Cardiac Surgery in the Elderly

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Joshua B. Goldberg

The United States Census Bureau estimates by 2030, 20% of the United States will be older than 65, accounting for over 78 million people [1]. Cardiovascular disease is a leading cause of morbidity and mortality among all adult patients. Independent of age, gender, or ethnicity, heart disease accounts for greater than 20% of deaths in the United States [2]. With advancing age, heart disease becomes far and away the leading cause of death, accounting for over 25% of all deaths. Furthermore, the proportion of deaths attributed to heart disease increases with age. According to the CDC, among people aged 45–64, heart disease accounts for 20.8% of deaths, 25.1% of deaths among patients greater than 65, and 28.6 of deaths among patients greater than 85 (Fig. 13.1). Furthermore, the incidence and prevalence of cardiovascular disease is only expected to increase as the population continues to age.

Cardiac surgery is a surgical subspecialty that focuses on the surgical management of diseases of the heart and great vessels. Given the aging population and the incidence, prevalence, and associated mortality of cardiovascualr disease among the patients of advancing age, cardiac surgery is a field largely focused on the care of the elderly population. For instance, the average age of patients undergoing coronary artery bypass grafting or aortic valve replacement, two of the most commonly performed cardiac surgical procedures, is 74 years [2, 3]. Furthermore, recent advances in the management of valvular heart disease has resulted in surgeries being routinely performed on octogenarians and nonagenarians. This chapter will focus on the surgical management of coronary artery disease, valvular disease, and aortic pathology in the elderly population. Each section will consist of a general overview of the disease process, its specific focus on older patients, procedural outcomes, and quality of life in the elderly.

J. B. Goldberg (✉)
Department of Surgery, Division of Cradiothoracic Surgery, Westchester Medical Center and New York Medical College, Valhalla, NY, USA
e-mail: Joshua.Goldberg@wmchealth.org

R. Latifi (ed.), *Surgical Decision Making in Geriatrics*,
https://doi.org/10.1007/978-3-030-47963-3_13

Coronary Artery Disease in the Elderly

Coronary artery disease (CAD) is defined as flow limiting obstruction to one or more coronary artery(ies). CAD is the most common form of heart disease in the general population. It is present in 12% of the general population and 20% of people over 65 [4, 5].

CAD is not only common, but it is a source of considerable morbidity and mortality. CAD represents the leading cause of death among men and women of advancing age. Obstructive coronary artery disease (CAD) is defined as a greater

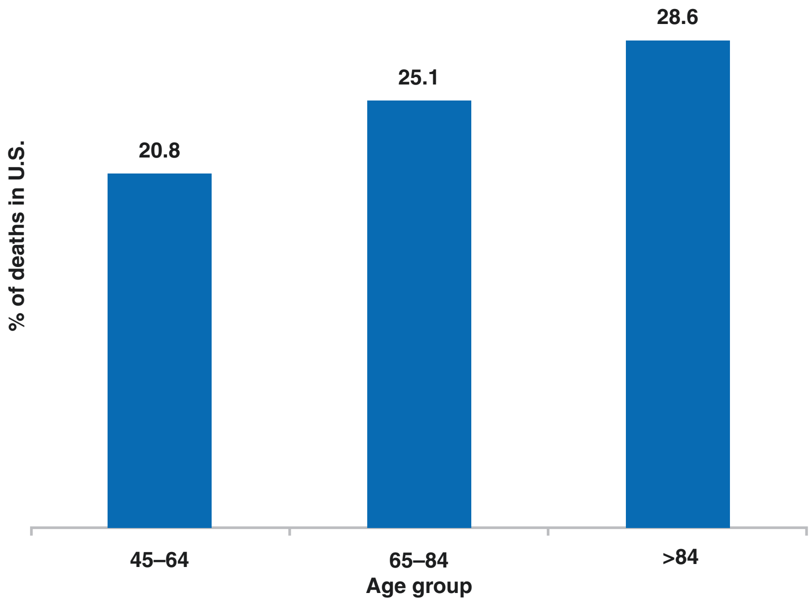

Fig. 13.1 Percentage of deaths in the United States due to heart disease increases with age. (From Centers for Disease Control and Prevention (CDC) [4])

than 50% obstruction of one or more coronary arteries. Obstructions are due to the accumulation of atherosclerotic plaques composed primarily of cholesterol and calcium that accumulate over many years. An atherosclerotic plaque can grow in size, resulting in limitations of downstream myocardial perfusion causing angina or myocardial infarction. Alternatively, atherosclerotic plaques can rupture showering atherosclerotic debris downstream while triggering platelet and coagulation factor activation which may also result in angina and myocardial infarction.

There are numerous genetic, comorbidity, and lifestyle components that contribute to the development of CAD, including diabetes, tobacco use, hypercholesterolemia, obesity, and diet. However, age has been thought to be the number-one associated condition linked with CAD as the deleterious effects of various chronic conditions and atherosclerosis accumulate over time. The incidence and prevalence of CAD increases with advancing age. Approximately 6% of patients between 45 and 65 are diagnosed with CAD, 14% between 65 and 75, and 24% greater than 75 (Fig. 13.2) [5]. The natural history of CAD culminates in decreased myocardial perfusion, resulting in angina or myocardial infarction. As expected, the incidence of MI and deaths from CAD increase with age (Figs. 13.1 and 13.3). There is an annual incidence of MI in patients <60 of approximately 3% which increases to 17% in patients over 80 [5].

There are 3 main treatment modalities for coronary artery disease: medical management, percutaneous therapies, and coronary artery bypass grafting. Medical management primarily consists of cholesterol-lowering therapies with lifestyle modification and medications such as statins, antihypertensives, and other preventive therapies. Percutaneous therapies and coronary artery bypass grafting are utilized when coronary artery disease progresses to a symptomatic level, resulting in angina or myocardial infarction. Percutaneous interventions (PCI) include: angioplasty or stent placement via a femoral or radial artery percutaneous puncture. In the setting of acute ST elevation MI, PCI is a preferred intervention as long as the patient's anatomy is sufficient. In addition, PCI is a preferred modality in patients with single or double vessel coronary artery disease with suitable anatomy for stent placement.

In the setting of multivessel coronary artery disease, left main coronary artery disease or left main equivalent coronary artery disease, diabetes, patients with heart failure

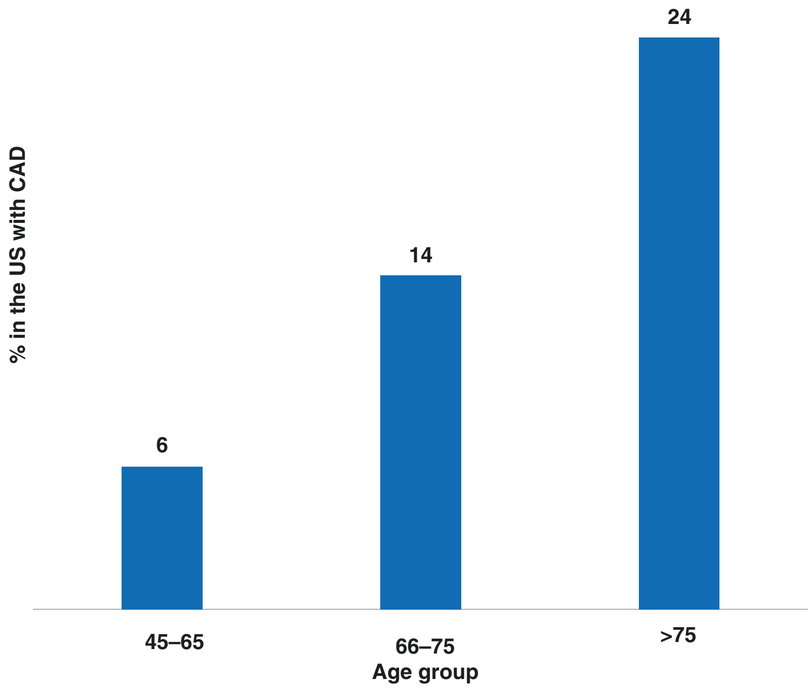

Fig. 13.2 Prevalence of CAD in the United States increases with age. (From Centers for Disease Control and Prevention (CDC) [4])

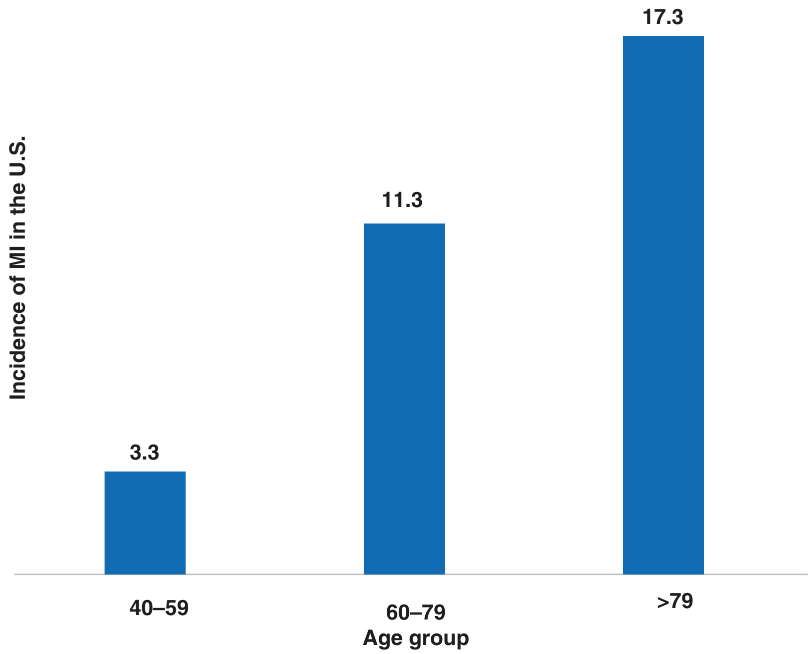

Fig. 13.3 Increasing prevalence of MI in United States with advancing age. (From Centers for Disease Control and Prevention (CDC) [4])

or reduced ejection fraction, coronary artery bypass grafting (CABG) is the recommended treatment modality as it has been shown to improve survival and freedom from future coronary events [2, 6].

Traditionally, CABG consists of a median sternotomy and bypassing significant coronary lesions utilizing a variety of arterial and venous conduits while on cardiopulmonary bypass. The left internal mammary artery (LIMA) is typically harvested from the chest wall, leaving its origin from the left subclavian artery intact. Due to its unique histologic and biochemical properties, the LIMA is typically anastomosed to the left anterior descending artery, the artery which perfuses the major portion of the left ventricle as well as the interventricular septum. A combination of saphenous vein grafts and/or other arterial grafts (right internal mammary artery or radial artery) are used to bypass the remaining diseased coronary arteries.

While a detailed discussion of bypass conduit choice is outside the scope of this chapter, it is important to understand that age and comorbid conditions influence the choice of bypass conduits. With rare exception, the disease of the LAD will be bypassed utilizing the LIMA. In general, the use of bilateral IMAs is reserved for younger patients (<65 years old) and those with few chronic conditions (no diabetes, smoking, immunosuppression, obesity) as bilateral IMA use is associated with sternal healing and infectious complications in older patients as well as those with significant comorbidities. It is important to mention that in the current era most saphenous veins are harvested in a minimally invasive, endoscopic technique that minimizes early mobility limitations compared with traditional, open saphenous vein harvest techniques which entailed an incision along the length of the saphenous vein. Lastly, radial artery harvest is typically performed with an open technique (incision from elbow to wrist) in most centers and can result in early mobility limitations, especially among patients who may be walker dependent. Thus, in older or polymorbid patients, bypass with LIMA and saphenous veins is preferred.

The safety and efficacy of CABG among all patients, independent of age, has been well established. Decades of large, multicenter series, national and international databases, and randomized controlled trials have concluded that, in the general population, CABG is a low morbidity and mortality procedure with an expected mortality of <1% [2, 6]. In comparison to PCI, multiple large randomized trials have concluded that CABG is superior to PCI in terms of survival as well as freedom from future coronary events. Long-term follow-up has demonstrated that CABG is cost effective with superior quality of life compared with PCI. The superiority of CABG has held true even with advances in stent technology as well as medical management.

The safety and efficacy of CABG observed in the general population also holds true with advancing age. In the not so distant past, a patient's age greater than 70 and definitely 80 was considered a relative contraindication for CABG and open heart surgery in general. However, numerous publications have demonstrated the safety of CABG performed in octogenarians as well as nonagenarians. While older patients undergoing CABG tend to have more acute presentations and more comorbidities than younger cohorts, short- and long-term survival are excellent. Overall CABG-associated mortality among octogenarians is around 2–4% with an approximate 5-year survival of 76%. Patients between 80 and 85 undergoing isolated CABG have a median survival of 7.4 years while patients ≥85 have a median survival of 5.4 years [7]. Thus, contemporary data concludes that CABG is a safe option for well-selected older patients.

When treating patients at extremes of age optimizing quality of life is often the prevailing goal of the patient and physician over increasing long-term survival. Exertional chest pain, dyspnea, and/or heart failure associated with CAD can be debilitating. Thus, in some patients of extreme age the goal of surgery may be symptomatic relief rather than long-term survival. Contemporary data has demonstrated that CABG among the elderly and debilitated results in improved quality of life and decrease in future cardiac events compared to medical management or PCI [8].

Innovations in cardiac surgery technique will likely positively impact the elderly population. Hybrid revascularization is a concept that is growing in popularity especially among higher risk surgical cohorts. Hybrid revascularization entails robotic LIMA dissection and LIMA to LAD anastomosis through a small right thoracotomy incision without the need for cardiopulmonary bypass with PCI revascularization of the remaining diseased vessels. This revascularization strategy takes advantage of the long-term patency of the LIMA to LAD anastomosis without the morbidity and mortality associated with a sternotomy and cardiopulmonary bypass. Preliminary data suggests the safety and efficacy of this strategy especially in higher risk and frail patients.

Thus, CABG can increase the longevity and quality of life of older patients including octogenarians and nonagenarians. As with other surgical procedures, patient selection is critical to a successful procedure and postoperative course. Age, in and of itself, should not deter a patient, or a patient's provider from the consideration of CABG in the setting of significant coronary disease.

Valvular Heart Disease

Valvular heart disease is a heterogenous assortment of independent and at times interdependent disease processes resulting from dysfunction of the aortic, mitral, pulmonic, and/or tricuspid valves. By far, aortic and mitral valvular diseases are the two most common valvular pathologies and will be the focus of this chapter [9]. While valvular heart disease is less prevalent than CAD (present in approximately 3% of the general population), it represents approximately 20% of open-heart surgical procedures. As with CAD, the incidence and prevalence of valvular heart disease increases with advancing age.

Aortic Valve Disease

The aortic valve represents the most common valve requiring surgery. The disease of the aortic valve can present in two, not mutually exclusive, forms: stenosis or regurgitation. Aortic insufficiency (AI) is the least common. It can be caused by a number of pathophysiologic processes including leaflet dysfunction, aneurysmal disease, connective tissue disorders, endocarditis, or aortic dissection. Primary AI is less common in older patients compared with younger patients due to a link with connective tissue disorders which tend to present at younger ages. There is a grading system based primarily on echocardiographic-derived hemodynamic parameters combined with clinical features which ranges from mild to severe. Surgery is indicated in the setting of severe symptomatic AI [10]. Most patients are able to tolerate gradual increasing severity with minimal symptoms until the AI becomes severe. While medical management can temporize the effects of AI, ultimately surgery with valve repair or replacement is the only definitive treatment.

Aortic stenosis is the most common valve pathology affecting the patients of advancing age. Classically there have been two categories of aortic stenoisis: congenital, which is usually associated with a bicuspid aortic valve and presents in the fifth to sixth decade of life, and degenerative aortic stenosis which results from calcific degeneration of the valve with aging. The vast majority of AS is secondary to a slowly progressing degenerative process of a trileaflet valve. Because of its increasing incidence and prevalence in progressively older patients, it was classically named "senile aortic stenosis." As with aortic insufficiency, there is a universally accepted AS severity grading system based primarily on echocardiographic or angiographic hemodynamic parameters and symptoms ranging from mild to critical [10].

Regardless of the etiology, the hemodynamic and mechanical effects are the same. As the valve becomes progressively stenotic, so does the LV afterload and work required by the LV to maintain perfusion pressure. Aortic stenosis progresses slowly over years if not decades. As such, the heart does an excellent job compensating for the increased afterload with increasing left ventricular hypertrophy. During this stage patients are usually asymptomatic. However, the heart reaches a "tipping point" when the AS is severe and the heart is no longer able to compensate; patients become symptomatic with evidence of diastolic heart failure which presents as increasing dyspnea on exertion, syncope, or angina. Classic studies that laid the foundation for the surgical management of aortic valve disease demonstrated that severe symptomatic AS is ominous without treatment as up to 50% will die with 1–3 years without valve replacement [11] (Fig. 13.4).

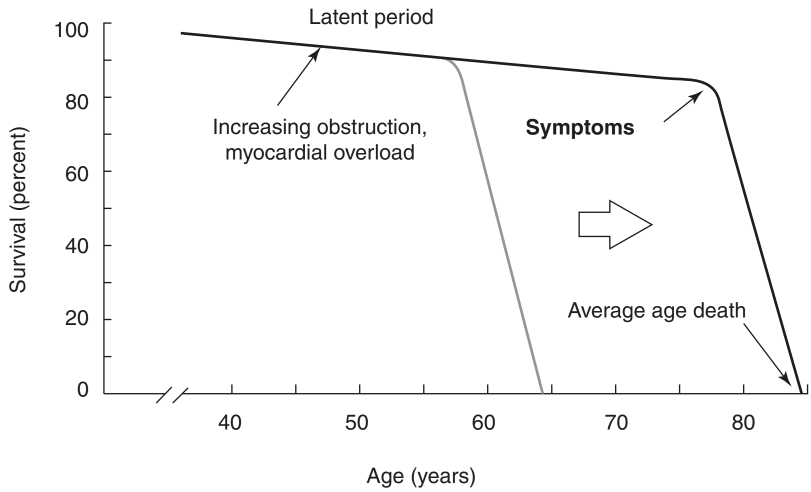

Fig. 13.4 The latent period of aortic stenosis occurs as the aortic valve becomes progressively stenoic with the absence of symptoms due to myocardial compensatory mechanisms. This occurs over many years to decades and has a low associated mortality rate. The development of symptoms with severs AS indicates a tipping point when compensatory mechanisms are exhausted and there is a drastic increase in mortality without surgical intervention. (From Ross Jr and Braunwald [11], with permission)

While the classic symptoms associated with aortic stenosis include dyspnea on exertion, syncope with exertion and/or angina, determining the presence of symptoms, especially, among elderly patients can be a challenge and requires an adept and quizzical practitioner. Because aortic stenosis develops gradually over many years, symptoms develop and evolve subtly and are often mistaken for "normal" signs of aging [12]. Older patients are more likely to have limited mobility due to osteoarthritic or musculoskeletal problems or other comorbidities which may limit the ability to illicit symptoms. Furthermore, as patients get to the more extremes of age (80s and 90s), patients, families, and even providers often ascribe their symptoms to being "old" rather than from aortic stenosis. Patients often comment that they are short of breath and fatigued because "I am 85" when in fact there is a potentially treatable condition causing their symptoms. In the setting of aortic stenosis, providers must be astute when taking a patient's history, especially when they are older and more frail.

For several decades, surgical aortic valve replacement (SAVR) was the only definitive treatment for aortic stenosis. SAVR, in most cases, requires a midline sternotomy, the use of cardiopulmonary bypass, and valve replacement with either a mechanical or tissue valve prosthesis. Patient age is one of the main considerations influencing valve choice (tissue versus mechanical). Younger patients (<65) are typically offered mechanical valves while older patients tissue valves. The younger the patient the shorter the expected lifespan of a tissue valve prothesis. For instance, a tissue valve prosthesis in a 35-year-old is expected to degenerate after 5–10 years. While a tissue valve in a 70-year-old is expected to degenerate after 15–20 years. Mechanical valves do not degenerate and can be fully functional for decades but have the disadvantage of requiring life-long anticoagulation which is not needed with tissue valves.

Outcomes after SAVR are excellent. In the general population, isolated aortic valve replacement is associated with low morbidity and mortality. In a large contemporary, multicenter series SAVR-associated in-hospital mortality was 1.3% [13]. Similar to CABG, SAVR performed in the elderly population is safe and effective with relatively low morbidity and mortality albeit slightly higher than younger cohorts. Published series report mortality rates ranging from 2% to 10% among octogenarians with much of the variability in mortality dependent on preoperative risk factors [13–16]. Similarly, small published series of SAVR in nonagenarians demonstrate reasonable survival in this high-risk patient population with a mortality rate of 5–10% [16–18]. Elderly patients who undergo SAVR enjoy good quality of life after initial recovery from surgery. Among octogenarians who undergo SAVR at 1-year quality of life is better than predicted by age and comorbidity status [19].

Up until this last decade, SAVR has been the only definitive treatment for AS until recently when transcatheter aortic valve replacement (TAVR) has revolutionized the treatment of aortic stenosis, especially among the elderly and frail. In the vast majority of patients, TAVR can be performed percutaneously through femoral arterial access. The native, stenotic valve is crossed with a wire over which the TAVR valve is placed with fluoroscopic guidance and expanded. Unlike SAVR, the native valve is not excised. Rather it is pushed to the side and replaced with a tissue prosthesis. TAVR avoids a sternotomy and cardiopulmonary bypass. Thus, recovery is relatively short with few limitations on a patient's mobility and pulmonary functional status. The permanent pacemaker rate with TAVR is high, around 10%, which is due to the radial force of the TAVR valve on the conduction system which resides close to the aortic valve annulus. In addition, because the technology is relatively new, longevity of the valve has not been proven.

TAVR was originally tested in extremely high-risk patients which included the elderly and extremely frail. The PARTNERS I trial, published in 2010, compared medical management to TAVR among patients with severe symptomatic aortic stenosis who were deemed too high risk for surgery. The results demonstrated clear improvement in survival and quality of life [20]. In a subsequent study of high-risk SAVR candidates, TAVR was shown to be superior in terms of survival and quality of life [21]. Since that time the study has been repeated in intermediate-risk and low-risk populations demonstrating its safety, efficacy, and equivalence or superiority to SAVR in appropriately selected patients [22–24]. Based on the aforesaid data, the only reason an elderly patient, especially with multiple comorbidities should undergo SAVR for severe AS is in the setting of anatomical features preventing the safe placement of a TAVR valve.

TAVR has revolutionized the treatment of AS in the elderly. With the adoption of TAVR, high-risk patients, including the extremely elderly, are routinely referred for TAVR with excellent outcomes. According to the Transcatheter Valve Registry (TVT) (US national registry of all TAVR patients), the median age undergoing TAVR is 84 with a mortality rate of 5% (Fig. 13.5) [25]. One must keep in mind that at the time these data were collected the only patients approved for TAVR were those considered high risk for surgery

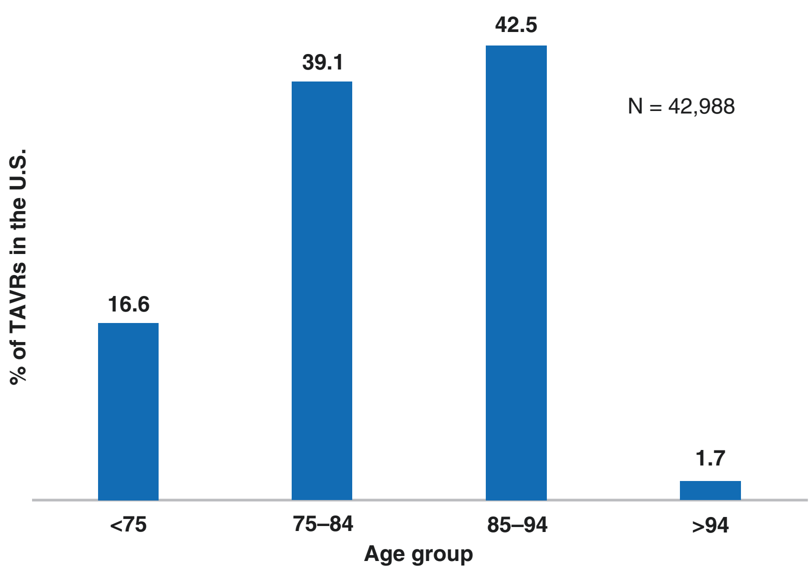

Fig. 13.5 Age distribution among the 42,988 TAVRs performed in the United States. (Adapted from Carroll et al. [25], with permission)

which was defined as a predicted risk of operative mortality of at least 8%. As of 2017 there were nearly 43,000 TAVRs performed in the United States and nearly 50% were performed in patients ≥85 years of age [25]. The subanalysis of TAVRs performed in nonagenarians has demonstrated its safety and efficacy with a 30-day mortality of 4% in a population with a mean age of 93 [26].

Mitral Valve Disease

Mitral regurgitation (MR) is the most common indication for mitral valve surgery. There are two types of MR: functional MR and degenerative MR. Degenerative MR is the least common and is caused by failure of one or more components of the valvular apparatus (valve leaflets and chordae tendineae) resulting in regurgitation. Functional MR is the most common cause of MR in the elderly. In functional MR the valvular apparatus is normal but becomes regurgitant due to annular dilation or leaflet restriction. The most common cause of functional MR is ventricular dilation from ischemic heart disease. As with aortic valve disease, MR is graded from mild to severe largely based on echocardiographic-derived hemodynamic and functional patterns [6]. Progression of MR is typically gradual, allowing for myocardial compensation. As MR becomes severe and myocardial compensatory mechanisms become exhausted, patients develop heart failure symptoms. Severe symptomatic MR is an indication for surgical repair or replacement. Mitral valve repair is preferred over replacement if a functional and lasting result can be achieved as tissue prosthetic valves are subject to limited functional lifespan and mechanical valves require lifelong anticoagulation.

Significant MR is common with aging. An estimated 10% of the patients greater than 75 have significant mitral regurgitation [27]. However, the vast majority of elderly patients who may benefit from surgery to treat their MR are denied surgery due to age and other risk factors [28]. Mitral surgery can be performed safely in older patients as demonstrated in a study investigating over 14,000 procedures which demonstrated a mortality rate of less than 3% among older patients. Furthermore, the long-term survival was equivalent to that of the general population matched for age and gender [29] (Fig. 13.6). Wide and varying outcomes have been reported among octogenarians undergoing mitral surgery with mortality rates ranging from 2% to 25%. The vast majority of reported morbidity and mortality is associated with preoperative comorbidities; and many elderly, higher-risk patients are referred for surgery later in the disease process. Modern series report superior survival of octogenarians after mitral surgery compared to predicted risk of mortality based on risk assessment models [30]. The analysis of mitral repair among octogenarians demonstrates excellent 30-day survival >97%. Replacement survival was less impres-

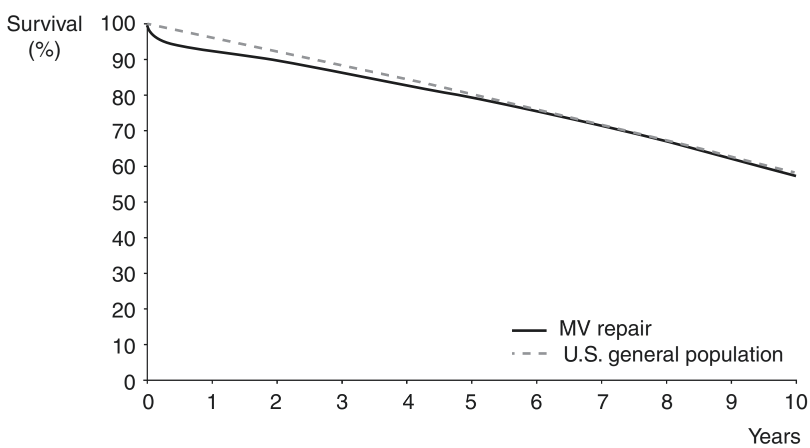

Fig. 13.6 Ten-year survival after mitral valve repair in patients aged 65 years or more. The Kaplan-Meier 10-year survival after valve repair (solid line) is equivalent to the age and sex-matched US population (dashed line). MV mitral valve. (From Ghoreishi et al. [44], with permission)

sive at 86%. However, there are important differences between the repair and replacement groups that have an impact on survival and confound survival analysis. Replacement patients tend to have more comorbid conditions, including a significant number with ischemic heart disease and significant number requiring concomitant procedures, such as CABG [31]. Elderly patients, including octogenarians experience improvement and freedom for heart failure as well as overall quality of life after mitral valve surgery. While mitral surgery among octogenarians is associated with adequate survival and improvement in cardiac-related symptoms, approximately 50% of patients >80 require some sort of assisted living at 1 year. Thus, mitral surgery can be performed safely and effectively in the elderly; patients need to be well selected for optimum outcomes.

There are multiple surgical approaches to the mitral valve that have an important impact on elderly patients. The traditional, and most common, surgical approach is via a median sternotomy. A minimally invasive approach through a right thoracotomy or robotically are increasingly being used. Data on right thoracotomy or robotic mitral surgery reports that it is associated with fewer postoperative mobility limitations and shorter lengths of stay with improved quality of life which may have a particular importance with elderly patients [32].

Just as TAVR has revolutionized aortic valve surgery for elderly and frail patients, Transcatheter Mitral Valve Repair (TMVR) is revolutionizing the treatment of MR. TMVR is an endovascular procedure during which a clip is advanced from the femoral vein into the right atrium and then left atrium through a transeptal puncture. Under TEE and fluoroscopic guidance, the clip is then passed through the mitral valve and the mitral leaflets are approximated. The concept is that the clip will improve leaflet coaptation and, therefore, reduce the MR.

TMVR has shown improvements in survival and quality of life in patients who are at high risk for surgical mitral valve repair or replacement. The EVEREST study randomized patients between surgery and clip for degenerative MR and concluded that, while the clip was less effective at reducing the MR than open surgery, it was associated with lower morbidity with equivalent mortality [33]. Subsequent long-term follow-up data demonstrates equivalent survival between the clip and surgery cohorts, with the clip cohort more likely to need subsequent mitral valve surgery. The COAPT trial investigated the high-risk, functional MR population who are traditionally denied surgery due to risk. The COAPT trial randomized high-risk patients to the clipping procedure or optimal medical therapy and discovered that the clip significantly improved survival as well as quality of life as measured by a decrease in admissions for heart failure. While the data is clear that the clip is not as effective at eliminating all of the MR compared to surgery, it is has less associated morbidity with equivalent risk-adjusted survival even among high-risk surgical patients, approximately 50–80% of whom are denied surgery [34, 35]. Other published series have demonstrated safety and efficacy of the transcatheter mitral repair with low procedural morbidity and mortality rates less than 4% and significant MR reduction in over 90% of patients [36–38].

Transcatheter mitral repair results in a significant improvement in patients' quality of life in the short and long term. While in the short term patients do not have to undergo the challenges of recovering from surgery, at 1 year the majority of patients have improvements from heart failure symptoms and improvements in functional status. This translates to fewer admissions for heart failure exacerbations which is a common problem among patients with severe MR. Furthermore, given the fact that TMVR is approved for patients with high and prohibitive predicted risk of mortality with mitral surgery patients, the vast majority of the patients undergoing the procedure are elderly with multiple comorbidities with median age in the mid-80s [37].

While mitral valve surgery can be performed safely in well-selected older patients, TMVR has changed the treatment paradigm of MR among high-risk patients including patients of advanced age.

Ascending Aortic Surgery

There are two main reasons to operate on the ascending aorta: aneurysm or acute aortic syndrome. Ascending aortic aneurysms are often associated with some form of connective tissue disorder and are asymptomatic until it reaches extremes of size and interacts with surrounding structures or develops acute aortic syndrome. Most aneurysms are detected incidentally during imaging for other reasons. Surgical indications for ascending aneurysms are based on size and growth rate with the intent of preventing dissection or rupture which is more likely to occur with increasing size. Acute aortic syndrome is defined as either aortic dissection or rupture and represents a life-threatening emergency. Aortic dissection has a 50% mortality rate at 48 hours without surgical repair [39]. Elective ascending aortic surgery is safe in the general population with a risk of mortality less than 2%. While the risk of morbidity and mortality of 8–10% is elevated among older patients, it more reflects the risk burden of comorbidities such as CAD and renal dysfunction rather than age alone [40].

Acute aortic syndrome is a lethal diagnosis and in the setting of ascending aorta pathology can only be definitively treated with open surgery. Two separate disease processes comprise acute aortic syndrome: aortic dissection and aortic rupture. Type A aortic dissections involve the ascending aorta and is associated with a 50% mortality within 48 hours of onset and 90% at 1 month without surgical repair [41]. The morbidity and mortality of surgical repair of acute type A AD is high and is largely associated with the preoperative state and comorbidities of the patient [42]. For instance, dissection patients who present to the operating room with evidence of coronary, cerebral, mesenteric, or extremity malperfusion have a significantly higher mortality (30–45%) versus those who do not (6–14%) [43].

Surgery has not been traditionally offered to elderly patients who present with acute type A aortic dissections given the high mortality associated with repair. However, with the aging of the population and increased experience and success with cardiac surgery in the elderly population, there is increasing experience with Type A aortic dissection repair in older patients. Current published experiences have reported mortality range among octogenarians ranging from 8–37% with mortality largely being associated with malperfusion syndromes and preoperative comorbidities. As with other areas of cardiac surgery, success is largely dependent on patient selection when considering aortic dissection repair in the elderly.

Conclusion

Cardiovascular disease is common in the elderly, and many may require surgery for definitive treatment. Current data suggests that age should not be a contraindication for surgical intervention on coronary artery disease, valvular heart disease, or ascending aortic disease as well-selected older patients, even those of very advanced age (90s), have good outcomes after surgery.

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