. These five risk factors likely point toward a vascular mechanism whereby either an ischemic or inflammatory insult is inflicted upon the brain, which then exhibits a spectrum of functional impairments.

Modification of These Questions in Light of New Research: Review of the available data indicates that either stroke or encephalopathy following cardiac surgery profoundly and negatively impacts both short- and long-term outcomes for older patients. No modification of the research agenda for this important area is recommended.

THE OCTOGENARIAN AS CARDIAC SURGICAL PATIENT

See *New Frontiers*, pp. 163–165.

***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.**

New Research Addressing These Questions: Although the majority of contemporary health care providers do not exclude patients from being considered for a cardiac operation on the basis of age alone, Rady et al questioned whether elderly patients are capable of making an informed decision regarding cardiac surgery. They conducted a cohort study of 96 octogenarians undergoing cardiac surgery and compared their outcomes with those of a younger group of 687 patients undergoing cardiac surgery. They also examined the use of hospital and Medicare expenses for both groups of patients. The cohorts examined differed in that the octogenarians were more likely female, and the comorbid conditions of pulmonary hypertension, previous malignancy, cerebral vascular disease, valvular heart disease, and congestive heart failure were more common in octogenarians. The rate of postoperative complications—cardiovascular, neurologic, and renal complications and nosocomial infections—was substantially greater in the elderly cohort than in the younger group. Most striking was the rate of death or discharge to a nursing facility: 53% in the over-80 group compared with 14% in the younger group. Hospital charges were greater in the elderly group. In multivariate analysis, these researchers found female sex, age 80 or older, congestive heart failure, and surgical re-exploration to be independent factors for death or discharge to a nursing facility. Given these outcomes, these investigators appropriately questioned the cost-effectiveness of referring elders aged 80 or older for cardiac surgery.[63]

Great strides have been undertaken to optimize outcomes following cardiac surgery in elderly patients. Though much attention has been focused on postoperative processes of care, growing interest in optimizing physical functional reserve before surgery now exists. This concept of enhancing physical function prior to elective surgery is now termed *prehabilitation*. Carli and Zavorsky reviewed the available literature and noted striking improvements in 275 elderly patients undergoing cardiac or abdominal surgery. In various programs of aerobic training and strength conditioning, improvement was noted in fewer complications, shortened time in the hospital postoperatively, and improvement in health-related quality of life.[64] It remains cogent to remember that prehabilitation can be offered only to patients undergoing elective cardiac surgical operations. Though limited, this therapy is intuitively attractive and is likely to offer an important adjunct to all other therapies directed at improving surgical outcomes for elderly patients.

Modification of These Questions in Light of New Research: No change in the research agenda in this important topic is recommended.

QUALITY OF LIFE AFTER CARDIAC SURGERY

See *New Frontiers*, pp. 166–167.

> ***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 peri-operative 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.**

New Research Addressing These Questions: A primary indication for undergoing cardiac surgery is to relieve symptoms of angina (CAB) or valvular-related pathology (aortic and mitral valve surgery). Until recently, data addressing quality of life after cardiac surgery was limited. As our population of aging patients is increasingly being considered for these invasive operations, it is desirable to offer improvement in health-related quality of life as well as improvement in survival.

Data derived from the Department of Veterans Affairs Processes, Structures, and Outcomes in Cardiac Surgery study yielded important insights into quality of life after CABG. Rumsfeld et al administered the Medical Outcomes Study Short Form 36-item health survey (SF-36) to elective CAB patients at baseline (preoperatively) and at 6 months or more after CAB; 1744 patients responded. The SF-36 variables were divided into a physical component summary (PCS) and a mental component summary (MCS). Both the PCS and the MCS were scored from 0 to 100, with a higher value reflecting better health status. On average, both physical and mental health status improved following CAB. The major determinant of change in quality of life following CAB was the preoperative health status. Patients with lower PCS or MCS scores were likely to enjoy the greatest positive change in quality of life after surgery, whereas patients with a higher preoperative score were less likely to have an improvement in quality in life.[65] In counseling patients about surgery, one should therefore perhaps offer patients with good preoperative health status CAB primarily for improved survival.

While many resources and much attention are devoted to the early outcomes and optimization of in-hospital outcomes following cardiac surgery for the elderly patient, outcomes in the longer term are important as well. Herlitz et al administered three separate quality-of-life questionnaires to the patients undergoing CABG. Patients answered three self-administered questionnaires—the Physical Activity Score, the Nottingham Health Profile, and the Psychological General Well-Being Index—at the time of their coronary angiography and postoperatively at 3 months and 1, 2, 5, and 10 years. Of the 2235 patients undergoing CAB, 637 responded before their surgery and at 10 years following CAB. Two factors independently predicted an inferior quality of life after 10 years with all three instruments: history of diabetes mellitus and chronic obstructive pulmonary disease. Not surprisingly, when these investigators introduced the variable of an inferior quality of life preoperatively, it was found to independently and strongly predict inferior quality of life at 10 years follow-up. Age did not consistently emerge as a strong predictor of impaired quality of life. [66]

Investigations specifically addressing long-term quality of life in elderly patients after cardiac surgery remain limited. Sjogren and Thulin undertook an analysis regarding the quality of life in octogenarians after cardiac surgery. SF-36 questionnaires were completed by 41 octogenarian patients at a mean follow-up of 8 years after their cardiac surgery, either CAB, AVR, or AVR with CAB. The results from this cohort were compared with an age-matched population. Two of the SF-36 headings differed significantly between the cardiac surgical patients and their age-matched cohorts: bodily pain and physical functioning. Although the cardiac surgery group had lower physical function scores, they had less pain in comparison with the overall population. On the basis of these results, these authors concluded that a selected population of elderly patients may undergo heart surgery with good long-term quality of life. [67]

NEW HORIZONS IN GERIATRIC CARDIAC SURGERY

With the explosion in the aging population and the prevalence of cardiac disease in the aged population, more cardiac surgical procedures will be performed in elderly patients. Even though the paradigm for the treatment of CAD continues to shift toward percutaneous approaches, a need for coronary artery surgery will remain in our older population. The impacts of newer technologies, such as off-pump surgery, are yet to be determined, and whether elderly patients will benefit from these techniques is still unknown. Cardiac surgical operations can be offered to elderly patients safely and with reasonable results—assuming that patients are appropriately selected.

Accurate data are needed to determine the population at risk for heart disease and to target groups who will benefit from surgical intervention. Primary care for elderly patients should include surveys and population-based data to ensure that referral bias is not excluding aged patients for surgery because of their age alone. Close collaboration between cardiologists, geriatricians, and cardiac surgeons must also occur to ensure optimal delivery of appropriate care for the management of heart disease in these patients.

CardiacSurg KQ4: **Does ageism adversely affect appropriate consideration of patients for cardiac surgical procedures?**

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