As life expectancy increases, the anesthetic management of older surgical patients has received increased attention. Current estimates suggest that approximately 20% or more of the surgical procedures performed in the United States are on persons 65 years or older, and if current trends continue, the number of older patients requiring anesthesia for surgical procedures is likely to increase. A thorough evaluation is required when planning for the anesthetic management of older adults. Older adults have specific management needs, and these demands continue to pose challenges to anesthesia providers. These challenges relate to the accrual of numerous and diverse anatomic and physiologic changes that occur in older adults throughout the course of aging.

**Keywords:** Aging, anesthesia assessment, evaluation, older adult.

**Objectives**

At the completion of this course the reader should be able to:

1. Identify age-related physiologic changes in organ systems that occur in older adults.
2. Recognize the normal physiologic changes that predispose patients to perioperative risk during the process of aging.
3. List and discuss comorbid conditions associated with increased risk of perioperative complications in older adults.
4. Describe the influence of age on functional capacity in older adults.
5. Articulate an understanding of how a thorough pre-anesthesia evaluation can be important in minimizing perioperative complications in older adults.

**Introduction**

The decision of whether a patient will be an acceptable candidate for anesthesia is one of the most important anesthetists are asked to make. A thorough preoperative assessment will provide information that is necessary for anesthesia providers to provide appropriate, tailored, perioperative interventions for older adults. The demographics of aging are dramatically changing such that the number of older adults requiring major surgical procedures will likely increase.

By the year 2020, the number of persons 65 years and older will increase to 55 million, representing an increase of 39% in the decade between 2010 and 2020. Persons older than 85 years are the fastest growing subgroup in this population. Older adults are at greater risk for perioperative and postoperative complications and death. The anesthetic management of older patients must be carefully individualized based on the patient and the type of surgery required. The spectrum of physiologic changes and the anesthetic management in older adults are complex and not entirely within the boundaries of this brief review, which will address a variety of the more relevant concerns that anesthesia providers may encounter when caring for this patient population. Given thorough patient evaluation and meticulous management, patients in this challenging group can have successful postoperative outcomes.

**Risks of Anesthesia and Surgery**

Aging is not routinely associated with increased surgical risk; however, progressive decline of baseline functions, age-related coexisting disease, and the ASA physical status classification are major predictors for perioperative complications. Older adults may also be at greater risk for postoperative adverse events and mortality than their younger counterparts. There is a greater than 2-fold likelihood that older patients will require emergency surgery.
compared with younger patients (37% as opposed to 17%), and emergency surgery is a significant predictor of adverse postoperative outcomes. Of noncardiac surgical patients 70 years or older, 21% will have 1 or more adverse postoperative events. The leading causes of postoperative adverse outcomes are cardiovascular, neurologic, and pulmonary in origin. In the adult surgical population, older patients have the highest postoperative morbidity and mortality rate. In addition, older patients who experience postoperative adverse events have a 2-fold greater risk of death within 3 months when compared with older patients who do not have adverse outcomes. Moreover, postoperative adverse outcomes dramatically increase the in-hospital length of stay and healthcare costs.

A speedy recovery and the avoidance of functional decline are the most important goals in the perioperative care of older patients. Maintenance of independence postoperatively is a foremost concern. Age-related changes in older patients can affect all aspects of anesthetic management; therefore, the importance of a thorough preoperative evaluation that takes into account age-related physiologic changes, concomitant diseases, and altered pharmacokinetics and pharmacodynamics cannot be overemphasized to optimize outcomes. Management strategies that help compensate for age-related changes to body systems, promote positive outcomes, and reduce complications are discussed in this article.

The Preanesthetic Evaluation: No Shortcuts!
An important element in the perioperative care of older patients is the preanesthesia evaluation. The preanesthesia evaluation includes a thorough history of previous anesthetic and surgical procedures, results of the physical examination, and an assessment of the emotional and psychological state of the patient. The process of aging is responsible for the normally accepted chronological alterations of life and the associated increases in the chance of disease and death in older adults. As such, anesthesia providers have a vital role in successful outcomes for older adults, with the understanding that profound effects on each and every organ system occur during the process of aging.

A careful evaluation of all organ systems is absolutely essential while planning for the anesthetic management of older adults. Given its positive effect on outcome, the preanesthesia evaluation stands as “the gatekeeper” for recognition of the critical interventions that may inevitably influence the perioperative course for older adults. Likewise, it represents a worthwhile approach to determine interventions that can be cost-effective during times of fiscal concern for healthcare cost containment. Changes in functional and physiologic capacity, concomitant illnesses, and type of surgery have direct effects on outcome.

The preanesthesia evaluation of older adults encompasses several dimensions. The preanesthesia evaluation allows for the appraisal of the natural processes that accompany aging and of the age-related disease and physiologic limitations that become evident as people age. During the preanesthesia visit, a meticulous review of previous medical records and the physical examination should facilitate the identification of current problems and help to detect abnormalities related to concomitant illnesses underlying the need for anesthesia and surgery. The preanesthesia evaluation should complement the personal interview and achieve the specific assessment objectives required to properly prepare an older adult for the rigors of the anesthetic and surgical experience (Table 1).

### Table 1. Preanesthesia Assessment Objectives

| Evaluate the general appearance, nutritional status, psychological state, and support system of the patient. |
| Determine the existence of chronic or debilitating disease and how well these conditions are controlled or can be optimized to reduce perioperative risk. |
| Determine whether previous anesthetics, surgeries, medication history, or organ system problems will potentiate perioperative complications, and refine regimen to optimize outcome. |
| Assess risk factors for perioperative complications, and develop therapeutic plan for anesthetic management. |

### Age-related Physiologic Changes in Older Adults

Aging refers to any time-related occurrence during the life of an organism and can be defined as a time-dependent biological continuum. Aging begins with birth and continues with a gradual impairment of organ subsystems such that people experience increased functional limitations, eventually becoming more susceptible to illness and death. Definitions of aging are many and often subjective. This review operationally defines “older adults” as persons 65 years or older. Aging and poor physiologic function are not synonymous. Variability exists in physical conditions among older persons, which stresses the fact that chronological age (age in years since birth), which is commonly used in clinical practice, differs from biological age (functional status). There is growing evidence that chronological age alone is not a reliable marker of morbidity or of mortality because chronological age as an independent factor may provide beneficial and negative effects on an organism.

Age-related system dysfunction and concomitant illnesses are largely responsible for increases in perioperative complications experienced by older adults. Preoperative conditioning and level of functioning are important predictors of perioperative complications. As a person ages, physiologic changes occur in most body organs, and these
changes are characterized by decreased functional reserve. Although assessing and documenting baseline physiologic function is important in the preoperative evaluation, the inclusion of concomitant diseases (comorbidities) in this assessment is essential. As the aging demographic continues to change, anesthesia providers need to be cognizant of the major organ-system changes that affect the course of anesthesia and surgery (Table 2).

The incidence of concomitant illnesses increase with age, and, in the United States, approximately 80% of older adults have at least 1 concomitant illness and 50% have 2 or more concomitant illnesses. Age-related changes in organ subsystems create specific physiologic effects that potentially alter an older adult’s response to anesthesia and surgery throughout the perioperative period. It is not the intent of this article to dictate the anesthetic course for any particular patient, but to provide readers with a targeted review and critique of the changes that occur with aging and how these changes might suggest modifications of the anesthetic course to improve perioperative outcomes for older adults. While anesthesia-related morbidity and mortality have steadily improved during recent decades, it is important not to discount the impact of age as an independent predictor of perioperative outcome.14,15

### Age-related Physiologic Changes in Organ Subsystems

#### Cardiovascular System
Cardiovascular disease is the most common concomitant illness in older adults and the primary cause of perioperative and postoperative risk. The most frequently associated cardiovascular-related complaints are hypertension, coronary artery disease, congestive heart failure, and myocardial ischemia. Myocardial infarction is the most common cardiac complication and the leading cause of death in the postoperative period. Likewise, a patient with preexisting congestive heart failure has a greater than 2-fold risk of developing postoperative complications.4

Age-related changes in the cardiovascular system involve structural and functional changes in the heart, vessels, and autonomic nervous system. In older adults, the heart and vascular system are less compliant, leading to faster propagation of the pulse pressure waveform, increase in afterload, and increase in systolic blood pressure, in turn, leading to ventricular thickening (hypertrophy) and prolonged ejection times. The combination of ventricular hypertrophy and slower myocardial relaxation often results in late diastolic filling and diastolic dysfunction. When these changes occur, atrial contrac-

<table>
<thead>
<tr>
<th>Organ system</th>
<th>Major changes occurring with aging</th>
</tr>
</thead>
</table>
| Cardiovascular | Increased left ventricular wall thickness and wall tension with subsequent increase in peripheral vascular resistance  
Increased afterload and heart rate causing an increase in end-diastolic volume and pressure with subsequent larger stroke volumes  
Prolonged circulation time causing delays in the onset of action of intravenous drugs and increased induction time with inhalation agents  
Increased heart size and tissue mass with subsequent increase in systolic blood pressure  
Decreased arterial compliance, coronary blood flow, and cardiac reserve (less compliant heart)  
Decreased response to inotropic and chronotropic stimuli |
| Respiratory | Increased fibrous connective tissue and alveolar compliance with subsequent decrease in elastin fibers and lung recoil  
Closing volume beginning to exceed functional residual capacity (FRC) after age 45 y  
Increased FRC, anatomic, and physiologic dead space  
Decreased vital capacity and reserve volumes (inspiratory and expiratory); decrease in small increments after age 20 years |
| Renal and hepatic | Decreased glomerular filtration rate and renal tubular function  
Decreased protein binding and hepatic blood flow (easier to overdose older adults)  
Note: Increased serum creatinine level may indicate severe renal dysfunction. Serum creatinine correlated significantly with lean mass and may not otherwise increase in older adults because of decreased muscle mass in this group. |
| Nervous | Peripheral nerve cell degeneration (some neuron size decrease with loss of synapses) leading to increased sensory block with spinal techniques and decreased segmental block with epidural techniques  
Increased threshold for numerous sensory modalities (eg, temperature, hearing, vision, touch)  
Action of sensory agents more pronounced due, in part, to a reduction in the synthesis and receptor sites of some neurotransmitters  
Cerebral autoregulation of blood unaffected |

Table 2. Major Organ System Changes That Occur With Aging
tion becomes important in the maintenance of adequate ventricular filling. Older adults have a reduced capacity to increase heart rate in response to hypotension, hypovolemia, and hypoxia. Prolonged circulation times cause a faster induction time with inhalation agents but delay the onset of action of intravenous drugs. Arrhythmias, conduction problems, and hypertension are common in older adults and may lead to ischemic heart disease.

Hypertension is a risk factor for perioperative complications with the risk doubling for every 20 mm Hg systolic/10 mm Hg diastolic increase in blood pressure. With aging, pulse pressure widens due to a greater proportionate increase in systolic blood pressure compared with diastolic blood pressure. Decreased vein compliance can lead to decreased venous return and reduced atrial filling. Age-related changes in the cardiovascular system of older adults also include changes in the heart's regulation of calcium, causing the myocardium to generate force for a longer period after excitation, thereby prolonging the systolic phase of the cardiac cycle. 16

The myocardium in older adults has decreased sensitivity to β-adrenergic modulation, which is physiologically evident as decreased heart rate and lower cardiac dilatation at the end of diastole and systole. The combined effect of decreased cardiac reserve and decreased maximum heart rate adversely affects the compensatory mechanisms of older adults under the stress of anesthesia and surgery. Older adults undergoing noncardiac surgery are at risk of cardiovascular complications as a result of anesthesia and surgery. Although there is evidence supporting the use of β-blockers as an effective method of reducing adverse perioperative cardiovascular events after noncardiac surgery in high-risk surgical patient populations, 29 this approach is currently under considerable scrutiny and debate. No matter what approach is taken, complete assessment of the cardiovascular system in older adults undergoing noncardiac surgery is essential according to the American College of Cardiology and American Heart Association guidelines for perioperative cardiovascular evaluation for noncardiac surgery. 1 According to the American College of Cardiology and American Heart Association, functional capacity is an objective quantification of a patient's exercise tolerance and can be measured in metabolic equivalents (METS). 17 Research suggests that for every 1 MET that a patient attained, there is a corresponding reduction in annual mortality of 11%. 18 The MET corresponds to the amount of oxygen consumed by a 70-kg male at rest (~3 mL of oxygen per kilogram of body weight per minute). Patients able to perform greater than 4 METs are at decreased risk for perioperative cardiac complications (Table 3).

In general, older adults may have higher blood pressures caused by increased peripheral vascular resistance, decreased arterial elasticity, and cardiac workload; likewise, older adults may have decreased cardiac output and stroke volume due to decreased conduction velocity and reduction in venous blood flow. The preoperative assessment should include the identification of major risk factors for perioperative cardiovascular complications, which include significant exercise intolerance, angina, history of myocardial infarction within the past 6 months, ventricular arrhythmias, acute coronary syndrome, decompensated congestive heart failure, and valvular disease. The use of β-blockers is common in older adults with chronic heart failure and ischemic heart disease. However, for patients admitted to the operating room who may not have had the benefit of long-term titration of this class of medication, a practical approach for anesthesia providers might include the administration of oral medication before induction and intraoperative intravenous administration (ie, of esmolol or metoprolol) to control heart rate.

- Respiratory System. Postanesthesia respiratory complications are common in older adults, often requiring upper-airway support during the immediate postoperative period. Age-related changes of the respiratory system are characterized by a loss of elastic recoil of the lung, decreased strength of respiratory muscles, decreased respiratory response to hypercapnia and hypoxia, and decrease in compliance of the chest wall. Impaired elastic recoil results in air trapping and ventilation/perfusion mismatch. Aging is associated with decreased vital capacity and forced expiratory volume in 1 second, increased residual volume, decreased arterial oxygen tension, increased physiologic dead space, and other related changes (see Table 2). The chest wall becomes stiffer with age and leads to decreased lung volumes and increased work of breathing. In older adults, protective airway reflexes (ciliary functioning and cough) are decreased, which may increase the risk for aspiration. The respiratory changes associated with aging include decreased pulmonary function, gradual decrease in PaO2, and a decreased respiratory response to hypercapnia and hypoxia.

Older patients are at increased risk for pulmonary-related disorders (eg, chronic obstructive pulmonary disease, pneumonia, sleep apnea), which are associated with increased morbidity and mortality. 8,19 The presence of pulmonary disease increases the risk of hypoxia, pneumonia, and atelectasis. Chronic obstructive pulmonary disease is a significant risk factor for the development of postoperative pulmonary complications. 20 The incidence of postoperative respiratory complications is 3- to 6-fold in persons who smoke. 8,21 Although smokers have a higher incidence of postoperative pulmonary complications, pulmonary complications may paradoxically increase in patients who quit smoking 2 months or less before surgery. 21-24 Despite this finding, short-term smoking cessation is still advised.

Pulmonary complications account for nearly 40% of perioperative deaths in persons older than 65 years. ASA physical status classes of greater than II predict a 2-fold
increased risk of respiratory complications. Older patients are more prone to have atelectasis and pulmonary infection. Therefore, preoperative pulmonary evaluation of older patients should focus on identifying people with limited pulmonary reserve and recognizing factors that aid in maximizing performance status. In patients older than 70 years, the number of stairs a patient can climb before the surgery is inversely proportional to cardiopulmonary complication rates after the operation. Pulmonary complications are also increased based on length of surgery, obesity, and sex (females slightly higher rate than males).

- Renal Function. Although decline in renal function is a common postoperative occurrence, it is often accompanied by particularly negative outcome in older adults. Older adults have a significant baseline decrement in renal function relative to their younger counterparts. Age-related changes in renal function are particularly significant because of the many roles of the kidneys. Changes in renal function in older patients are characterized by a progressive atrophy of kidney parenchymal tissues, deterioration of renal vascular structures, decreased renal blood flow, and an overall decrease in renal mass. The cumulative effect is a decrease in the glomerular filtration rate, resulting in decreased renal drug clearance and decreased renal blood flow from age 20 years to age 90 years (approximately a 25%-50% decline). The combined effect is particularly apparent with diminished renal clearance of hydrophilic agents and hydrophilic metabolites of lipophilic agents.

### Table 3. Estimated Intensity and MET Level for Various Activities

<table>
<thead>
<tr>
<th>Level of intensity</th>
<th>MET level</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>1</td>
<td>Combing hair</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dressing self</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Showering self</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Cooking a light meal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Typing or keyboarding for 1 hour or more</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Walking at a leisurely pace on level ground</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Scrubbing floor or bathtub</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Putting away groceries</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Walking up 1 flight of stairs</td>
</tr>
<tr>
<td>Moderate</td>
<td>4</td>
<td>Walking up 1 flight of stairs carrying a child</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Walking 2 city blocks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light housework (washing dishes, vacuuming, dusting)</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Playing Frisbee</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Playing doubles tennis for 1 hour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Walking at a very brisk pace (~15 min/mile)</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>High-impact aerobic dancing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water aerobics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Competitive table tennis</td>
</tr>
<tr>
<td>Vigorous</td>
<td>7</td>
<td>High-impact aerobic dancing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Step aerobics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Singles or wheelchair tennis</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Jogging at 6 mph</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shoveling heavy snow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vigorous dancing</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Most competitive sports (eg, football, basketball)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carrying several heavy bags of grocery (&gt; 25 lb) up several flights of stairs</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Standing or walking while carrying loads of ≥ 50 lb</td>
</tr>
<tr>
<td></td>
<td>&gt; 10</td>
<td>Canoeing or rowing (≥ 4 mph)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kayaking in whitewater rapids</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cross-country skiing</td>
</tr>
<tr>
<td></td>
<td>&gt; 10</td>
<td>Running at ≥ 8 mph</td>
</tr>
</tbody>
</table>

MET indicates metabolic equivalents.
Because of the vital role of the kidneys in the maintenance of fluid and electrolyte balance and their contribution to acid-base balance and to the excretion of drugs and their metabolites, it is essential that great consideration be given to the renal function of aged patients. The decrease in glomerular filtration rate and impairment of the diluting segment of the nephron can easily predispose a patient to fluid overload if overzealous intravenous fluid is administered. The production of renin and aldosterone is decreased with age, causing impairment of sodium conservation. Sodium conservation and hydrogen ion excretion are decreased, resulting in impaired ability of the kidneys to respond to changes in electrolyte concentrations, intravascular volume, and free water. The kidneys do not respond to nonrenal loss of water and sodium, and, as a result, dehydration can commonly occur. The serum creatinine level is often unchanged (if there is no renal failure) because of decreased creatinine production from the overall declining skeletal muscle mass associated with aging. Creatinine clearance is the best indicator of drug clearance. A common method for estimating creatinine clearance in healthy older adults involves using the Cockcroft and Gault estimation of creatinine clearance formula:

\[
\frac{(140 - \text{age in years}) \times \text{(weight in kg)}}{72 \times \text{(serum creatinine in mg/dL)}}
\]

When this formula is applied to females, the factor 0.85 should also be included in the numerator; however, when this formula is applied to critically ill or patients receiving medications that directly affect renal function, caution must be used. It should be noted that this formula often overestimates creatinine clearance. Therefore, older patients with renal impairment may be at increased risk for the following: (1) fluid overload; (2) accumulation of metabolites and drugs that are excreted by the kidneys; (3) decreased drug elimination, which can prolong the effects of a wide range of anesthetic drugs and adjuncts; and (4) electrolyte imbalances, which can lead to arrhythmias by affecting cardiac conduction. Furthermore, overhydration in a compromised heart with marginal reserves must be cautiously avoided because the physiologic changes in the kidneys of older adults decrease the ability to excrete a large volume load. Perioperative management of renal function should be geared toward preventing acute renal failure during the preoperative planning phase. Nephrotoxic medications should be discontinued preoperatively, and careful maintenance of an adequate circulating volume and perfusion pressure is of paramount importance.

**Hepatic Function.** The liver is responsible for drug metabolism or biotransformation. Drug metabolism is subdivided into phase I and phase II processes. Phase I drug metabolism involves oxidation, reduction, hydroxylation, and demethylation and is mediated by the cytochrome P450 system. The effect of age on phase I drug metabolism is somewhat variable; however, because older adults often have comorbid conditions, anesthesia providers should consider the possibility that increased age will have a negative impact on phase I drug metabolism. This is because of diminished rate of drug clearance, which increases the incidence of drug toxicity.

Phase II drug metabolism involves conjugation reactions or acetylation. Age has been identified as an insignificant factor during phase II drug metabolism, with the exception of the morphine metabolite, morphine-6-glucuronide. This pharmacologically active metabolite causes respiratory depression by crossing the blood-brain barrier and binding to receptors. Age-related physiologic changes in hepatic function and disease processes can increase sensitivity to anesthetic agents in older adults. After the age of 50 years, there is a steady decline in the weight of the liver, which is about 2.5% of the total body weight throughout adulthood until age 50 years. By the age of 90 years, the liver is only approximately 1.6% of the total body weight. How the body responds to administered agents is a function of the relationship between the administered dose and the concentration of the drug in the systemic circulation (pharmacokinetics). The changes in hepatic function may affect hepatic drug clearance, particularly if the patient has a concomitant disease, smokes, or is consuming multiple medications that alter blood flow or up-regulate or down-regulate hepatic functional biochemistry. Furthermore, increased body fat and decreased water content in older patients have considerable impact on the volume distribution of many drugs. The volume distribution of hydrophilic drugs in older patients may be decreased, causing an increase in plasma concentration. The volume distribution of lipophilic drugs in older adults may be increased, causing a decrease in plasma concentration.

The age-related physiologic changes in hepatic function may cause decreased clearance, prolonged half-life, and increased or decreased volume of distribution of the drugs. Because of the high prevalence of concomitant illnesses, older adults are more likely to take multiple prescription medications, over-the-counter medications, and herbal remedies, which also increase the risk of adverse reactions. Therefore, the potential for drug interactions is increased as a result of age-related changes in hepatic function.

As previously stated, age-related changes in hepatic function are characterized by decreased liver mass, decreased portal and hepatic blood flow, decreased serum albumin level, and decreased enzyme activity; therefore, the dosing of drugs dependent on hepatic metabolism must be carefully considered. The decrease in overall liver mass results in a reduction in the rate of plasma clearance and a prolongation of the effects of opiates. Furthermore, the delivery of drugs to the liver is highly
influenced by hepatic blood flow. Age-related changes in hepatic function should be presumed to modify the metabolism of most anesthetic agents and nondepolarizing neuromuscular blocking agents. In general, anesthesia providers can anticipate an increase in duration of activity of the drugs most commonly used in anesthesia care (Table 4).

- **Endocrine System.** The endocrine system undergoes many age-related changes that have widespread effects on other body systems and processes. The endocrine system has multiple feedback loops and is strongly influenced by anesthesia and surgical stress. Anesthesia and surgery cause a neuroendocrine stress response that is reflected by increased secretion of epinephrine, norepinephrine, adrenocorticotropic hormones, and growth hormone (insulin antagonist) which causes insulin resistance at the tissue level. Furthermore, increased hepatic production of glucose, impaired insulin secretion, and impaired breakdown of fats and proteins have widespread consequences.

While risk stratification of patients exist (eg, ASA Physical Status, Goldman's Cardiac Risk Index, and Lee's revised Cardiac Risk Index), defective glucose and insulin control further increases the risk for adverse reactions in patients with cardiovascular disease and increases the risk of perioperative complications. Older adults are more susceptible to the effects of increased glucose levels due to hyperglycemia-induced immune defects and age-related immune senescence. Diabetes affects perioperative cardiovascular risk and autonomic dysfunction and is associated with an increased risk for stroke, myocardial infarction, ketoacidosis, and deterioration in renal function. Patients with long-term diabetes often have compromise in one or more organ systems. These factors place patients with diabetes at increased risk for complications during the perioperative period. The extent of endocrine and metabolic changes is influenced by preoperative diabetes control, type of diabetes, magnitude of surgery, and perioperative complications.

Assessment of older patients with diabetes includes identification of the type of diabetes, diabetes control (hemoglobin A1C), length of disease, and complications from diabetes. Patients with a history of diabetes for greater than 10 years are particularly at increased risk for complications. Perioperative assessment of the degree of endocrine dysfunction is essential, along with ongoing monitoring and timely intervention when appropriate.

- **Central Nervous System (CNS).** Age-related physiologic changes of the CNS are characterized by a progressive loss of neurons and neuronal substance, decrease in neurotransmitter activity, and decreased brain mass. These losses are most prominent in the cerebral cortex, particularly the frontal lobes. The associated physiologic changes cause an increase in cerebrospinal fluid, decrease in intracranial volume, decrease in nerve conduction velocity, and degeneration of peripheral nerve cells. The CNS is also responsible for the regulation of cognitive, sensory, and behavioral processes. The regulation of brain function, including neuronal membranes, receptors, ion channels, neurotransmitters, cerebral blood flow, and metabolism is affected by general anesthetics at all levels. As a result, there are changes in mood, memory, and motor function. In addition, cellular processes that participate in neurotransmitter synthesis and release, such as intraneuronal signal transduction and the second messenger system, may be altered. The CNS changes experienced by older patients results in an increased sensitivity to anesthetic agents and an increased risk for postoperative delirium and cognitive dysfunction.

Older patients may experience increased sensitivity to drugs because the number of receptors available are decreased. As a rule, older patients frequently experience an exaggerated response to CNS-depressant drugs, with particular sensitivity to general anesthetics, hypnotics, opioids, and benzodiazepines. The dosing of induction agents is decreased by as much as 30% to 40% in older patients, arguing for very meticulous titration. General anesthesia may deteriorate the mental capacity in patients with preexisting problems and may have a strong association with postoperative cognitive dysfunction. The loss of neurons and decrease in mental capacity may have deleterious effects on cognitive and sensory functions, thereby jeopardizing an older adult's ability to give informed consent. Likewise, older patients may experience delirium, dementia, cerebrovascular disease, and transient ischemic attack, which may require a surrogate to provide consent before anesthesia and surgery.

Although normal intellectual function peaks between the ages of 20 and 30 years, it reaches a relative level of stability until 83 to 87 years and then begins to decline. After surgery, some older adults experience a transient reversible state of cognitive alteration: postoperative delirium. Postoperative delirium is characterized by disruption of perception, thinking, memory, psychomotor behavior, sleep-wake cycle, consciousness, and attention. Delirium occurs in 10% to 26% of patients older than 65 years. The exact cause of delirium is not known but is

<table>
<thead>
<tr>
<th>Drug</th>
<th>Young adults</th>
<th>Older adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fentanyl</td>
<td>250 min</td>
<td>925 min</td>
</tr>
<tr>
<td>Alfentanil</td>
<td>90 min</td>
<td>130 min</td>
</tr>
<tr>
<td>Diazepam</td>
<td>24 h</td>
<td>72 h</td>
</tr>
<tr>
<td>Midazolam</td>
<td>2.8 h</td>
<td>4.3 h</td>
</tr>
<tr>
<td>Vecuronium*</td>
<td>16 min</td>
<td>45 min</td>
</tr>
</tbody>
</table>

Table 4. Elimination Half-life of Commonly Used Drugs by Age Epochs

*Return of twitch height from 25% to 75% of control.
likely multifactorial. Risk factors that have been associated with the development of delirium are older age, male gender, dementia, history of alcohol abuse, depression, duration of anesthesia, poor functional status, abnormal electrolyte and glucose levels, Parkinson disease, cardiovascular disease, dehydration, metabolic diseases (e.g., diabetes, hyperthyroidism), anticholinergic drugs used intraoperatively, need for admission to the intensive care unit, inadequate pain control, and type of surgery.42-48 Postoperative delirium is believed to be related to anesthesia-stimulated vasodilatation with a resultant hypermetabolic state in the brain. This hyperbolic state leads to oxidative stress and irregularities in the cholinergic, dopaminergic, histaminergic, and noradrenergic neuronal systems. Hence, synthesis and release of acetylcholine from cholinergic cells may be reduced, causing disorientation and memory impairment or agitation and hallucinations.

Symptoms associated with delirium typically begin early during the postoperative period and can last for several days or weeks. Delirium is associated with increased risk of postoperative adverse reactions (i.e., pulmonary edema, myocardial infarction, respiratory failure, pneumonia, and death), increased length of hospital stay, increased healthcare costs, and poor functional and cognitive recovery.28,45-51 Delirium is more common in older orthopedic patients (i.e., femoral fractures) and patients undergoing cardiac surgery, with incidence rates of 28% to 60% and 32% to 47%, respectively.45,52-54 In cardiac surgery patients, the presence of 4 preoperative factors (depressive symptoms, impaired cognitive function, prior stroke or transient ischemic attacks, and abnormal albumin level) have been independently associated with postoperative delirium.54-57

For practical clinical purposes, the most common CNS disorder in the older patient is delirium.58 A history of neurological deficits and neurological diseases is most frequently associated with risk of delirium; therefore, symptomatology related to these disorders should be included in the preoperative evaluation and consultation requested when needed.58 The evaluation of cognitive function should always be completed. Increased age alone is an associated risk factor for postanesthesia CNS change. Other factors such as a history of cognitive dysfunction emphasize the need for strict evaluation of CNS status in older patients.

• Body Composition and Thermoregulation. Body composition and thermoregulation in older patients have very important implications for anesthesia providers. Age-related changes to the body’s composition are characterized by loss of lean body mass, increased total body fat, decreased metabolic rate, and decreased total body water. In addition, there is a reduction in blood volume of 20% to 30%.32 A number of factors may contribute to the decrease in lean body mass and increase in total body fat in older people. Aging is associated with decreases in the senses of smell and taste, thus rendering foods less palatable. Subsequent assessment can also be confusing because disease and aging cause decreased lean body mass that may mimic malnutrition.

Epidemiologic studies have demonstrated that older persons frequently consume less than two-thirds of the recommended daily allowance for several nutrients. For surgical patients, decreases in caloric intake, combined with illness, deplete the body caloric reserves necessary for the stress of anesthesia and surgery. Regrettably, no clearly beneficial preoperative medication has been identified that stimulates the appetite in older adults. The value of enteral supplements used to reduce postoperative complications and to improve clinical outcomes in older adults postoperatively is unclear59-61; however, older adults may substitute enteral formulas intended for supplementation for their regular meals. As a result of decrease in total body water, older adults are more vulnerable to hypotension and have difficulty compensating for positional changes.

In older patients, there is a decrease in the function of the hypothalamus,6 which controls the regulation of body temperature. Although much attention is given to malignant hyperthermia, the hypermetabolic state that develops in susceptible people in response to a triggering event (e.g., drugs, physical or emotional stress), little attention is given to the challenges that older patients face in general with thermoregulation. Older patients are more susceptible to hypothermia. The decrease in the ability of older patients to generate and regulate heat is related to a combination of decreased functioning of the hypothalamus, decreased metabolic rate, and decreased threshold for peripheral vascular response to environmental change and shivering.6 Shivering during the postoperative period usually occurs after the use of inhalation anesthetics (especially if the operating room is cold and the patient is not warmed perioperatively) as a result of these agents inhibiting the temperature-regulating centers in the hypothalamus; thus, older adults have this added insult to an already inhibited hypothalamus. The skin arterioles of older adults do not constrict as well as in younger people, and older adults produce less heat per kilogram of body weight; therefore, older adults may be unable to maintain body heat in the cooler environment of the operating room. Likewise, dehydration, as a result of illness, hospitalization, invasive testing, diuretics, and nothing by mouth status, occurs easily in older adults and may be underappreciated because the thirst response is also diminished.6 Methods to maintain normothermia in older adults should involve prevention of heat loss and active warming during the perioperative period. The administration of all fluids and blood transfusions through a warming device, use of a thermal mattress or forced air warmer, and maintaining an environmental humidity
higher than 50% are useful methods to achieve this goal.

Summary

Older adults undergoing general anesthesia are at an increased risk of adverse outcomes. Knowledge of age-related changes, preoperative assessment, and preoperative preparation are important for optimal anesthetic management and to limit avoidable adverse outcomes. Age, comorbidity, pharmacodynamics, and pharmacokinetics are important considerations. Most critical is the management and to limit avoidable adverse outcomes. Increased risk of adverse outcomes are useful methods to achieve this goal.

REFERENCES


multidisciplinary care of delirium in older medical inpatients: a randomized trial. CMAJ. 2002;167(7):753-759.


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