# Clinical Medicine Reviews in Therapeutics

# General Anesthesia in the Elderly Patient with Cardiovascular Disease

Mojca Remskar Konia and Richard C. Prielipp

Department of Anesthesiology, University of Minnesota, Minneapolis, Minnesota 55455, USA.
Corresponding author email: konia012@umn.edu

**Abstract:** Anesthesiologists are faced with increasing numbers of elderly patients in their practice due to ageing population, especially in Western societies. Ageing is associated with physiologic changes that decrease the ability to respond to surgical and disease-related stress. Moreover, elderly patients suffer from significant co-morbidities including diseases of cardiovascular and pulmonary system. Both of these factors add to the challenges of anesthetic care in this patient population. Lastly, chronological age alone is an inadequate predictor of the response expected in an individual patient (the paradox of the "old" 65 year-old vs. a "young" 85 year -old patient). In our review we discuss the physiologic changes of ageing and write about most frequent or significant co-morbidities of old age and their effects on the anesthetic choice. We further review sedative and anesthetic agents, pain medications and other adjunct medications, which may result in important, potentially detrimental consequences for the elderly patient.

**Keywords:** elderly, cardiovascular conditions, anesthesia

## Introduction

'Elderly' is defined as individuals more then 65 years old for the Western population, where by the year 2030 one in five Americans will be elderly.[1] Ageing related phenotypic changes in combination with age-related alterations in cellular homeostatic mechanisms have important cardiovascular effects. Addition of the traditional risk factors further increases the incidence of cardiovascular conditions in the elderly. Heart disease and stroke account for over 40% of all deaths between 65 and 74 and close to 60% at age 80 and older.[2]

Thus, the choice of anesthetic technique and drugs for an elderly patient with cardiovascular disease must take into consideration age-related, physiologic changes associated with ageing.

## Physiologic Changes of Ageing

Ageing organs and cells undergo oxidative stress, low-grade inflammation, senescence-associated secretory phenotype, apoptosis and impaired endothelial progenitor function.[3–9] Cell aging results in physiologic alterations in organ system functions that are highlighted below and need to be considered when providing general anesthesia for an elderly patient.

## Cardiovascular

The cardiovascular system in elderly patients is inherently unstable,[10] as elastance is lost in the arterial wall, venous vessels, and myocardium.[11] The arterial stiffening causes hypertensive disease—especially systolic hypertension with a large pulse pressure—leading to increased systemic vascular resistance.[12] Furthermore, reflected pulse waves from vessel bifurcations return prematurely and increase LV afterload and increased myocardial wall tension during the end of the end of systole. Meanwhile, stiffening of the venous system leads to the limited ability to autoregulate preload, so changes in blood volume are poorly tolerated. Myocardial stiffening causes delayed relaxation with impaired early and late diastolic filling. The impaired left ventricular relaxation is readily diagnosed with echocardiography tissue Doppler (Fig. 1). In summary, elderly patients are dependent on atrial-ventricular conduction synchrony and atrial contraction to maintain optimal cardiac performance.[13]

Changes of the autonomic nervous system are due to sympathetic hyperactivity with β-adrenoreceptors
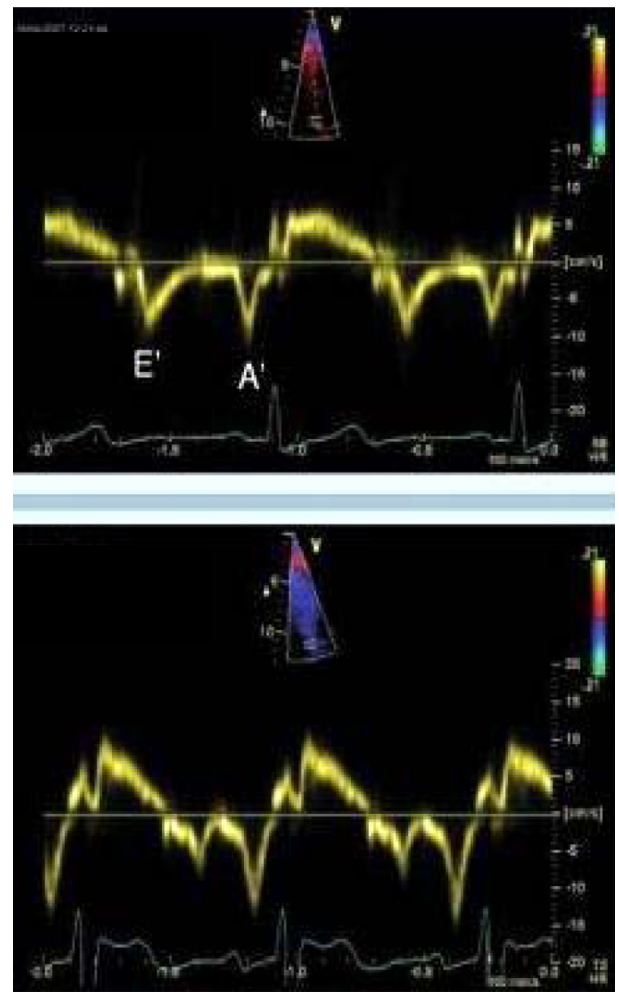


**Figure 1.** Mitral annular velocity tissue Doppler. The upper panel illustrates a normal subject. Upward wave Sa (systolic myocardial motion) is followed by two downward peaks: Ea (early diastolic motion) and Aa (atrial contraction). Second panel illustrates a subject with impaired relaxation. Ea wave is decreased and Aa wave increased.

desensitization—decreasing inotropic and chronotropic responses.[14] Baroreceptor reflex is altered. Basal vagal tone in older patients is diminshed and the response to medication such as atropine is diminished.[14,15] Thus, adequate cardiac output and organ perfusion become dependent on normal cardiac contractility to maintain normal stroke volume in the elderly.

## Respiratory

Ageing causes structural protein changes in lung and chest wall,[16] leading to decreases in chest wall compliance, respiratory muscle strength and protective cough/swallowing reflexes. Meanwhile, lung compliance, airway resistance, residual volume, small airway closure and ventilation-perfusion mismatch

are increased.[17] These changes increase the work of breathing, and decrease ventilatory response to exercise and impaire gas exchange. Aspiration risk is increased as secretion clearance is decreased.[18,19] Lastly, the responsiveness to hypoxemia and hypercarbia is decreased and sensitivity to anesthetic agents and opioids is markely increased. Thus, elderly patients are vulnerable to hypoxemia and hypercarbia in the early postoperative period.

## Pharmacokinetics and Pharmacodynamics

Important changes in drug processing occur in older patients:[20]

1. **Drug absorption and bioavailability**—intestinal absorption of drugs differ widely from individual to individual. Oral drugs such as labetalol, verapamil, nifedipine, and lidocaine may have increased bioavailability due to a decreased first-pass metabolism in the elderly,[21] whereas morphine, metoprolol, amitriptyline and meperidine are unaffected.[22]

2. **Drug distribution**—plasma half-life of a drug changes directly with the volume of distribution. Body fat content increases with age by as much as 33%–45% and may affect the volume of distribution. Total body water content, on the other hand, is decreased by 10%–15% by the age of 80.[23] Thus, hydrophilic drugs have a decreased volume of distribution with a consequent increased plasma concentration. By contrast, lipophilic drugs have an increased volume of distribution and their plasma concentration may decrease. Bolus doses of drugs should therefore be modified by 10% to 20% down or up. Protein binding may decrease by 15% to 25% and also affects drug distribution by increasing the free plasma levels of drugs that have high protein-binding capacity.[20,24]

3. **Hepatic metabolism**—liver size decreases by 25%–50% with old age. The endoplasmic reticulum is diminished and hepatic extracellular space increases. As liver blood flow decreases by 40%, bile production is reduced and the rate of synthesis of proteins, lipids and glucose is decreased. Routine liver tests do not reflect these significant alterations however, although serum albumin may decrease slightly.[25–27] Drugs with blood-flow limited metabolism (high hepatic extraction) have a reduced hepatic clearance in old age, which correlates with the fall in hepatic blood flow.[20] Drugs with capacity-limited metabolism (low hepatic extraction) have unaltered hepatic clearance.[20]

4. **Renal excretion**—Decline in renal function begins after the age of 35 and accelerates after the age of 50 to 60.[28] The aging kidney loses 60% of its glomeruli between age 30 and 90 due to progressive glomerulosclerosis. Glomerular filtration rate decreases by 50% by the age of 90 and renal blood flow after the age of 40 decreases by 1% per year due to patchy tubular atrophy, interstitial fibrosis and atherosclerosis caused by oxidative stress or actions of angiotensin II.[29,30] Creatinine clearance, used in clinical practice as a surrogate measure of renal function, decreases with age. The average decline in creatinine clearance was reported to be −0.75 ml/min/year.[31] Complicating creatinine clearance calculations in the elderly is the finding that muscle creatinine (and therefore circulating serum creatinine) is usually decreased, which leads to artificially high creatinine clearance calculations. Drugs such as aminoglycosides, vancomycin, and cefotaxim, which are excreted unchanged by the kidney, naturally have decreased clearance.[32]

5. **Pharmacodynamics**—aging decreases functionality of a host of key receptors—altering both their density and agonist affinity—that adversely impacts signal transduction and intracellular response.[33] Loss of muscarinic acetylcholine receptors in central nervous system characterizes older patients with degenerative mental disease such as Alzheimer's. Decreased baroreceptor response is at least partly due to a quantitative reduction of $\alpha_1$-adrenergic receptors.[34] Cardiac muscarinic $M_2$ receptors are decreased in number, and cardiac $\beta$-adrenoreceptors are decreased in number and function in aged myocardium. Part of the diminished inotropic and chronotropic response to catecholamines is due to reduced coupling of the $\beta$-adrenoreceptor to the Gs proteins and the catalytic unit, adenylyl cyclase.[35] By contrast, the elderly show an increased sensitivity to midazolam and diazepam due to increased receptor binding and increased receptor functionality.[36,37]

While most age-related physiologic changes are readily compensated under baseline conditions in older patients, the decreased functional reserve becomes apparent whenever demand is increased, such as during surgery.

## Age Related Co-morbidities

Physiologic changes associated with ageing described above need to be distinguished from common co-morbidities present in older population. Leung and colleagues analyzed 544 elderly patients and report disease prevalence of hypertension (58.1%), ischemic heart disease (angina pectoris 16.4%, history of myocardial infarction 9.1% and coronary artery bypass grafting 5.9%, PTCA 3.7%), neurologic disease (22.4%), pulmonary disease (21.9%), valvular heart disease (17.7%), diabetes mellitus (14.9%), congestive heart failure (7.8%), and renal disease (7.6%).[38] The cardiovascular system is highly vulnerable in old age, increasing the challenge to maintain homeostasis during anesthesia.

1. **Hypertension** occurs in almost two thirds of elderly. Howell and colleagues reviewed 30 observational studies and showed the odds ratio for the association between hypertension and perioperative cardiac outcome (ischemic events, arrhythmias and hemodynamic instability) to be 1.35 (1.17–1.65),[39] especially when systolic blood pressure is >180 and diastolic blood pressure >110 mm Hg. However we have no evidence that postponing the surgery reduces perioperative risk, so anesthesiologists should be prepared to manage intravascular volume depletion and labile blood pressure throughout anesthesia.

2. **Ischemic heart disease** is present in close to 35% of elderly patients. AHA/ACC guidelines published in 2007 provide specific algorithm on how to proceed in case of the presence of heart disease.[40] According to the preoperative evaluation guidelines, acute cardiac conditions such as acute coronary syndrome, decompensated congestive heart failure (CHF), severe aortic or mitral valve disease and hemodynamically significant arrhythmias are an indication for surgery cancelation and evaluation of the underlying condition, unless the surgery is emergent. If none of the acute conditions are present, patient's physical capacity is evaluated. If a patient can function at the level of 4 metabolic equivalents (MET) or more without difficulty, surgery should proceed. MET is used as a practical way of expressing the intensity and energy expenditure of physical activities compared to energy cost of the reference metabolic rate of quiet sitting. Moderate intensity activities, such as walking at 3.4 mph, golfing, climbing stairs, leisurely bicycling, raking, planting shrubs, or weeding the garden are considered activities level equal to 4 Mets (meaning during these activities the person would consume four times the energy of quiet sitting). If functional capacity is unknown or lower then 4 Mets the risk stratification is based on revised Lee cardiac risk index. Risk factors including high risk surgery, ischemic heart disease, congestive heart failure, cerebrovascular disease, kidney failure with creatinine over 2, insulin-dependent diabetes mellitus and age >75 yrs. Patients with 3 or more risk factors should undergo stress testing to identify patients who may develop ischemia and would benefit from 30-day period to optimize medical therapy. Long-term beta-blocker therapy and statin therapy is recommended in patients with 0–2 risk factors prior to high-risk and vascular surgery. Special care should be taken to maintain heart rate below 70 beats/minute and systolic blood pressure over 120 mmHg to prevent risk of stroke and increased mortality.

3. **Heart failure** can be systolic or diastolic and is associated with high perioperative morbidity and mortality.[41] Liu and Leung demonstrated that congestive heart failure increased the odds ratio for adverse postoperative events [OR 2.7, 95% CI 1.4–5.3, $P = 0.004$].[42] Clinicians must recognize that one-third to one half of all patients with "congestive heart failure" actually suffer from diastolic cardiac dysfunction (defined as left-atrial pressure >12 mm Hg to maintain adequate cardiac output). Often the elevated left-sided filling pressures are due to increased myocardial stiffness and/or delayed relaxation of the myocardium. Diastolic failure conveys equal risk as systolic heart failure for perioperative outcomes.[43]

4. **Valvular heart disease**—Aortic stenosis is the most significant valvular abnormality in elderly with severe stenosis likely present in >2% of elderly patients.[44] Progression of aortic valve disease is

reported to be 0.14 cm² per year.[45] Co-morbidities such as the severity of valve disease, concomitant coronary artery disease, and the intensity of the surgical procedure contribute to adverse outcomes in non-cardiac surgery.[46] Severe or symptomatic aortic stenosis requires further evaluation before surgery, whereas patients with mild-to-moderate aortic valvular stenosis are often appropriate to proceed to surgery of limited or modest intensity.

5. **Arrhythmias** in elderly have been reviewed previously.[47] Atrial fibrillation is the most frequent supraventricular arrhythmia and impairs cardiac performance of the heart—especially those highly dependent on atrial contraction for ventricular filling. Conduction defects can occur due to loss of pacing myocytes, necrosis of muscle cells, extensive fibrosis, microcalcification and infiltrating adipose and amyloid into the bundle of His. Sinus bradycardia is also commonly observed in elderly and may indicate impending complete heart block.[48]

6. **Diabetes** leads to end-organ injury of cardiovascular, renal, and central nervous systems, and is therefore associated with adverse perioperative outcomes. Diabetes is also an independent predictor of long-term decreased quality of life following surgery.[49,50] The optimal intraoperative blood glucose concentration remains controversial, as several recent meta-analyses of intensive insulin therapy trials found severe hypoglycemia an important and common adverse side-effect. It is likely that aggressive glycemic control is beneficial but only in a select group of surgical patients.[51]

7. **Malnutrition** is associated with increased morbidity and mortality.[52] Albumin is an important predictor of adverse postoperative outcomes, where serum concentrations <21 gm/L are associated with nearly a 30% mortality.[53] Clinicians may find the Mini Nutritional Assessment and Subjective Global Assessment useful as it predicts mortality in elderly surgical patients.[54] Hypoalbuminemia is also associated with adverse reactions to iv medications because of greater bioavailability of protein bound drugs. For instance, a case report associated propofol with the onset *of* torsade de pointes in a severely hypoalbuminemic patient.[55]

8. **Cognitive function** affects postoperative morbidity and mortality. Alzheimer's disease, an important predictor of postoperative cognitive dysfunction, is present in 6% to 8% of patients 65 years and older. Postoperative delirium is more likely in patients with dementia and is associated with a marked increase in surgical mortality.[56,57] Evaluation of preoperative cognitive function with the Folstein Mini-Mental State examination can predict the risk for postoperative delirium and postoperative cognitive dysfunction. Additional risk factors include advanced age, lower educational level, sensory impairment, decreased functional status, co-morbid medical illnesses, malnutrition and depression.[58] Precipitating hospital factors are orthopedic surgery, vascular surgery and cardiac surgery, emergent procedures, delayed hip surgery, peri-operative hemodynamic instability, hypoxemia, electrolyte disturbance, transfusion requirement, sleep deprivation, urinary catheter, immobility, poorly controlled pain, polypharmacy, benzodiazepines, anticholinergics and meperidine (Table 1). Postoperative care of elderly can be complicated by either postoperative delirium (PD) or postoperative neurocognitive disorder (POCD). Fluctuating levels of consciousness and temporary abnormalities in memory and perception characterize PD. Hyperactive, hypoactive and mixed subtypes have been described.[59,60] POCD is a condition with a variable time course characterized by impaired concentration, language comprehension, and social integration. These deficiencies manifest themselves days to weeks after surgery.[61] In vitro experiments have suggested that some anesthetics may interfere with the processing of amyloid β peptide.[62] Amyloid β peptide oligomerization is observed in neurodegenerative disease processes such as Alzheimer' disease. Nuclear magnetic resonance spectroscopic studies suggest that smaller-sized volatile anesthetic agents such as isoflurane and sevoflurane will promote amyloid β peptide oligomerization.[63,64] Larger molecules of propofol, thiopental and diazepam, have not been observed to induce these same amyloid changes. Clinical studies, on the other hand, have not been able to demonstrate significant difference in cognitive outcomes between elderly patients who underwent general or regional anesthesia. The perioperative cognitive dysfunction may be due to factors other then anesthetic agents, such as global perioperative stress hormone release.[65]

**Table 1.** Commonly used sedatives, induction agents and opiates in elderly. The target receptor, perioperative use, active metabolite, and cardiovascular effects are summarized.

| | Receptor | Use | Active metabolite | Cardiovascular effects |
|---|---|---|---|---|
| Midazolam | GABA$_A$ | Sedation | Yes | Minor decrease in BP |
| Diazepam | GABA$_A$ | Sedation | Yes | Minor decrease in BP |
| Fentanyl | μ | Analgesia | No | Bradycardia, mild decrease in BP |
| Hydro-morphone | μ | Analgesia | No | Bradycardia, mild decrease in BP |
| Morphine | μ | Analgesia | Yes | Bradycardia, moderate decrease in BP (histamine release) |
| Remi-fentanyl | μ | Analgesia | No | Bradycardia, decrease in BP |
| Propofol | GABA$_A$ | Sedation/induction | No | Big decrease in BP, bradycardia |
| Etomidate | GABA$_A$ | Sedation/induction | No | Mild to moderate decrease in BP |
| Thiopental | GABA$_A$ | Sedation/induction | Yes | Big decrease in BP |
| Dexmedetomidine | $\alpha_{2a}$ agonist | Sedation/analgesia | No | Bradycardia, mild decrease in BP |

As our population demographics continue to shift into the seventh, eighth, and ninth decades of life, the complexity of patient care will still be dominated by cardiovascular disease. Clinicians must anticipate decreased compensatory reserve and greater sensitivity to many drug effects. Guidelines will continue to be developed that assist our perioperative management of these patients.[40] Improved therapies for diastolic dysfunction, cardiac arrhythmias, malnutrition, and chronic inflammation will optimize patient care in the elderly.

## General Anesthesia in Elderly Patients with Cardiovascular Conditions

Surgery demands augmentation in global blood flow to match increased metabolic requirements commensurate with surgical stress. However, these compensatory mechanisms may be limited in the elderly. Blunted β-adrenoceptor responsiveness results in decreased responsiveness of heart rate, ejection fraction, and global cardiac output. Simultaneous increases in end-diastolic volume, left ventricular size, and myocardial O$_2$ demand are observed. In combination with reduced or absent preload reserve due to an inelastic venous capacitance system, the patient is at an increased risk of circulatory failure. Preload is further decreased due to the depleted intravascular volume as a consequence of diuretic therapy and NPO status associated with surgery. Other cardiac co-morbidities such as ischemic heart disease, systolic and/or diastolic heart failure, and valvular abnormalities further decrease cardiovascular reserve.

Table 2 lists frequently used sedative, analgesic and induction medications for all patients.

When choosing the appropriate agent for the elderly, those with active metabolites must be avoided or used cautiously—especially in those with decreased hepatic or renal reserve. Cardiovascular side-effects are usually characterized in healthy young volunteers, and therefore practitioners should expect exaggerated effects in the elderly.

## Perioperative cardiovascular home medications

Most—but not all—baseline cardiovascular medications should be continued right up until the time of anesthesia and surgery. The AHA/ACC guidelines suggest continuation of perioperative beta-blockers as a Class I recommendation.[40] The intraoperative goal is titration of medications to maintain tight heart rate control, to rates of 70–80 bpm. In recent years significant evidence suggests a protective effect of perioperative statins, which reduce cardiac complications during noncardiac surgery. Perioperative use of calcium channel blockers reduces ischemia and supraventricular tachycardia and is associated

**Table 2.** List of medications that have been demonstrated to be associated with delirium.

Neuroleptics
Fentanyl
Morphine
Meperidine
Oxycodone
Codeine
Midazolam
Diazepam
Lorazepam
Dephenhydramine

with decreased myocardial infarction and mortality. Some of these and other drugs used in the perioperative period may be associated with significant intra-operative hypotension, especially during induction in elderly patients.[66] At this time, clinical investigations have not yet demonstrated an association of such transient hypotension and poorer postoperative outcomes.

## Preoperative sedation

Preoperative sedation is often unnecessary in elderly. Midazolam is metabolized in the liver to 1-OH-midazolam, an active metabolite with 25% the potency of the parent compound (midazolam). This often leads to prolonged confusion and increased delirium in the postoperative period. Due to loss of hepatic tissue with age and reduced hepatic perfusion the clearance of drug is decreased by 30%.[67] Termination of the effect of bolus dose of midazolam is a result of redistribution and is prolonged in elderly. Thus, it is not surprising that midazolam administration increases the incidence of postoperative cognitive dysfunction in elderly patients as compared to propofol.[68] Moreover, the elderly patient receiving midazolam 0.06 mg/kg showed significant reduction in mean arterial blood pressure, respiratory rate and oxygen saturation, potentially leading to additional adverse events.[69]

## Induction agents

Older patients often come to the operating room with depleted intravascular volume. In combination with decreased homeostatic mechanisms this may lead to significant hypotension on induction of anesthesia. On the other hand the decreased myocardial compliance and decreased β-adrenergic responsiveness induces increased sensitivity to fluid overload. Cautious volume replacement in the perioperative time period is required. Most frequently used induction agents are propofol and etomidate:

a) *Propofol* dose needs to be reduced by 20% due to decreased central volume of distribution and decreased systemic and inter-compartmental clearance of the drug in elderly population.[70] The lag time between development of plasma concentration and actual effect site concentration is increased in elderly due to slower circulation times.[71]

Slow titration and use of BIS monitor (target BIS < 60) is recommended to prevent overdose (Fig. 2). Context sensitive half-life for propofol is prolonged exponentially with age and needs to be considered to prevent delayed emergence when infusions of propofol are planned.[70] Propofol decreases blood pressure by three mechanisms:

- vasodilation and lower systemic vascular resistance,
- decreased preload,
- depression of baroreceptor response.

The effect can be pronounced in intravascularly depleted elderly population.[72] Significant bradycardia has also been reported after administration of propofol.[73–75] The proposed mechanism of bradycardia is inhibition of sympathetic cardio-accelerator fiber activity.[76] The bradycardia can be severe in patients also receiving β-blockers.[77] Severe bradycardia requires immediate treatment with atropine, or even more aggressive vasopressors. One other potential negative effect of propofol in the elderly patient is worsening of diastolic function, as demonstrated by Filipovic.[78]

b) *Etomidate* is often used due to its minimal effects on cardiovascular system. Slight decline in blood pressure is caused by a small decrease in systemic vascular resistance. The dose should be reduced by 25% to 50% in elderly due to decreased volume of distribution and diminished clearance.[79]

c) *Thiopental* is rarely used in current practice except in neurosurgical procedures. It causes peripheral



**Figure 2.** Bispectral index uses processed electroencephalogram signals to measure the depth of sedation on a scale from 0 to 100 (0—coma, 40–60 general anesthesia, 60–90 sedated, 100-awake).

vasodilation and direct negative inotropic effects, together producing sharp reductions in cardiac output and blood pressure.[80] Currently, there is no manufacturer marketing thiopental in the United States. A similar barbiturate, thiopentone causes tachycardia and may lead to cardiac ischemia in patients with cardiovascular conditions.[81] Similar to the other induction agents the induction dose should be decreased by 15% to 20%.[82]

## Anesthesia maintenance

Onset of inhalational agents is faster in elderly patients due to reduced cardiac output and faster equilibration between arterial and inspired alveolar concentration. Inhalational anesthetics have a circulatory depressant effect (decreased contractility and slower heart rate). This can lead to a dangerous positive-feedback cycle of decreased uptake ➜ escalating alveolar concentration and ➜ further reductions in cardiac output. Anesthetic potency, MAC, decreases by about 6% per decade.[83] Therefore for all inhalational anesthetics, inspired concentrations should be reduced for patients with advanced age.[11] All volatile agents also induce myocardial depression and may induce nodal rhythms, which may be especially detrimental in patients with valvular stenotic lesions or hypertrophic obstructive cardiomyopathy. Studies comparing sevoflurane and desflurane recovery times demonstrated faster early recovery (time to extubation, eye opening, squeezing fingers on command, orientation) for desflurane. However, intermediate recovery, evaluated by Digit-Symbol Substitution Test (DSST), was similar for both inhaled agents.[84] Comparison of propofol, desflurane and isoflurane anesthesia maintenance demonstrated no statistically significant time improvement in propofol and desflurane group.[85] Inhalational agents have been demonstrated to improve echocardiographic parameters of diastolic function by shortening isovolumic relaxation time and increasing early diastolic peak velocity of the lateral mitral annulus.[78] Whether this translates into clinical benefit for the patient remains to be investigated. Total intravenous anesthesia with propofol in elderly may confer benefits for patients' postoperative cognitive recovery. Unlike inhalational anesthetics propofol does not induce amyloid β peptide oligomerization implicated in the mechanisms of Alzheimer's disease.

## Neuromuscular blocking drugs

Shorter acting nondepolarizing neuromuscular blocking agents are preferred. Changes in renal excretion, hepatic metabolism and volume of distribution should be considered when deciding on the drug of choice. Vecuronium, rocuronium or cistaracurium are frequently utilized. Neostigmine is safely used for reversal of neuromuscular blockade. The effects are prolonged due to decreased clearance and decreased initial volume of distribution.[11,86]

## Pain control

Poorly controlled postoperative pain is a significant factor in postoperative cognitive dysfunction in the elderly. Careful planning of pain management is therefore an important part of anesthetic management. However, we will not discuss regional pain management techniques in this review.

a) *Opiates*: The risk of respiratory depression with opioids is increased 2.8 fold in patients 61–70 years old as compared to younger patients. Side effects such as nausea and vomiting however are decreased by 13%.[87,88] When morphine is used the potential for accumulation of active metabolite morphine-6-glucuronide has to be considered in the presence of renal dysfunction. In the management of acute postoperative pain elderly require the same amounts of morphine as younger patients. Aubrun and colleagues suggested administration of 2–3 mg iv bolus every 5 minutes titrated to a visual analog scale below 30. No toxicity was observed in elderly with acute pain when this approach was used.[89,90] Several days after surgery, however, elderly patients require less opioid than younger patients. In a prospective patient-controlled analgesia (PCA) study older patients self-administered less opioid than younger patients.[91]

b) *Dexmedetomidine* has been successfully used for intraoperative and postoperative sedation and/or analgesia. Its sedative/analgesic properties have been demonstrated to decrease the prevalence of postoperative delirium and systolic hypertension in patients undergoing cardiac surgery.[92] The patients treated with dexmedetomidine however have an increased incidence of bradycardia, especially if loading doses are administered rapidly.

## Summary

The goal of anesthetic management in elderly patients needs to be preservation of hemodynamic stability, and avoidance of excessive sedation and respiratory depression. The co-morbidities and special requirements of each patient must be evaluated in our older patients, and a careful anesthetic plan tailored to account for significant variation in physiological responses between individuals.

As a general rule benzodiazepines are not recommended in elderly due to an prolonged cognitive deficits. All induction agents can be used safely if doses are decreased, pharmacokinetic and pharmacodynamic changes are taken into account and hemodynamic effects are carefully monitored. Exaggerated cardiovascular effects of medications are expected since the cardiovascular system has a decreased ability to respond, even in the absence of cardiovascular disease. When cardiovascular disease is present ACC/AHA guidelines provide a basic tool, which needs to be modified according to the patient's overall condition, type and purpose of the surgery and other co-morbidities. Hemodynamic effects of inhalational anesthetics can be easily managed, but the requirements are decreased also for these agents. Maintenance with inhalational anesthetics—especially excessively "deep levels"—may have deleterious effects on cognition especially in patients with preexisting cognitive deficits. Total intravenous anesthesia with propofol is a valid option, but the exponential increase in context sensitive half-life may delay the wakeup. Postoperative pain control is important due to its effects on hemodynamic stability and cognitive function. Immediate requirements of elderly for pain medications are the same as for younger patients, but decrease 2–3 days postoperatively. Adjunct agent such as dexmedetomidine can be used successfully in elderly patient for sedation/analgesia. Constant vigilance by the anesthesia professional is the ultimate safeguard against unanticipated side effects and deleterious outcomes.

## Disclosure

## References

1. Hobbs FB. Population profile of the United States. The elderly population. US. Census Bureau. Available at http://www.census.gov/population/www/pop-profile/elderpop.html. Accessed on 11/16/2010.
2. Ungvari Z, Kaley G, de Cabo R, et al. Mechanisms of vascular aging: New perspectives. *J Gerontol A Biol Sci Med Sci*. 2010;65A:1028–41.
3. Jablonski KL, Seals DR, Eskurza I, et al. High-dose ascorbic acid infusion abolishes chronic vasoconstriction and restores resting leg blood flow in healthy older men. *J Appl Physiol*. 2007;103:1715–21.
4. Ungvari Z, Buffenstein R, Austad SN, et al. Oxidative stress in vascular senescence: lessons from successfully aging species. *Front Biosci*. 2008;13:5056–70.
5. Franceschi C, Bonafe M, Valensin S, et al. Inflamm-aging. An evolutionary perspective on immunosenescence. *Ann N Y Acad Sci*. 2000;908:244–54.
6. Miles EA, Rees D, BanerjeeT, et al. Age-related increases in circulating inflammatory markers in men are independent of BMI, blood pressure and blood lipid concentration. *Atherosclerosis*. 2008;196:298–305.
7. Erusalimsky JD. Vascular endothelial senescence: from mechanism to pathophysiology. *J Appl Physiol*. 2009;106:326–32.
8. Boddaert J, Mallat Z, Fornes P, et al. Age and gender effects on apoptosis in the human coronary arterial wall. *Mec Ageing Dev*. 2005;126:678–84.
9. Gonzalez A, Rota M, Nurzynska D, et al. Activation of cardiac progenitor cells reverses the failing heart senescence phenotype and prolongs lifespan. *Circ Res*. 2008;102:597–606.
10. Rooke GA. Cardiovascular ageing and anesthetic implications. *J Cardiothorac Vasc Anesth*. 2003;17:512–23.
11. Das S, Forrest K, Howell S. General Anesthesia in elderly patients with cardiovascular disorders. *Drugs Aging*. 2010;27:265–82.
12. Bulpitt CJ, Rajkumar C, Cameron JD. Vascular compliance as a measure of biological age. *J Am Geriatr Soc*. 1999;47:657–63.
13. Downes TR, Nomeir AB, Smith KM, et al. Mechanisms of altered pattern of left ventricular filling with ageing in subjects without cardiac disease. *Am J Cardiol*. 1989;64:523–7.
14. Ebert TJ, Morgan BJ, Barney JA, et al. Effects of ageing on baroreflex regulation of sympathetic activity in humans. *Am J Physiol*. 1992;263:H798–803.
15. Critchley LAH, Conway F. Hypotension during subarachnoid anaesthesia: hemodynamic effects of colloid and metaraminol. *Br J Anaesth*. 1996;76:734–6.
16. Sprung J, Gajic O, Warner DO. Review article: Age related alterations in respiratory function—anesthetic considerations. *Can J Anesth*. 2006;53:1244–57.
17. Tonner PH, Kampen J, Scholz J. Pathophysiological changes in elderly. *Best Pract Res Clin Anaesthesiol*. 2003;17:163–77.
18. Erskine RJ, Murphy PJ, Langton JA, et al. Effects of age on the sensitivity of upper airway reflexes. *Br J Anaesth*. 1993;70:574–5.
19. Zaugg M, Lucchinetti E. Respiratory function in elderly. *Anesthesiol Clin North America*. 2000;18:47–58 [vi.].
20. ElDesoky ES. Pharmacokinetic-pharmacodynamic crisis in the elderly. *Am J Therap*. 2007;14:488–98.
21. Turnheim K. Drug dosage in the elderly. Is it rational? *Drugs aging*. 1998;13:357–79.
22. Wilkinson GR. The effects of diet, aging, and disease-states on presystemic elimination and oral drug bioavailability in humans. *Adv Drug Deliv Rev*. 1997;27:129–59.
23. Turnheim K. When drug therapy gets old: pharmacokinetics and pharmacodynamics in the elderly. *Experimental Gerontology*. 2003;38:843–53.
24. Grandison MK, Boudinot FD. Age-related changes in protein binding of drugs: implications for therapy. *Clin Pharmacokinet*. 2000;38:271–90.
25. Schmucker DL. Aging and drug disposition: an update. *Pharmacol Rev*. 1985;37:133–48.
26. Durnas C, Voi CM, Cusack BJ. Hepatic drug metabolism and aging. *Clin Pharmacokinet*. 1990;19:359–89.

27. Le Couteur DG, McLean AJ. The aging liver. Drug clearance and an oxygen diffusion barrier hypothesis. *Clin Pharmacokinet*. 1998;34:359–73.

28. Macias-Nunez J-F, Lopez-Novoa JM. Physiology of the healthy Aging kidney. In: Oreopoulos DM, Cameron JS, Macias-Nunez JF, editors. *The aging kidney in health and disease*. New York: Springer; 2008. p. 93–112.

29. Muhlberg W, Platt D. Age-dependent changes of the kidneys: pharmacological implications. *Gerontology*. 1999;45:243–53.

30. Zhou XJ, Rakheja D, Yu X, et al. The ageing kidney. *Kidney Int*. 2008;74: 710–20.

31. Lindeman RD, Tobin J, Shock NW. Longitudinal studies on the rate of decline in renal function with age. *J Am Geriatr Soc*. 1985;33:278–85.

32. Morike K, Schwab M, Klotz U. Use of aminoglycosides in elderly patients. Pharmacokinetic and clinical considerations. *Drugs Aging*. 1997;10: 259–77.

33. Feely J, Coakley D. Altered pharmacodynamics in the elderly. *Clin Geriatr Med*. 1990;6:269–83.

34. Jones PP, Christou DD, Jordan J, et al. Baroreflex buffering is reduced with age in healthy men Circulation. 2003;107:1770–4.

35. Roth DA, White CD, Podolin DA, et al. Alterations in myocardial signal transduction due to aging and chronic dynamic exercise. *J Appl Physiol*. 1998;84:177–84.

36. Mangoni AA, Jackson SHD. Age-related changes in pharmacokinetics and pharmacodynamics: basic principles and practical applications. *Br J Clin Pharmacol*. 2003;56:254–60.

37. Platten HP, Schweizer E, Dilger K, et al. Pharmacokinetic and pharmacodynamic action of midazolam in young and elderly patients under tooth extraction. *Clin Pharmacol Ther*. 1998;63:552–60.

38. Leung JM, Dzankic S. Relative importance of preoperative health status versus intraoperative factors in predicting postoperative adverse outcomes in geriatric surgical population. *J Am Geriatr Soc*. 2001;49:1080–5.

39. Howell SJ, Sear JW, Foex P. Hypertension, hypertensive heart disease and perioperative riks factors. *Br J Anaesth*. 2004;92:570–83.

40. Fleisher LA, Bechman JA, Brown KA, et al. ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery. Executive summary: report of the American College of Cardiology/ American Heart Association task force on practice guidelines. *J Am Coll Cardiol*. 2007;50:1707–32.

41. Howell SJ, Sear YM, Sear JW, et al. Cardiovascular death within 30 days following anesthesia and urgent or emergency surgery: determination of risk factors using a nested case control study. *Br J Anaesth*. 1999;82: 679–84.

42. Liu LL, Lueng JM. Predicting adverse postoperative outcomes in patients aged 80 years and older. *J Am Geriat Soc*. 2000;48:405–12.

43. Redfield MM, Jacobsen SJ, Burnett JC Jr, et al. Burden of systolic and diastolic ventricular dysfunction in the community: appreciating the scope of the heart failure epidemic. *JAMA*. 2003;289:194–202.

44. Lindroos M, Kupari M, Heikkila J, et al. Prevalence of aortic valve abnormalities in the elderly: an echocardiographic study in a random population sample. *J Am Coll Cardiol*. 1993;21:1220–5.

45. Brener SJ, Duffy CI, Thomas JD, Stewart WJ. Progression of aortic stenosis in 394 patients: relation to changes in myocardial and mitral valve dysfunction. *J Am Coll Cardiol*. 1995;25:305–10.

46. Christ M, Sharkova Y, Geldner G, Maisch B. Preoperative and perioperative care for patients with suspected or established aortic stenosis facing noncardiac surgery. *Chest*. 2005;128:2944–53.

47. Priebe H-J. The aged cardiovascular risk patient. *Br J Anaesthesia*. 2000;85: 763–78.

48. Sear JW, Higham H. Issues in the perioperative management of the elderly patient with cardiovascular disease. *Drugs Aging*. 2002;19:429–51.

49. Manku K, Leung J. Prognostic significance of postoperative in-hospital complications in elderly patients. II Long-term quality of life. *Anesth Analg*. 2003;96:590–4.

50. John AD, Sieber FE. Age associated issues: geriatrics. *Anesthesiology Clin N Am*. 2004;22:45–58.

51. Griesdale DEG, de Souza RJ, van Dam PM, et al. Intensive insulin therapy and mortality among critically ill patients: a meta-analysis including NICE-SUGAR study data. 2009;180:821–7.

52. Gibbs J, Cull W, Henderson W, et al. Preoperative serum albumin level as a predictor of operative mortality and morbidity: results from National VA surgical risk study. *Arch Surg*. 1999;134:36–42.

53. Daley J, Khuri SF, Henderson W, et al. Risk adjustment of the postoperative morbidity rate for the comparative assessment of the quality of surgical care: results of the National Veterans Affairs surgical risk study. *J Am Coll Surg*. 1997;185:328–40.

54. Persson MD, Brismar KE, Katzarski KS, et al. Nutritional status using mini nutritional assessment and subjective global assessment predict mortality in geriatric patients. *J Am Geriatr Soc*. 2002;50:1996–2002.

55. Irie T, Kaneko Y, Nakajima T, et al. QT interval prolongation and torsade de pointes induced by propofol and hypoalbuminemia. *Int Heart J*. 2010;51: 365–6.

56. Dyer CB, Ashton CM, Teasdale TA. Postoperative delirium. A review of 80 primary data-collection studies. *Arch Intern Med*. 1995;461–5.

57. Bernstein GM, Offenbartl SK. Adverse surgical outcomes among patients with cognitive impairments. *Am Surg*. 1991;57:682–90.

58. Bagri AS, Rico A, Ruiz JG. Evaluation and management of the elderly patient at risk for postoperative delirium. *Thorac Surg Clin*. 2009;19:363–76.

59. Cole MG. Delirium in elderly patients. *Am J Geriatr Psychiatry*. 2004; 12:7–21.

60. Inouye SK, Delirium in older persons. *N Engl J Med*. 2006;354:1157–65.

61. Loran DB, Hyde BR, Zwischenberger. Perioperative management of special population: the geriatric patient. *Surg Clin N Am*. 2005;85:1259–66.

62. Fodale V, Santamaria LB, Schifilliti D, Mandal PK. Anaesthetics and postoperative cognitive dysfunction: a pathologic mechanism mimicking Alzhemer's disease. *Anaesthesia*. 2010;65:388–95.

63. Mandal PK, Fodale V. Isoflurane and desflurane at clinically relevant concentrations induce amyloid beta-peptide oligomerization: an NMR study. *Biochemical and Biophysical Research Communication*. 2009;379: 716–20.

64. Mandal PK, Fodale V. Smaller molecular-sized anaesthetics oligomerize a beta peptide simulating Alzheimer's disease: a relevant issue. *Eur J Anaesth*. 2009;26:805–6.

65. Ancelin ML, de Roquefeuil G, Scali J, et al. Long-term post-operative cognitive decline in the elderly: the effects of anesthesia type, apolipoprotein E genotype and clinical antecedents. *J Alzhemiers Dis*. 2010;Suppl 3:105–13.

66. Rosenman DJ, McDonald FS, Ebbert JO, et al. Clinical consequences of withholding versus administering rennin-angiotensin-aldosteron system antagonists in the preoperative period. *Journal of Hospital Medicine*. 2008;3:319–25.

67. Maitre PO, Buhrer M, Thomson D, et al. A three step approach combining Bayesian regression and NONMEM population analysis: application to midazolam. *J Pharmacokinet Biopharm*. 1991;19:377–84.

68. White PF, Negus JB. Sedative infusion during local and regional anesthesia: a comparison of midazolam and propofol. *J Clin Anesth*. 1991;3:32–9.

69. Sun GC, Hsu MC, Chia YY, et al. Effects of age and gender on intravenous midazolam premedication: a randomized double-blind study. *Br J Anaesth*. 2008;101:632–9.

70. Shafer SL. The pharmacology of anaesthetic drugs in elderly patients. *Anesthesiol Clin North Am*. 2000;18:1–29.

71. Schnider TW, Minto CF, Shafer, et al. The influence of age on propofol pharmacodynamics. *Anesthesiology*. 1999;90:1502–16.

72. John AD, Sieber FE. Age associated issues: geriatrics. *Anesthesiol Clin North Am*. 2004;22:45–58.

73. Thomson SJ, Yate PM. Bradycardia after propofol infusion (letter). *Anaesthesia*. 1987;42:430.

74. Huang J, Wilson S. Severe bradycardia after propofol infusion (letter). *AANA*. 2008;76:413.

75. Egan TD, Brock-Utne JG. Asystole after anesthesia induction with fentanyl, propofol, and succynilcholine sequence. *Anesth Analg*. 1991;73:818–20.

76. Krassioukov AV, Gelb AW, Weaver LC. Action of propofol on central sympathetic mechanism controlling blood pressure. *Can J Anaesth*. 1993;40: 761–69.

77. Yang H, Raymer K, Butler R, et al. The effects of perioperative beta-blockade: results of Metoprolol after Vascular Surgery (MaVS) study, a randomized controlled trial. *Am Heart J*. 2006;152:983–90.

78. Filipovic M, Wang J, Michaux I, et al. Effects of halothane, sevoflurane and propofol on left ventricular diastolic function in humans during spontaneous and mechanical ventilation. *Br J Anaesth*. 2005;94:186–92.

79. Arden JR, Holley OF, Stanski DR. Increased sensitivity to etomidate in the elderly: initial distribution versus altered brain response. *Anesthesiology*. 1986;65:19–27.

80. Dundee JW. Fifty years of thiopentone. *Br J Anaesth*. 1984;56:211.

81. Sinntag H, Hellberg K, Schenk HD, et al. Effects of thiopental on coronary blood flow and myocardial metabolism in man. *Acta Anesthesiol Scand*. 1975;19:69–78.

82. Stanski DR, Maitre PO. The effect of increasing age on thiopental disposition and anesthetic requirement. *Anesthesiology*. 1985;62:714–24.

83. Mapleson WW. Effects of age on MAC in humans: a meta-analysis. *Br J Anaesth*. 1996;76:179–85.

84. Heavner JE, Kaye AD, Lin B-K, King T. Recovery of elderly patients from two or more hours of desflurane or sevoflurane anaesthesia. *Br J Anaesth*. 2003;91:502–6.

85. Fredman B, Zohar E, Philipov A, et al. The induction, maintenance, and recovery characteristics of spinal versus general anesthesia in elderly patients. *J Clin Anesth*. 1998;10:623–30.

86. Young WL, Backus W, Matteo RS, et al. Pharmacokinetics and pharmaco-dynamics of neostigmine in the elderly. *Anesthesiology*. 1984;61:A300.

87. Cepeda MS, Farrar JT, Baumgarten M, et al. Side effects of opioids during short term administration: effects of age, gender and race. *Clin Pharmacol Ther*. 2003;74:102–12.

88. Sinclair DR, Chung F, Mezei G. Can postoperative nausea and vomiting be predicted? *Anesthesiology*. 1999;91:109–18.

89. Aubrun F, Monsel S, Langeron O, et al. Postoperative titration of intrave-nous morphine in the elderly patient. *Anesthesiology*. 2002;96:17–23.

90. Aubrun F, Bunge D, Langeron O, et al. Postoperative morphine consump-tion in the elderly patient. *Anesthesiology*. 2003;99:160–5.

91. Gagliese L, Jackson M, Ritvo P, et al. Age is not an impediment to effective use of patient-controlled analgesia by surgical patients. *Anesthesiology*. 2000;93:601–10.

92. Shehabi Y, Grant P, Wolfenden H, et al. A randomized controlled trial (DEX-medetomidine Compared to Morphine—DEXCOM study). *Anesthesiology*. 2009;111:1075–84.