Syllabus on Geriatric Anesthesiology

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Disclaimer

The opinions expressed in this document represent those of the authors. The purpose of the document is to educate physicians and others about anesthetic issues pertinent to the elderly population. The document specifically does not purport to provide practice guidelines. The text is not intended to be comprehensive and any apparent anesthetic management suggestions will not apply to all patient situations.

Introduction

One of the goals of the ASA Committee on Geriatric Anesthesia is to promote education of residents and anesthesiologists about those aspects of aging that affect anesthetic practice. This syllabus is our attempt to provide basic information useful to all anesthesia practitioners. Chapters are deliberately short in order to force focus on the important issues. More detailed information can easily be obtained from the references at the end of each chapter.

You are free to use this syllabus as you see fit for your colleagues', your residents' and your own education. You may make copies of all or part of the syllabus, so long as it is not used for commercial purposes. Please give appropriate credit to the authors whose work you use.

The syllabus should be considered a work in progress. With the availability of the syllabus through the ASA Web site, all ASA members will have immediate access to the latest revision. Chapters may be added or deleted, and existing chapters will change as new information becomes available or revisions are made for clarity. Your comments and suggestions are welcome and can be addressed to me. Another useful, web-based resource is the book, "Geriatrics at Your Fingertips". This small, reference textbook is published annually by the American Geriatrics Society. As of 2002, the AGS has made it available online for free at www.geriatricsatyourfingertips.org. Although designed for primary caregivers, many of the chapters have application to anesthesia. The text is a nice counterpart to the geriatric anesthesia syllabus and is highly recommended as a quick and dirty resource for information on aging.

Many people have contributed to this syllabus. Although each chapter has been edited, each chapter reflects the author's assessment of the literature and bias as to content. There are strengths to multi-author works, and it was particularly gratifying to find individuals other than present or former committee members who were willing to contribute. The success of the syllabus resides with the authors and we are very grateful for their efforts. We hope you find the syllabus useful in your care of the most rapidly growing segment of our population. Anyone interested in getting further involved with geriatric anesthesia is encouraged to contact the ASA about the Committee on Geriatric Anesthesia or to contact the newly founded Society for the Advancement of Geriatric Anesthesia (www.sagahq.org).

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Gerontology

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Geriatric Anesthesia - Are You Ready?

Increased life expectancy and reduced mortality from chronic age-related disease continue to enlarge that fraction of the surgical patient population considered elderly. These apparently beneficial demographic changes have further amplified the societal impact of the increasing per capita health care costs that already represent a formidable fiscal burden for modern societies. As they age, adult patients also exhibit an increasingly complex array of unique physical responses to environmental and socioeconomic conditions and to concurrent disease states. Survival to adulthood and beyond permits the full expression of even the most subtle genetic differences between individuals, differences that might not be fully apparent over shorter life span intervals. People are never more alike than they are at birth, nor more different or unique than when they enter the geriatric era. Precise assessment and appropriate perioperative management of the elderly surgical patient represents a great challenge to all medical health care providers.

Surgical procedures in the elderly will continue to require a disproportionately large share of societal and institutional health care resources. Routine postoperative hospitalization and intensive care, especially after major trauma, are frequently protracted and may be further complicated by infection, poor wound healing and by multiple organ system failure for critically ill elderly patients. Of equal concern are recent findings that postoperative cognitive dysfunction may persist at least three months after otherwise uncomplicated surgery.

Although they represent only 12 percent of the United States population, individuals 65 years of age or older undergo almost one-third of the 25 million surgical procedures performed annually, and they consume about one-third of all health expenditures and fully one-half of the $140 billion annual U.S. federal health care budget. Therefore, every anesthesiologist in contemporary practice eventually becomes a subspecialist in geriatric medicine, with a special responsibility for delivering cost-effective health care to older adults.

In its broadest sense, gerontology refers to the study of aging.[1] Biogerontologists usually limit their scope to the physiological and biochemical, rather than the socioeconomic, aspects of aging. Although many gerontologists study human aging exclusively, others have extended their interests to a cellular or subcellular level and therefore this discipline may encompass the study of nonhuman organisms. In contrast, *geriatrics*, a term with origins early in this century, is more specific because it describes the medical subspecialty that focuses upon care of the elderly patient.[2] Geriatricians are physicians who specialize in the care of the elderly patient.

Studies of human aging have been further complicated by difficulties in discriminating clearly between aging itself and the consequences of age-related disease and cohort-specific effects that make data from cross-sectional studies ambiguous. *Cross-sectional studies* measure physiologic parameters simultaneously in young and in elderly subjects. Therefore, changes due to undiagnosed age-related disease may be erroneously attributed to age itself. Similarly, this experimental design cannot be controlled for cohort-specific factors such as nutritional and environmental history, genetic background or prior exposure to infectious agents. Consequently, data from cross-sectional studies rarely permit unambiguous conclusions regarding the effect of age itself on any one measured physiologic parameter. Many of the "classic" cross-sectional studies of aging in the gerontologic literature must be reconsidered.

Some biogerontologists feel that processes of aging can be unequivocally identified only when a *longitudinal study* is used to supplement carefully performed cross-sectional studies. For some measurements such as glomerular filtration, data from longitudinal studies have validated the results of earlier cross-sectional investigations.[3] However, longitudinal studies of human aging require an arbitrary chronological "starting point" for the geriatric era that may change significantly during the duration of the study itself because of increases in life expectancy.[4] They also have intrinsic sources of error.[5] In addition, the validity and utility of the data they generate are subject to the evolution or revision of physiologic concepts and measurement techniques over the long time period required to study human aging.

Processes of aging are usually distinguishable from age-related disease by the fact that they are universally present in all members of an elderly population and, in longitudinal studies of aging subjects, become progressively more apparent with increasing chronological age. Aging is a *universal and progressive* physiologic phenomenon characterized by degenerative changes in both the structure and the functional reserve of organs and tissues. It produces many physical manifestations due to reduced connective tissue flexibility and elasticity or the degeneration of highly structured molecular arrangements within specialized tissues. At the tissue level, cross-linking, glycosylation, or similar dysfunctional interactions occur.[6] The difference between maximum capacity and basal levels of function is *organ system functional reserve*, a "safety margin" available to meet the additional demands imposed by trauma or disease, or by surgery, healing and convalescence. Cardiopulmonary functional reserve, for example, can be quantified and assessed clinically using various exercise or maximal stress tests. However, there is at present no comparable approach to assessment of renal, hepatic, immune, or nervous system functional reserve. It is simply assumed that the functional reserve of these organ systems is reduced in elderly patients and that this is the mechanism by which the obvious susceptibility of elderly patients to stress- and disease-induced organ system decompensation occurs.

CONCEPTS OF AGING

Life span is an idealized, species-specific biologic parameter that quantifies maximum attainable age under optimal environmental conditions. Historical anecdote suggests that human life span has remained constant at 110 to 115 years for at least the past 20 centuries.[7] In contrast, *life expectancy* describes an empirical estimate of typical longevity under prevailing or predicted circumstances. Advances in medical science and health care have improved life expectancy dramatically in industrialized societies and increased their relative "agedness" but do not appear to have altered human life span. The mechanisms that control the aging process and determine life span remain unknown. Perhaps because gerontology is a relatively new discipline, theories of aging have been presented from various individual perspectives, many without any logical interconnection or relationship.

In general, however, theories of aging fall into two major categories. One group can be described as stochastic because it is essentially time- and probability-dependent. The nonstochastic group includes those theories proposing that there are programmed or predetermined mechanisms that explain aging. Nonstochastic theories of aging share a common theme of a "biological clock" or “life pacemaker” for each species.[8] In order to effect processes of aging throughout the organism, the pacemaker tissue or organ must itself have widespread interaction with all other organ systems. Therefore, this type of theory usually involves a neuroendocrine or immune mechanism.

The "error-catastrophe" theory of aging is a stochastic concept. It postulates that random errors of protein synthesis due to faulty nucleic acid transcription or translation eventually accumulate to compromise cellular function and produce the physical signs of aging. However, there is little evidence that the individual cells of older subjects contain more defective protein than do young cells. This theory also fails to explain the dramatically different patterns of aging that are seen in various animal species that share a common ecosystem and are exposed to similar catabolic environmental forces such as ionizing radiation. Similarly, a "genetic wear and tear" theory of aging proposes that recurrent damage to nuclear deoxyribonucleic acid (nDNA) eventually exhausts intrinsic intracellular capacity for nuclear chromosomal repair, leading to a critical loss of functioning cellular and tissue elements. Although there is a general correlation between species longevity and nDNA repair capacity, there is no firm evidence that the ability to recover from random nDNA damage is, in fact, progressively or universally compromised in older human subjects.[9]

However, investigations of oxidative phosphorylation in aging mitochondria suggest that progressive increases in the incidence of defects within mitochondrial DNA (mDNA) may lead to a decline in bioenergetic capacity and a progressive reduction in the efficiency with which free radical species such as superoxide, routinely produced in the mitochondria during aerobic metabolism, are scavenged from the cytosol of aging cells.[10] Free radicals damage the unsaturated fatty acid and nucleic acid components of cells and cross-link protein molecules, eventually damaging cellular microarchitecture.[11] Superoxide dismutase appears to be the most important endogenous enzymatic scavenger of free radical species and, in fact, it is present in higher concentrations within human cells than in the cells of species with a shorter life span. A relatively recent proposal suggests that cellular aging is due to a “vicious cycle” of diffuse bioenergetic failure in the mitochondria of metabolically-active tissues.[12] This mechanism, which may be thought of as progressive failure of a genetically-determined capacity to clear random damage to mDNA by free-radicals, is compatible with both stochastic and nonstochastic theories and falls within the larger evolving concept that aging is a consequence of a lifetime of “oxidative stress.”[13,14]

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Cardiovascular and Autonomic Nervous System Aging

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With advancing age, the autonomic nervous system (ANS), heart and blood vessels become less capable of maintaining hemodynamic stability. While aging is, of course, a heterogeneous process both within and among individuals, some aspects are characteristic of the elderly cohort. Typical developments include a diminution in the tonic influence of the parasympathetic nervous system (PNS), a decline in the responsiveness of β-receptors and a progressive replacement of supple, functional cardiac and vascular tissue by stiff, fibrotic material.

With advancing age, increasing arterial rigidity tends to elevate the systemic vascular resistance (SVR). Increased sympathetic nervous system (SNS) activity may also contribute to the increase in SVR, although this age-related change is controversial in its magnitude and importance. Hypertension in the elderly is characterized by a disproportionate increase in systolic pressure. In consequence, the left ventricle (LV) must work harder to eject blood into a more rigid aorta. This chronic strain eventually causes the LV to become hypertrophied. Also controversial is the degree to which aging is associated with decreases in cardiac output (CO) and stroke volume (SV) at rest. Decreases of upwards of 5% per decade have been described, but other studies show very little change with age. Part of the disparity may revolve around the cardiovascular health of the subjects studied, and the fact that the decrease in metabolic demand with age can be expected to reduce cardiac output requirements.

Veins are also subject to progressive stiffening with age. The decreased compliance of the capacitance system reduces its ability to "buffer" changes in intravascular volume. Thus, aging can exaggerate the hypotension that results from blood loss, as well as from the peripheral pooling of blood with general or conduction anesthesia.

Increased stiffness of the (hypertrophied) elderly cardiac ventricle impairs diastolic filling, and could cause a reduction in end-diastolic volume. The elderly heart may have an increased end-diastolic pressure that can overcome the stiffened ventricle, but the proof of this assertion is weak except in those elderly patients with severe diastolic dysfunction. In such cases, the elevated left ventricular filling pressures are reflected into the left atrium and the pulmonary vasculature and can lead to pulmonary congestion. Clinically important diastolic dysfunction likely involves poor ventricular relaxation in early diastole as well as the natural ventricular tissue stiffening from aging and hypertrophy. In less affected elderly individuals, ventricular filling may be preserved without excessive increases in atrial pressure via the atrial kick to enhance late diastolic filling. Loss of the sinus rhythm, a common event during general anesthesia, may well depress cardiac output and arterial pressure more markedly in the elderly than it would in a normal younger patient.

In healthy young adults, the baseline autonomic tone is dominated by the parasympathetic branch. With advancing age, tonic parasympathetic outflow declines, while overall sympathetic neural activity increases. However, elderly subjects generally manifest a reduced responsiveness to β-adrenergic stimulation. Although resting heart rates do not change much with age, the maximal attainable heart rate, stroke volume, ejection fraction, cardiac output and oxygen delivery (DO2) are all reduced in healthy older adults. The administration of β-adrenergic agonists elicits lesser inotropic and chronotropic responses in the elderly, while β-blocking drugs retain their effectiveness. (In contrast, the vascular responses to exogenous α-adrenergic agonists do not appear to be much affected by age, although experimental results are not all in agreement.)

As aging impairs both the diastolic filling and the chronotropic and inotropic responsiveness of the heart, the ability of the older patient to cope with perioperative stress is predictably impaired. Increased metabolic demands, such as those imposed by sepsis or postoperative shivering, may not be met when the maximal CO and DO2 are limited by aging. While young adults can compensate for blood loss (exacerbated by anesthetic-induced vasodilation) with increases in heart rate and ejection fraction, the elderly cannot so readily maintain their cardiac output and are more dependent upon vasoconstriction to sustain adequate arterial pressures.

The maintenance of hemodynamic homeostasis largely depends upon the baroreceptor reflex. Baroreceptors in the aortic arch and carotid sinus are actually stretch receptors; a decrease in distention of these receptors results in augmented SNS activity and inhibition of PNS outflow. Arterial stiffening may reduce the ability of the baroreceptors to transduce changes in pressure, diminishing the magnitude of the baroreflex. Both aging and hypertension are associated with increased arterial rigidity. It is therefore not surprising that, in general, both advancing age and chronic hypertension, alone or together, are associated with impairment of baroreflex responsiveness. This impairment likely contributes to the increased susceptibility of older adults to orthostatic hypotension, a problem that is exacerbated by the common administration of diuretic and other medications, such as those used to treat hypertension, depression and Parkinsonism.

The aging of cardiac and vascular tissues, the decline of β-adrenergic and baroreceptor responsiveness and common pharmacologic regimens thus combine to render the elderly patient less capable of defending his or her CO and BP against the usual perioperative challenges. In addition, atherosclerosis may convert a moderate degree of hypotension into an intolerable reduction in cardiac, cerebral or renal blood flow. Although different individuals age in different ways and degrees, we can expect our older patients to require greater vigilance and more active interventions to guide them safely through surgery and anesthesia.

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Physiology of the Cardiovascular Effects of General Anesthesia in the Elderly

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Three general anesthetics, isoflurane, desflurane and sevoflurane, are commonly employed in the elderly. All three show a similar decline in MAC with age that is about 6 percent per decade. In healthy and generally younger patients and volunteers, these anesthetics enjoy reasonably similar properties of maintaining cardiac output, despite dose related decreases in myocardial contractility, blood pressure and systemic vascular resistance. The maintenance of cardiac output is more dependent on increases in heart rate with isoflurane than with either sevoflurane or desflurane. Although there is limited data comparing these anesthetics in the elderly, some general observations are worth commenting on. First, with increasing age, there are well described changes in cardiac, vascular and autonomic function. There is a reduction in the maximum attainable heart rate due to a decrease in the response to beta adrenergic receptor stimulation and an increased dependence on late diastolic filling due to a reduction in diastolic compliance of the heart. The decreased cardiac response to beta adrenergic stimulation also compromises the baroreflex-mediated heart rate increase to hypotension.

There is a general perception that the elderly have a larger decrease in blood pressure at a given concentration of a volatile anesthetic than younger patients. The hard science to support this frequent observation is generally lacking. In one study, 1 MAC isoflurane decreased cardiac output in elderly patients compared to younger patients. The mechanism appears to be more related to a lack of an increase in heart rate during isoflurane in the elderly. Because cardiac output was reduced, the decrease in blood pressure was greater in the elderly. Certainly other factors may account for the perceived greater hemodynamic sensitivity of the elderly. First, the age related impairment of reflex heart rate responses to hypotension in the elderly and the further depression of the other components of the baroreflex by the volatile anesthetics are likely to act in concert to compromise blood pressure in the elderly. Secondly, because all volatile anesthetics reduce myocardial contractility, any underlying cardiac pathology might exaggerate the expected myocardial effect of the anesthetics. Third, many elderly patients are relatively volume contracted. Therefore, the direct effects of volatile anesthetic to cause vascular relaxation might enhance the blood pressure decrease during anesthesia by several mechanisms: cardiac filling pressures might be reduced thereby compromising the preload dependent, "stiff" ventricle of the elderly and vascular relaxation of narrowed arterioles might result in exaggerated decreases in vascular resistance.

One should also consider the fact that the elderly have a higher incidence of other disease processes and a higher frequency of concurrent medications. For example, both diabetes and hypertension are more prevalent in the elderly. These disease processes have substantial effects on the autonomic nervous system, baroreflex function and vascular pathology. The use of a volatile anesthetic in these patients should exaggerate hemodynamic responses. Concurrent medications, such as beta-adrenergic blocking drugs, might further impair reflex heart rate and cardiac output increases of the elderly during blood loss. Thus, the perception that volatile anesthetics are associated with heightened blood pressure decreases in the elderly is likely correct and can be attributed to multiple factors including cardiovascular and autonomic changes with age, concurrent disease processes and medications.

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Cardiovascular Response to Spinal Anesthesia in the Elderly

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Spinal anesthesia blocks the sympathetic efferent nerves that release norepinephrine onto vascular smooth muscle, the SA node, the AV node, the conduction system and the muscle cells of the heart. The actual degree of sympathetic blockade depends on the spread of the local anesthetic. Limited spread may only block sympathetic fibers in the lower thoracic dermatomes, but rostral spread can easily extend to include the cardiac accelerator fibers (T1-T4). There is considerable debate over how much sympathetic blockade is achieved with any given level of sensory blockade, but at least one study indicates that partial sympathetic blockade can extend many dermatomes above the identified level of sensory blockade. Thus one must be prepared for possible significant hypotension with even modest levels of spinal anesthesia. Even though it may not be easily determinable, the level of sympathetic blockade is important. Although the sensory input of the baroreflex system is carried by the vagus and therefore not affected by spinal anesthesia, greater degrees of sympathetic blockade will eliminate a greater proportion of sympathetic nervous system outflow (sympathetic tone). Loss of sympathetic nerves will limit the ability of the baroreflex to combat hypotension not only by minimizing the portion of the body over which compensatory vasoconstriction can occur but by possibly even eliminating stimulation of the heart. Even though aging appears to have minimal effects on vasoconstriction, the aged heart does not respond to beta receptor stimulation as effectively as a young heart so there will be less of an increase in heart rate and contractility in the elderly, and therefore these mechanisms for increasing cardiac output will be less effective than in young adults. One might argue that the control of heart rate by the vagus is still operative during spinal anesthesia. Unfortunately, it appears that aging is associated with decreased vagal tone, thereby limiting vagal tone withdrawal as a means of increasing heart rate.

With a high spinal anesthetic one can anticipate that all the components of blood pressure could be compromised. Loss of sympathetically mediated vasoconstriction would decrease vascular resistance, loss of sympathetically mediated cardiac stimulation could decrease both heart rate and stroke volume by decreasing contractility (decreased ejection fraction), and loss of venous smooth muscle constriction might permit peripheral pooling of blood and lower the end-diastolic volume of a preload-dependent, aged left ventricle, further lowering stroke volume and cardiac output. The question is, do the elderly respond in an exaggerated manner compared to young adults with respect to any of these mechanisms? The answer is hampered by the lack of studies that examined both young and old subjects; but two studies performed on only elderly subjects do suggest differences when historically compared to studies of spinal anesthesia in younger, healthier subjects, where both vascular resistance and cardiac output appear to decrease by approximately 10 percent with high spinal anesthesia.[1,2 3] The studies on elderly subjects also observed 10 percent decreases in cardiac output, but in contrast to studies on younger subjects, systemic vascular resistance decreased by 26 percent and 21 percent in the elderly.[2,3] Such a result is not all that surprising if one believes the evidence that the elderly have increased sympathetic tone at rest and are therefore at risk for greater decreases in vascular resistance when that tone is removed by spinal anesthesia. One of the studies also examined blood distribution throughout the body and observed that the decrease in cardiac output was primarily due to a decrease in stroke volume that was, in turn, due to a 19-percent decrease in left ventricular end-diastolic volume.[1] The effect of the decrease in end-diastolic function on stroke volume and cardiac output was limited by an increase in the ejection fraction that was presumably due to afterload reduction, not an increase in contractility. During the spinal anesthetic, there were shifts in blood volume with the most important increases in volume observed in the mesentery (+6.7%) and the legs (+6%).

Given these effects of spinal anesthesia in the elderly, the next question centers around the appropriate treatment of hypotension from a spinal anesthetic. Crystalloid administration is a commonly chosen therapy, but in the elderly crystalloid is frequently insufficient by itself either prophylactically or after the hypotension develops.[2,4] Logically, it would be surprising if fluid alone was sufficient, given that it is difficult, if not impossible and dangerous, to give enough fluid to increase stroke volume to a level that could compensate for the precipitous decrease in vascular resistance. Epinephrine has been advocated, and has been extensively studied when administered as a low dose infusion (approximately 0.04 $ucg/kg^{-1}/min^{-1}$) during epidural anesthesia.[5] This technique effectively supports cardiac output, usually increasing cardiac output to above prespinal levels, but does not raise blood pressure and may even lower pressure due to $beta_2$ receptor vasodilation. Phenylephrine or other alpha-agonists effectively increase blood pressure but may compromise cardiac output or cause coronary artery vasoconstriction. The ideal drug likely lies somewhere between epinephrine and phenylephrine, and the practitioner must use his or her own judgment as to which agent or combination of agents to use, including crystalloid.

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Hemodilution Tolerance in Elderly Patients

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Postoperative outcome in the elderly is determined by their compensatory capacity to offset the effect of perioperative stress, such as blood loss. During blood loss, several defensive mechanisms are activated. One of these mechanisms is the translocation of water from extravascular space into the intravascular compartment that results in hemodilution. Similarly, preoperative acute normovolemic hemodilution (ANH) has been introduced into clinical practice whereby blood is removed and simultaneously replaced with an appropriate volume of crystalloid and/or colloid. The application of ANH may decrease the need for allogenic blood transfusion, thereby decreasing the risk of transfusion-transmitted disease, transfusion reactions and cost. Subsequent reinfusion of the patient's own blood may also help preserve platelet function.

There is some hesitancy to use acute normovolemic hemodilution in the elderly due to these patients' limited capacity to increase cardiac output, in part due to their reduced β-receptor responsiveness.[1] Nevertheless, there is a strong desire to avoid allogenic blood transfusion under at least some surgical circumstances, such as colorectal and hepatic cancer surgery where perioperative use of allogenic blood transfusion has been shown to increase tumor recurrence.[4,5] Acute normovolemic hemodilution may help minimize such transfusion.

Recent studies have shown that the danger of ANH in the elderly had been exaggerated. For example, when 2 units of blood were removed and replaced with an equal volume of 6 percent hydroxyethyl starch in a group of elderly ASA I-III patients scheduled for noncardiac surgery, cardiac output increased mainly due to an increase in stroke volume; the heart rate did not change.[2] Oxygen extraction increased, oxygen consumption remained stable and mean arterial pressure and systemic vascular resistance both decreased slightly. No patient developed ST segment alterations suggestive of myocardial ischemia. During the surgical procedure, after preoperative hemodilution, hemoglobin decreased further, and the autologous blood was transfused to achieve a hemoglobin value of 7.7 g/dL. Even at the lowest hemoglobin level encountered, there were no direct nor indirect signs of myocardial ischemia such as ST segment deviation, hypotension, arrhythmias or increased filling pressure. In a group of elderly patients scheduled for cardiac surgery, ANH produced increases in cardiac output, oxygen transport capacity and decreases in systemic vascular resistance and myocardial oxygen consumption.[3] No signs of ischemia were found in either the EKG or the EEG during hemodilution.

For these reasons, it is safe to conclude that moderate ANH can be performed in at least reasonably healthy elderly patients undergoing cardiac or noncardiac operations.

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Aging and the Respiratory System

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Because many of the intraoperative manipulations performed by anesthesiologists in the conduct of an anesthetic focus on the respiratory system (e.g., assessing adequacy of patient ventilation, gas exchange, acid-base balance, delivery of volatile and inhalational agents), it is important for anesthesia providers to understand how aging affects the respiratory system. Such knowledge is becoming increasingly important as the U.S. population ages and this aged population presents more often for surgery. Knowledge of the age-related decrease in pulmonary capacity, combined with an understanding of the effects of the anesthetic process, will aid the practitioner in selecting appropriate supportive and prophylactic measures before and after surgery in the aged patient. With such information in hand, nonagenarians and even centenarians should not be denied either elective or emergency surgery for fear of respiratory limitations.

Characterizing the affect of the normal aging process on the respiratory system is a complex concept as it is difficult to separate the changes associated with age from those attributable to diseases of the aged. In fact, age-related disease has far more impact on the respiratory system and the conduct of an anesthetic than do age-related respiratory changes. This discussion will focus on those respiratory changes that can be attributable to age alone.

The respiratory system can provide a young adult with adequate gas exchange at many times beyond resting requirements even in the face of both major reductions in pulmonary function (i.e., a 40 – 50 percent loss of maximal ventilation), as well as a significant increases in metabolic rate (e.g., a doubling of metabolic rate, as in severe fever). The magnitude of this reserve will easily see an otherwise physically fit patient through the convalescence of a major procedure even if complicated by major pulmonary morbidity without pulmonary mortality. However, aging inexorably reduces the capacity of all pulmonary functions. Complicating our understanding of this process is the fact that the rate of loss of function is extremely variable among persons of the same chronological age. However, there are four hallmarks of the aging process: 1) a decline in elasticity of the bony thorax, 2) a loss of muscle mass with weakening of the muscles of respiration and reduced mechanical advantage, 3) a decrease in alveolar gas exchange surface and 4) a decrease in central nervous system responsiveness, which have anatomical, mechanical and functional consequences. There is very little information in the literature as to whether pulmonary mechanics under anesthesia are influenced by age.

There are a number of striking anatomic changes which occur in the respiratory system with age. As a consequence of a generalized loss of all muscular and neural elements (muscle fibers, mucosal receptors, nerve fibers, etc.), laryngeal structures undergo a slow but continual decline in function. Protective reflexes involved in the regulation of coughing and swallowing are diminished. The end result is chronic pulmonary inflammation from repeated aspirations with frequent contamination of the lower airway with oral and gastric organisms.

With aging, the larger and more central airways increase in diameter, as noted by an increase in anatomic and physiologic dead space. The trachea and large bronchi increase in size about 10 percent from youth to old age. However, expiratory flow and resistance to gas flow in the large airways changes with little or no physiological consequence. Beyond age 40, the diameter of the small airways, not privileged to have cartilaginous support, decreases significantly. Despite the decrease, overall airway resistance does not appear to increase significantly. There is a small but measurable increase in dead space. Further out in the lung there are more functional changes. Elastic elements of the lung parenchyma are lost with age. The distal orders of respiratory bronchioles dilate as do alveolar ducts. The alveoli become dilated, Kohn's pores become more numerous and larger, and fine parenchymal tissue is lost with a loss of tethering support. The end result is the smaller distal airways with a tendency to early collapse, dilated alveolar ducts and fewer gas exchange surfaces. These changes are manifest functionally by air trapping, increased closing capacity, frequency-dependent compliance and gas exchange problems.

A combination of factors alters the mechanical function of the lung with age. These include: 1) a decrease in motor power as a consequence of fewer muscle fibers and a decrease mechanical advantage, 2) an increase in parenchymal compliance decreasing elastic recoil of the lungs and ultimately a change in structure and function of the chest wall due to a loss of intervertebral spaces, and 3) a stiffening of the chest wall from changes in ribs, sternum and articular cartilages making the chest less expansible.

The tendency of the lung to assume a larger resting volume and the limitations imposed by a stiffer chest wall plus a decrease in motor power result in a change in the components of the total lung capacity. Vital capacity declines progressively with age. As a rough rule of thumb, there is a linear loss of 5 to 20 percent of functional ability per decade, which may be helpful in comparing an elderly patient's current capacity against normal values. From age 20, vital capacity (VC) decreases progressively (-20 to -30 ml/yr) whereas residual volume (RV) increases (+10 to +20 ml/yr). In fact, the ratio of RV to TLC increases from 25 percent at 20 years of age to about 40 percent in a 70-year-old man, which gives the chest wall a somewhat barrel-like appearance. It is interesting that the decrease in elastic recoil of the lungs and progressive stiffening of the chest wall serendipitously counteract each other with no net significant change in absolute FRC. The total lung capacity (TLC) grows with age until puberty, where it reaches an average value of 6 to 7 liters, after which a slow loss of volume begins. With the age-related loss in total lung capacity (TLC), plus the very modest increase in FRC, the ratio of FRC to TLC tends to increase with age.

The reduction in motor power of the accessory muscles of breathing as well as the decreased expansion of the chest wall cause the dynamic lung volumes and capacities to decrease progressively with age (e.g., FEV_1). The FEV_1 decreases with age by about 27 ml/yr in men but by only 22 ml/yr in women. However, the percent change in the two sexes is similar because men start off with higher absolute values of these measurements.

There is a clear age-related increase in the closing volume (CV) and closing capacity (CC). In childhood and youth, the closing capacity remains well within the expiratory reserve volume. Over time it progressively enlarges, encroaching on the tidal volume in the 60-year-old. Both the CV and CC also increase with recumbency, a common position perioperatively. During active breathing, closing pressure in young subjects is about -1.25 cm H_20 pressure, and opening pressure is +2.5 cm H_20, the difference being attributable to hysteresis. The values for closing pressure (CP) and opening pressure (OP) in subjects aged 65-75 years are 0 and 4.5 cm H_20, respectively. The higher values for both CP and OP will decrease the elderly patient's ability to keep some ventilated areas open and to re-open those areas that have collapsed.

The pressure-volume curve of an older lung is similar in shape, but shifted upward and to the left; in other words, the aged lung possesses less elastic recoil. This change in compliance is quite regional rather than being evenly distributed across the lung. The effect is to slow passive exhalation in some lung areas while other lung areas empty normally. The dynamic lung compliance (compliance measured during active breathing) becomes more frequency dependent with age. Thus as breathing rate increases, lung expansion becomes less effective particularly in some areas, thereby increasing the maldistribution of ventilation to perfusion. Also, in older subjects the pressure across basal lung units may be positive rather than subatmospheric. During quiet breathing, inspired gases will preferentially go to the more distensible upper lung units leading to an uneven distribution of gases. However, these variably compliant lung areas are surrounded by a thoracic cage that has become stiffer; the stiffness of the older chest wall overshadows the lesser elastic recoil of the lung and the anesthesiologist may perceive a less compliant respiratory system.

The functional, or gas exchange capability, of the aged lung is affected by the anatomical and mechanical changes of age. The efficiency of alveolar gas exchange decreases progressively with age for a number of reasons. Alveolar surface area decreases with age from about 75 m^2 at age 20 years to about 60 m^2 at age 70 years.

Although blood volume does not change with age, the quantity of blood present in the pulmonary circulation at any given instant does decrease with age. There is also evidence that the distribution of pulmonary blood flow changes with aging. The change in blood flow, combined with the altered distribution of inspired gas, promotes even more V/Q mismatching. Alveolar dead space, which is a good index of the distribution of pulmonary blood flow, increases with age. The increased V/Q mismatch plus the increased alveolar dead space adversely affect the aged patient's blood gas values.

Arterial blood gases become integral components in the interpretation of lung function during anesthesia. There are reference values available to aid in the interpretation of arterial blood gases in middle-aged and elderly persons (40-70 yr). The normal alveolar oxygen tension PAO_2 is fairly constant from infancy to senescence. A number of studies have demonstrated the mean PaO_2 declines from 95 ± 2 mmHg at age 20 to 73 ± 5 at age 75 years. This decline in arterial oxygen tension is modest: approximately 0.4 mmHg/year. After age 75, however, PaO_2 stays relatively constant at approximately 73 mmHg.

In humans there is a normal amount of relative hypoxemia due to shunt, diffusion block and ventilation/perfusion mismatch. Age and anesthesia worsens hypoxia mostly by increasing ventilation/perfusion maldistribution. We also know this can be made more prominent by pulmonary disease, the effects of aging and the application of mechanical ventilation.

The efficiency of vascular distensibility and recruitment decreases with age. The increasingly rigid pulmonary vasculature probably blunts the hypoxic pulmonary vasoconstrictor (HPV) reflex. The loss of physical support of surrounding pulmonary elastic tissue surrounding both the small airways and pulmonary vessels may be a contributing factor. Thus the ability of the aged lung to respond to altered ventilation/perfusion matching is compromised.

Finally, it is important to recognize that the ventilatory response to hypercapnia and hypoxia is blunted in the elderly patient. The ventilatory response (change in minute ventilation) in the healthy aged patient (70-year-old) to either a hypercapnic or hypoxic stimulus is half that seen in the 25-year-old.

In summary, the aged lungs have some but certainly not all of the features of chronic obstructive lung disease, e.g., increased RV and RV/TLC, reduced VC and FEV_1 plus a compliance that worsens as breathing rate increases. The fact that older patients have some of the features of chronic obstructive pulmonary disease (COPD) should not imply that they should be considered as having COPD, however.

What does all of this mean to the clinician expected to provide anesthesia for the aged patient? An increase in ventilation during hypoxia and hypercapnia is a useful clinical sign and also a homeostatic response. The fact that these responses are blunted in older subjects indicates that simple clinical observation of ventilatory frequency and chest movement with breathing may not be an accurate manifestation of the ventilatory stimulus to an aged patient. The clinician should also realize that, together with these age-related decreases in reserve in the awake state, the ventilatory responses to hypercapnea are reduced by narcotic premedication and by thiopentone and narcotic and inhalational anesthetics in a dose-related manner.

Aged patients may be hypoxemic during normal spontaneous ventilation postoperatively because of the mechanical changes of the aged lung and chest wall.. The risk is increased by the supine position and by the use of narcotic analgesics in an age group that already has blunted ventilatory reflexes to hypoxia and hypercapnia. Any residual anesthetic will also exert an additive effect. The elimination of narcotics and muscle relaxants may be delayed due to the impaired renal function in older patients. The effects of large volumes of crystalloid infusion may manifest in the recovery room.

Older subjects are less able to increase and maintain ventilation at high levels than young adults during periods of increased demand for oxygen. Ventilatory muscle fatigue is quite likely to occur early due to the altered physiology of voluntary muscle. It seems reasonable to assume that older patients will develop ventilatory inadequacy earlier for any given ventilatory load. The subjective feature of ventilatory inadequacy is dyspnea.

The anesthetic technique and agents are of less importance than the degree of preparedness and the acumen of the anesthesiologist. In the aged the strategies are the same: increasing FIO2 as necessary while remembering that oxygen toxicity is a concern. Large tidal volumes are useful until circulatory impediment and barotrauma become a concern. Aging limits the effectiveness of each of these therapeutic interventions.

Finally, one should remember that, overall, the age-related changes of the respiratory system essentially consists of a mix of restrictive and obstructive lung disease. The whole picture and how these changes impact the aged patient may not be apparent immediately after surgery, but the changes may become maximally manifest any time during the first 2 to 3 days after the operation.

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Aging and the Urinary System

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Aging results in both structural and functional changes in the kidney that effect drug metabolism and kinetics as well as predisposing the patient to fluid and electrolyte abnormalities.

Between the ages of 40 and 80, the kidney loses approximately 20 percent of its mass, primarily from the cortex. Microscopically there is a reduction in the number of functional glomeruli, but the size and capacity of the remaining nephrons increase to partially compensate for this loss. Vascular changes also occur in the aging kidney, and after the age of 30 years renal blood flow (RBF) declines progressively at a rate of 10 percent per decade. Most of the decline in RBF occurs in the cortex with a relative increase in blood flow to the juxtamedullary region. The glomerular filtration rate (GFR) decreases by approximately 1 ml/min/year beginning by age 40. However, this decline in GFR is accompanied by a gradual loss of muscle mass and is rarely associated with an increase in serum creatinine. Thus, serum creatinine is a poor indicator of GFR in the elderly patient. Dosing intervals for drugs that are excreted by the kidney, such as aminoglycoside antibiotics, digoxin and pancuronium need to be adjusted and drug levels closely monitored.

Under normal circumstances, age has no effect on electrolyte concentrations or the ability of the individual to maintain normal extracellular fluid volume. However, the adaptive mechanisms responsible for regulating fluid balance are impaired in the elderly and the aging kidney has a decreased ability to dilute and concentrate urine. This problem is compounded by the fact that older individuals have a decreased thirst perception and fail to increase water intake when dehydrated. Age also interferes with the kidney's ability to conserve sodium. The geriatric patient excretes a sodium load more slowly and has a decreased ability to conserve sodium if dietary sodium is restricted, possibly predisposing the elderly patient to hemodynamic instability. Thus, fluid and electrolyte status should be carefully monitored in the elderly patient.

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Perioperative Renal Insufficiency and Failure in Elderly Patients

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The aging process results in profound anatomic and functional changes in virtually all major organ systems, including the cardiovascular, respiratory and renal systems. Much attention has been devoted to studying the effects of aging on the kidney[1]. The changes in kidney function with normal aging are as dramatic as any human organ or organ system. These changes are both structural and functional. Microscopic examination confirms the disappearance of the kidney's functional units with age; as many as one-half of the glomeruli present in young adults may be gone or rendered nonfunctional by 80 years of age. The common denominator of these functional changes is a diminution in renal reserve, along with constraints on the kidney's ability to respond appropriately to challenges of either excesses or deficits. Advanced age markedly decreases renal function reserve. Glomerular filtration rate, normally about 125 ml/min in a young adult, decreases to about 80 ml/min at 60 years of age and to 60 ml/min at 80 years.[3,4] Although these alterations are unlikely to be of major clinical consequence under everyday conditions, they attain clinical significance when residual renal function is challenged by the superimposition of an acute illness. Clinicians of all specialties should be familiar with these alterations because they predispose to diverse fluid and electrolyte abnormalities and have important implications for drug therapy in the elderly.[2] The prevalence of renal disease not only increases perioperative risk of acute renal insufficiency or failure but also affects the duration of action of many anesthetic and adjuvant drugs. A major pharmacokinetic consequence of age-related changes in renal function is prolongation of the elimination half-time of anesthetic drugs and any metabolites requiring renal clearance.[3,4] Elderly patients frequently suffer from comorbid conditions such as hypertension and heart disease, which may be additive to the changes of aging, thereby amplifying these abnormalities.

Renal dysfunction remains a serious complication during the perioperative period and is most likely to occur in critically ill patients undergoing major surgery. Typically, only after a patient has sustained renal injury are clinicians focused on "renal protective strategies," and by then it is often too late. Despite significant advances in hemodynamic monitoring and hemodialysis during the past three decades, the mortality rate from acute renal failure has not changed significantly. Acute renal failure is in fact responsible for at least one-fifth of all perioperative deaths among elderly surgical patients.[3,4] Perioperative renal failure following trauma and thoracic or cardiovascular surgery carries a reported incidence of 0.1% to 50%, depending on the population analyzed and the methods used to define renal failure, and is associated with a reported mortality of 20 percent to 90 percent. Perioperative renal failure accounts for one-half of all patients requiring acute dialysis.[5] The precise mechanisms heralding the transition from compensated preserved renal function to uncompensated renal failure during the perioperative period remain poorly understood, in part because the methods used to assess renal function are insensitive and nonspecific.[3,4] Acute tubular necrosis accounts for nearly 90 percent of the cases of perioperative renal failure.[5] Perhaps one reason for our inability to prevent renal failure is a shift in medical populations to older and more critically ill patients.

The wealth of data available on senescence and the kidney precludes a complete examination of the subject in this limited space. (For an excellent discussion on this topic, see the article "Aging and the Kidney" by Murray Epstein, M.D.)

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Thermoregulation in the Elderly

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Normal autonomic responses to decreases in core body temperature include vasoconstriction and shivering. Of the two defense mechanisms, shunt vasoconstriction is the more efficient. Restriction of blood flow, especially to the fingers, toes, and nose, reduces heat loss to the environment. Shivering occurs at core body temperatures that are about 1° C lower than those required for activation of vasoconstriction. Although shivering can double metabolic rate, most of it occurs in the extremities. As heat is generated in the extremities, peripheral blood flow will increase due to local heating as well as to meet the increased muscle metabolic demand. The end result is that much of the heat produced by shivering is lost to the environment.

Elderly patients are unable to regulate their body temperature to the same degree as young adults because their responses to changes in body temperature are altered. They do not respond normally to hypothermic challenges. In general, geriatric patients neither vasoconstrict nor shiver in response to cold until their temperature has fallen to levels below that required for activation of these defense mechanisms in young adults. The relationship between impairment of thermoregulation and age is not linear and it does not occur in all aged patients. Rather, it is most common in patients over the age of 80. While younger patients will shiver at a temperature of 36.1°C, most patients over the age of 80 will not shiver until their core body temperature falls to 35.2°C, on average. Furthermore, the ability to vasoconstrict and reduce skin blood flow is reduced with age, making obligatory heat loss in a cold environment greater than in young adults. These alterations in the elderly patient's ability to regulate body temperature result in more frequent and severe hypothermia in this patient group.

Anesthetics alter thermoregulatory responses in all patients. In clinically useful doses, sedatives and general anesthetics impair thermoregulatory responses by preventing vasoconstriction or shivering until more extreme decreases in body temperature are achieved in comparison to the absence of the anesthetic agents. Consequently, the immobile, vasodilated patient in a cold operating room will lose heat unless active measures are taken. Geriatric patients are even more prone to intraoperative hypothermia, not only for the reasons cited in the previous paragraph, but also because the inhibition of thermoregulatory responses by anesthetics is greatly exaggerated in elderly patients. Body temperature must decrease to a lower level in the elderly before vasoconstriction or shivering is triggered. Because clearance of anesthetic agents tends to be reduced in the elderly, their effects in this patient population are prolonged. This renders the geriatric patient more susceptible to postoperative hypothermia as well.

Hypothermia, in addition to being more pronounced, lasts longer in geriatric patients than it does in young patients. Recovery from mild hypothermia is accompanied by shivering in elderly patients. The shivering that does occur, though, is milder than it is in young patients. In elderly patients who shiver, body oxygen consumption only increases approximately 38% over nonshivering levels. Whether or not patients are shivering, there is an increase in their oxygen consumption that is proportional to the degree of hypothermia. Recovery from even mild hypothermia is prolonged in the elderly because their lower metabolic rate produces less heat.

Elderly patients are not immune to the adverse effects of hypothermia, which include bleeding, decreased immune function, and decreased wound strength. Bleeding is increased due to impaired platelet function and inhibition of the enzymes in the coagulation cascade. Decreases in temperature as little as 2°C will increase blood loss and transfusions. The vasoconstriction that accompanies hypothermia causes relative tissue hypoxia as less oxygen rich blood is brought to the vasoconstricted areas and the hypoxia results in decreased wound strength.

Hypothermia may exacerbate the decreased clearance of drugs in the elderly. This diminished clearance, accompanied by a decreased MAC in the elderly, means that anesthetic effects may be both pronounced and prolonged.

Elderly patients are more prone to have coronary disease than are younger adults. Hypothermia causes an increased incidence of myocardial ischemia in geriatric patients that is not related to shivering. Instead, ischemia is likely due to hypertension and increased plasma concentrations of norepinephrine. Consequently, it is not too surprising to note that hypothermia is associated with an increased risk of perioperative myocardial infarction.

The last major complication of hypothermia is an increased risk of infection. In a randomized study of colorectal surgery, patients assigned to routine care were almost 2°C colder at the end of surgery than patients who received aggressive intraoperative warming. Despite achieving normothermia in both groups by 6 hours postoperatively, the subjects receiving routine care suffered three times as many wound infections (19% vs, 6%) and remained hospitalized an average of two days longer than the patients who were more aggressively warmed.

As temperature regulation is altered in elderly patients, extra care must be taken to maintain their body temperature. This can be done by several consecutive measures, which include: warming the operating room until the patient is covered with drapes and warming blankets, prepping preoperatively and cleaning postoperatively with warmed solutions, not infusing cold intravenous fluids, and covering the patient with warm blankets at the end of a surgical procedure for transport to the post anesthesia care unit. Maintenance of temperature is extremely important as the elderly are susceptible to all of the adverse effects of hypothermia, which may be more prolonged in this patient population.

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Pharmacokinetic and Pharmacodynamic Differences in the Elderly

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Pharmacokinetic and Pharmacodynamic Differences in the Elderly

Pharmacokinetic variables determine the relationship between the dose of a drug administered and the concentration delivered to the site of action. Pharmacodynamic variables determine the relationship between the concentration of the drug at the site of action and the intensity of the effect produced. Physiologic changes occur during aging that impact on the pharmacokinetic and pharmacodynamic responses of elderly patients to administered drugs. For example, changes occur in plasma protein binding, the percentage of body content that is lipid or lean, the efficiency of metabolism and elimination of drugs and in the elderly patient's sensitivity to administered drugs, an effect due to pharmacodynamic changes. Each of these physiologic changes will be discussed.

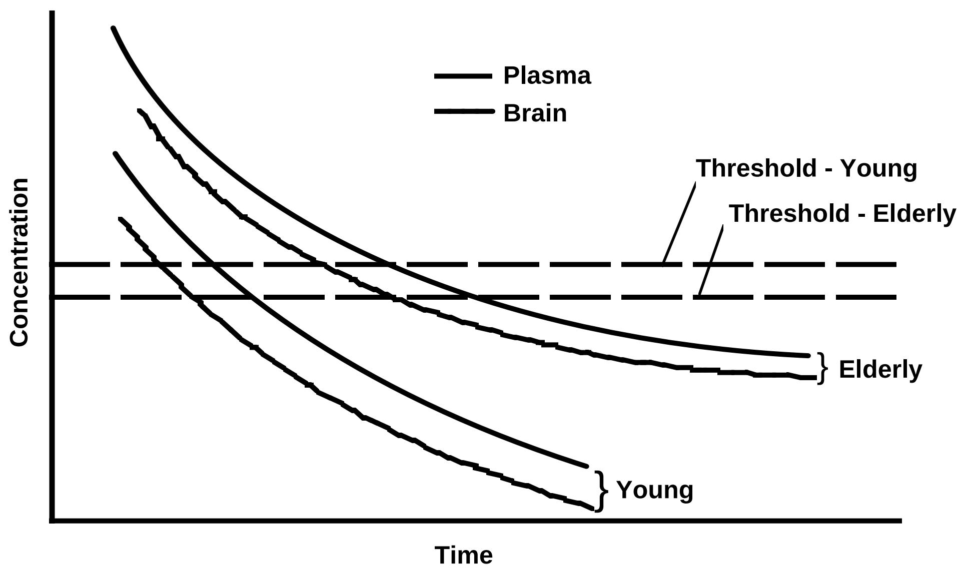

Figure 1. Hypothetical response of young and elderly subjects to a bolus administration of a drug. The figure illustrates higher blood levels in the elderly, initially due to a smaller volume of distribution, and later due to a slower drug metabolism. Furthermore, in this example, the brain is more sensitive to the drug in the elderly. All these effects conspire to increase the length of time that the drug is active in the elderly patient.

Protein Binding

All anesthetic agents are to some extent protein-bound to plasma proteins. The portion of the drug that is bound to protein is unable to cross membranes to produce the desired drug effect. On the other hand, the portion that remains free in plasma is able to cross membranes, including the blood brain barrier, and is responsible for drug effect. In the elderly, protein binding of anesthetic drugs is less efficient resulting in an exaggerated pharmacologic effect.

Four factors may explain the reduced drug-binding to serum protein in elderly individuals. First, with aging, the circulating level of serum protein, especially albumin, decreases in quantity, reducing available protein-binding sites for a variety of anesthetic drugs. Second, qualitative changes may occur in circulating protein that reduces the binding effectiveness of the available protein. Third, co-administered drugs may interfere with the ability of anesthetic agents to bind to available serum protein binding sites. Fourth, certain disease states exaggerate this phenomenon. Thus, anesthetic agents that are highly protein bound should be delivered to an elderly individual with the expectation that reduced protein binding will lead to higher free drug levels and an enhanced delivery of the drug to the brain. Figure 1 illustrates the effect of decreased plasma protein binding as a smaller difference between brain and plasma drug levels in the elderly than in young adults.

Change in Body Compartments

Important age-related changes in body composition include a loss of skeletal muscle (lean body mass) and an increase in percentage of body fat. These changes are more exaggerated in women. In addition, it has been suggested that a 20-30 percent reduction in blood volume occurs by age 75. Therefore, injection of anesthetic drugs will initially be dispersed in a contracted blood volume in the elderly patient producing a higher than expected initial plasma drug concentration. (See Fig. 1)

The increase in percentage of body fat that occurs with age results in an increased availability of lipid storage sites and a greater reservoir for deposition of lipid-soluble anesthetic drugs. The greater sequestration of anesthetic agents in the lipid storage tissues of the elderly allows for a more gradual and protracted elution of anesthetic agents from these storage sites, increasing the time period required for their elimination and resulting in greater residual plasma concentrations of drugs that contribute to prolonged anesthetic effects.

Hepatic and Renal Function

Hepatic and renal function are reduced about one percent per year beyond age 30. The age-related reduction in renal blood flow is accompanied by a gradual loss of functioning glomeruli. The combination of these changes produces a predictable decline in glomerular filtration rate that in old age is only 60 percent of that found in younger individuals. These renal changes result in a reduced ability of an elderly patient to excrete administered drugs and their metabolites. The combination of reduced hepatic and renal elimination and more protracted elution of drug from lipid stores contribute to the more gradual fall in plasma-drug concentration in the elderly depicted in Figure 1, and reflected in the table below as an age-related change in the beta elimination half-life of many of our administered anesthetic agents.

T 1/2 b – Elimination Half-life

Drug	Young Adults	Old Adults
Fentanyl	250 min	925 min
Alfentanil	90 min	130 min
Diazepam	24 hrs	72 hrs
Midazolam	2.8 hrs	4.3 hrs
Vecuronium	16 min	45 min

(Return of twitch height from 25 percent to 75 percent of control)

Central Nervous System (CNS)

Classically, it has been thought that the physiologic function of most organs, including the central nervous system, undergoes a gradual decline during the aging process. There is a continual loss of neuronal substance with advancing age. On average, a daily attrition of perhaps as many as 50,000 neurons from an initial neuron pool of approximately 10 billion occurs during the life span of an individual. The reduction in neuronal density that occurs with age is accompanied by a parallel reduction in cerebral blood flow and cerebral oxygen consumption ($CMRO_2$).[1]

Regional cerebral blood flow remains as tightly coupled to cerebral metabolic activity in the healthy elderly individual as it does in young adults. The absence of a quantitative relationship between age-related brain atrophy (accompanied by reduced cerebral blood flow) and general level of mental function, however, suggests that at the time of maximum brain weight there is considerable redundancy of neuronal function within each cortical, subcortical and spinal region. Although an obligatory age-induced decline in cerebral cognitive function remains controversial, it is generally agreed that geriatric patients have a reduced requirement for anesthetic agents. This may not be distinguishable in any given patient but is observed in cross-sectional studies comparing elderly to younger individuals and is believed to be due, at least in part, to a reduction in pre-existent CNS activity.

A classic example of age-related reduced anesthetic requirement is the reduced minimum alveolar concentration (MAC) necessary in elderly patients to produce anesthesia with either cyclopropane, halothane, isoflurane or desflurane.[2] The requirement for these inhalational agents decreases linearly with patient age. The reduced anesthetic requirement for geriatric patients applies not only to inhalational anesthetics but also to local anesthetics, narcotics, barbiturates, benzodiazepines and other intravenous anesthetic agents. Elderly patients achieve a comparable level of sedation at diazepam plasma concentrations significantly lower than that required in young adults. Equivalent EEG suppression occurs at lower plasma concentrations of both fentanyl and alfentanil in the aged.[3] Similar to narcotics, the induction dose of barbiturates required in 70 year old adults is approximately 30 percent less than that required for individuals four to five decades younger. However, it has been suggested that the greater sensitivity of the elderly to the same dose of thiopental is based on a reduced initial volume of distribution that results in a higher plasma concentration following the same administered dose.

Desflurane

As indicated above, the desflurane MAC requirements are reduced with age. In addition, similar to intravenous agents with shorter elimination half-lives, desflurane, by virtue of its low blood/gas and tissue/blood solubility coefficients, may have advantage over other inhalational agents in the elderly. By virtue of its lower solubility coefficients, following a typical anesthetic exposure, less desflurane will be absorbed, making less of the drug available both for metabolism and for residual postanesthetic effect. For example, Yasuda, et al., demonstrated that two days following an administered anesthetic, the residual desflurane end-tidal concentration, compared to the concentration at time of discontinuing the anesthetic, was 10-fold less for desflurane than for isoflurane.[4] Five days following the anesthetic, the difference in residual concentrations was 20-fold less for desflurane. Thus, desflurane may be of particular value in elderly patients where residual postoperative mental impairment may be both more severe and more protracted. Similar arguments can be applied to sevoflurane, although elimination of sevoflurane is not as rapid as for desflurane.

Regional Versus General Anesthesia

Selection of the anesthetic technique should be influenced not only but the patient's clinical condition and surgical requirements, but also by the anesthetist's skill and experience. In general, a fragile geriatric patient should be handled gently and the anesthetic regime maintained in as simple a fashion as possible. Evidence suggests that geriatric patients have improved prognosis if their surgical procedure is performed under local anesthesia rather than general anesthesia or major regional anesthesia.[5] During certain surgical procedures regional anesthesia in the elderly may have the advantage of: (1) reduced postoperative negative nitrogen balance, (2) amelioration of endocrine stress responses to surgery, (3) reduction in blood loss, (4) a reduced incidence of postoperative thromboembolic complications, and (5) reduced postoperative mental confusion.

However, Chung and colleagues have demonstrated that relatively modest doses of sedative agents produce mental impairment postoperatively, similar to that resulting from general anesthesia.[6] Thus it is difficult to recommend regional anesthesia over general anesthesia for all kinds of surgical procedures in the geriatric patient group. The selection of anesthesia must be individualized. Spinal anesthesia has particular advantage for certain types of surgery including transurethral resection of the prostate where the patient remains awake and responsive and can give early warning signs of surgical complications which is not possible in a patient receiving a general anesthetic. Similarly, allowing a patient to remain conscious during regional anesthesia allows patient recognition of an anginal attack or acute cerebral changes due to a variety of causes. For older patients who are cooperative, regional techniques, especially subarachnoid and epidural block, can be used effectively and safely for procedures requiring anesthesia below the T-8 dermatome. Extremity blocks may also be effectively employed for various procedures on the extremities. However, an injudicious use of supplemental agents may actually result in a pseudo-general anesthetic for a patient which obviates some of the advantages of a regional anesthetic technique. Over sedation of a patient may lead to hypoventilation, an unprotected airway, and the possibility of mental changes postoperatively resembling those of general anesthesia.

Outpatient Anesthesia for the Elderly Patient

In our current system of health care reform, great emphasis has been placed on cost containment. This has caused an overall shift in perioperative health care from the inpatient to the outpatient setting. Recent data from the American Hospital Association show that more than 50% of all surgical procedures in the U.S. are performed on an outpatient basis. This trend which has been seen in hospitals of all size will likely continue in the future. This, of course, has brought the geriatric patient, like all other patients, into the outpatient setting. For example, a recent report by Mark Warner and colleagues describing morbidity within one month of ambulatory anesthesia and surgery examined 45,090 anesthetics.[7] Typical of the American trend, these adult patients ranged in age from 18 to 96 years.

Postoperative Mental Dysfunction

Postoperative confusion and mental dysfunction are of great concern in the elderly patient. The databases of 18 studies were combined into one comprehensive data set and subjected to meta-analysis by Cryns and colleagues.[8] These authors concluded that "surgery has a significantly decompensating impact on the mental status of older persons." Spiro in a recent editorial in Science and Medicine underscores the importance of this potential complication. In his anxiety-creating comments, he describes his observation of six of his Nobel Laureate colleagues, who as older individuals, underwent anesthesia and surgery with demonstrable temporary or primary post-operative mental changes.[9] Although this side effect may occur whether geriatric patients are managed on an outpatient or inpatient basis, it is hoped that it may be reduced in severity when elderly patients undergo surgery on an outpatient basis. In this setting they will be given fewer medications and be allowed a quicker return to their normal surroundings with their relatives and friends nearby. In fact, the overall disruption of the perioperative period is significantly less if the geriatric patient can be managed on an outpatient basis. For example, there is less disruption in their sleep cycle, less disruption in their familiar environment, less disruption in their overall daily habits. Hopefully this reduction in disruption will reduce mental dysfunction postoperatively. Rowe and Kahn have also suggested that maintenance of control or autonomy for elderly individuals (where they make decisions regarding their choice of activity, timing, pace, etc.) have other benefits.[10] Lack of control has adverse effects on the emotional state, performance, subjective well-being and physiologic function of geriatric patients. As a result, elderly patients undergoing surgery in an outpatient setting where there is a lesser loss of autonomy and control may be of distinct benefit.

Obviously, not all geriatric patients should have surgery in an ambulatory setting. Many of these individuals have a multiplicity of diseases or significant physiologic decrement in function, which prevents them from being adequate candidates for ambulatory surgery. Peter Duncan and colleagues have shown that intraoperative and postoperative adverse events are more likely to occur in patients presenting for outpatient surgery who have preoperative medical conditions.[11] Thus, judging the preexisting medical conditions of each patient requires an individual medical decision. However, if an elderly patient does pass a routine preoperative screening visit, then there is no reason why age alone should prevent him from being considered a candidate for an outpatient procedure. Meridy has found that age alone does not affect the duration of recovery from anesthesia nor the rate of complications following outpatient surgery.[12] However, others have observed in patients emerging from thiopental, halothane, and nitrous oxide anesthesia for cervical dilation and curettage that more time was required for older patients to successfully complete a manipulative skill test.[13]

A preoperative screening visit by an anesthesiologist prior to surgery is of prime importance. It is recommended that screening of an elderly patient be performed prior to the day of surgery. This enables anesthesia personnel to make rational judgments as to the patient's acceptability for surgery as an outpatient, permits treatment of pre-existent diseases, contributes to more efficient scheduling, allows appropriate lab testing to be performed, enhances the visibility of the anesthesiologist in the overall medical practice scheme, and enables an interview of the "responsible adult" who will not only ensure the patient's delivery from the hospital back home but who will also stay with the patient and assist with his recovery in the home setting. Natof in a special study sponsored by the Federated Ambulatory Surgery Association reviewed 87,492 patients undergoing outpatient procedures and found a relationship between the incidence of complications and the length of the surgical procedure.[14] As a result, the type and difficulty of the surgical procedure should be taken into consideration prior to allowing a complex and protracted surgical procedure to be performed on an elderly patient as an outpatient. Similarly, the relationship of complication rate to pre-existent disease again demonstrates the importance of pre-anesthesia screening in determining if elderly individuals with one or more pre-existent medical conditions should be allowed to undergo their surgical procedure as an outpatient.

Not all elderly patients have multiple medical problems. Physiologic age is obviously more important than chronological age and a profile of the patient's past medical history and current level of physical activity is a far better indicator of his or her ability to tolerate a surgical procedure as an outpatient than is age alone. Ambulatory surgery should not be denied a patient solely on the basis of age.

Summary

Aging is an all-encompassing, multifactorial process which results in a decreased capacity for adaptation and produces a gradual decrease in functional reserve of many of the body's organ systems. Aging itself is not a disease process but instead, serves as a reminder of the potential for development of many age-related disease states. There is no ideal anesthetic for all elderly patients. A thorough understanding of the physiological changes which occur with aging and the altered pharmacokinetic and pharmacodynamic responses of the elderly to a variety of anesthetic drugs help in the design of an optimal anesthetic technique for each elderly patient. Appropriate anesthetic management must therefore be based on a thorough medical evaluation preoperatively, with correction, if possible, of any detected abnormality. Intensity of monitoring during and following anesthesia will likely be greater than that selected for younger patients but should be determined on an individual basis taking into consideration the patient's condition and proposed surgical procedure. Because elderly patients are not only pharmacologically but also physically fragile, they require great care during positioning and moving. By offering geriatric patients the safest anesthetic possible, we can contribute to the revolutionary increase in life span of our citizenry and directly enhance their health span, the maintenance of full function as nearly as possible to the end of life.

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Induction Agents

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Thiopental is the most commonly used induction agent in the United States. Barbiturates decrease the rate of dissociation of GABA from its receptors, thus depressing the reticular activating system. This unique property of barbiturates is responsible for their ability to induce unconsciousness. Administration of intravenous barbiturates typically produces peripheral vasodilation with a moderate decrease in blood pressure. This hypotension reflects the drug's depression of the medullary vasomotor center and outflow from the sympathetic nervous system. In a healthy young patient, this is compensated for by the baroreceptor reflex, but in an elderly patient with a decreased baroreceptor reflex and increased vascular wall rigidity, barbiturates may cause a dangerous drop in blood pressure. Barbiturates also depress medullary ventilatory centers, leading to a dampened response to carbon dioxide. This apnea will be more pronounced if a barbiturate is used in conjunction with an opioid.

In the elderly, thiopental's elimination half-life is 13-25 hours as opposed to 6-12 hours in the young (due in part to an increase in volume of distribution at steady state). The thiopental dosage requirement decreases 25-75 percent as one ages, but it takes longer to induce unconsciousness. Methohexital is rapid acting and has a higher hepatic clearance rate and shorter elimination half-life than thiopental. For these reasons, it is favored over thiopental by some for use in outpatient anesthesia. Elderly patients treated with methohexital show a postoperative prolongation of central nervous system depression (fatigue and motor skill impairment).

Ketamine is a sedative-hypnotic amnestic and a potent analgesic that can be injected intravenously or intramuscularly. This drug stimulates the cardiovascular system, which is beneficial in hypovolemic patients and disadvantageous in patients with ischemic heart disease because it may increase myocardial oxygen demand. When used in combination with a benzodiazepine, the cardiovascular stimulation will be attenuated. Ketamine increases airway secretions, decreases airway resistance and increases intracranial pressure.

Etomidate is a rapid, short-acting carboxylated imidazole derived hypnotic. It is a good choice for inducing anesthesia in the hemodynamically tenuous elderly because it possesses less cardiovascular depression than the barbiturates. Rapid recovery is due to the extensive hydrolysis of etomidate to inactive metabolites, but clearance is hepatic blood flow dependent. Disadvantages of using etomidate include a high incidence of postoperative nausea and vomiting (decreased with prophylaxis with an antiemetic drug) and a postoperative suppression of adrenocortical function seen with infusion of this sedative-hypnotic.

Propofol is a rapid, short-acting alkylphenol with few side effects. It has a high lipid solubility and is solubilized in a lecithin containing emulsion. Induction using 1.2 to 1.7 mg/kg in the elderly (versus 2.0 to 2.5 mg/kg in younger patients) produces a rapid onset of anesthesia (less than one minute) lasting five to 10 minutes. There is an age-related decrease in propofol clearance, resulting in a decreased maintenance anesthetic requirement with age. Propofol produces dose-dependent cardiovascular and respiratory depression, leading to greater decreases in systemic blood pressure than thiopental when used for induction in elderly patients. These effects can be minimized if propofol is injected slowly with sufficient time allowed to achieve the full effect of the dose, thereby decreasing the total dose. Nevertheless, propofol is a good choice for many elderly patients because it has a quick recovery with few side effects. For example, patients older than 80 exhibit less post-anesthetic mental impairment with propofol compared to other agents. Thus, although propofol has theoretical advantages in the elderly, its hypotensive side effects will require slow administration of a reduced dose, titrated to effect rather than administering a preselected standardized dose which might be more applicable to younger patients.

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Opioids

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Opiates were primarily used as analgesics until approximately 20 years ago, when it became known that larger doses of some agents caused loss of consciousness (more reliably so in the elderly as opposed to young patients). The potent and rapid-acting opiates (fentanyl, sufentanil, alfentanil) can be used as the sole induction agents in cardiovascular surgery where hemodynamic stability is critical. High doses of these analgesics not only produce loss of consciousness, they effectively blunt the blood pressure and heart rate responses to laryngoscopy and intubation. Opioids can be administered in lower doses by intermittent intravenous injections or continuous infusion for maintenance of anesthesia or as adjuvants to inhaled anesthetics.

Fentanyl in doses of 50 to 150 mcg/kg IV are usually necessary to induce unconsciousness. Because the elimination half-life of fentanyl is significantly longer in elderly patients compared to young patients (roughly 945 min and 265 min, respectively), such a dose will produce respiratory depression and analgesia for a long time in the elderly. Transdermal fentanyl has been used for postoperative analgesia; however, because of the increased sensitivity to the depressant effects of opioids in the elderly, the occurrence of respiratory depression with the usual 50-75 mcg/hr dose makes the transdermal patch method of pain control unsuitable in opioid-naïve elderly patients. Administering 25 mcg of fentanyl with bupivacaine during spinal anesthesia in the elderly significantly decreases pain intensity in the post operative period. The only significant side effect of this was pruritus; respiratory depression occurred only if benzodiazepines were used in conjunction with the spinal fentanyl.

Alfentanil is a very rapid, short-acting synthetic derivative of fentanyl. It has a low pK_a, so much of the drug exists in the nonionized form at physiologic pH and thus readily crosses the blood brain barrier. It has a smaller volume of distribution and shorter elimination half-time in comparison to fentanyl. Alfentanil can be used as the sole induction anesthetic (150 to 300 mcg/kg IV produces unconsciousness in approximately 45 seconds) and, at a continuous infusion of 25 to 150 mcg/kg/hr IV, for anesthetic maintenance in combination with volatile anesthetics. Alfentanil is a good choice for short operative procedures in the elderly because it does not produce sustained postoperative sedation and respiratory depression.

Opioids have a high lipid solubility and therefore a large volume of distribution. Recovery from a single analgesic dose of fentanyl or sufentanil may be rapid, owing to the redistribution from the brain to lean muscle and fatty tissue. However, recovery from a larger dose used for induction tends to be protracted due to the saturation of the inactive tissue sites and to the long elimination half-life of fentanyl and sufentanil (three to six hours). In spite of the high hepatic clearance rate, the elimination half-life is long due to the large volume of distribution. In the elderly, there is a decreased hepatic clearance rate, resulting in even longer half-life of elimination. Thus, a given dose would be clinically effective for a longer period of time. Another potential reason for the decreased requirement of opioids when used in the elderly is an increase in sensitivity of the brain to at least some narcotics with aging.

Lower doses of fentanyl (1 to 3ug/kg), alfentanil (10 to 20ug/kg) or sufentanil (0.125 to 0.25 mcg/kg) are effective adjuvants to thiopental (2 to 3 mg/kg) for induction of anesthesia because they decrease the need for barbiturates and diminish the cardiovascular response to laryngoscopy and intubation.

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Muscle Relaxant Selection and Administration

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Aging affects the neuromuscular junction in many ways. The distance between the junctional axon and the motor end-plate is increased; the folds of the motor end-plate are flattened; the concentration of acetylcholine receptors at the motor end-plate is decreased; the amount of acetylcholine in the junctional vesicles is decreased; and the amount of acetylcholine released is also decreased. In spite of all of these changes in the neuromuscular junction, alterations in the pharmacodynamics of nondepolarizing neuromuscular blocking agents in the elderly are largely due to alterations in the pharmacokinetics of these agents. Sensitivity of the acetylcholine receptor to neuromuscular blocking agents is not affected by advanced age. Altered pharmacokinetics are the result of decreases in hepatic and renal blood flow and function that occur with advanced age as well as altered volumes of distribution of relaxants in geriatric patients.

Clearance is decreased in the elderly for those nondepolarizing muscle relaxants that depend primarily on either the kidney or the liver for their elimination from the plasma. The long-acting agents metocurine, pancuronium and d-tubocurarine have all been found to have a prolonged duration of action in the elderly. Surprisingly, the newer long-acting relaxants, doxacurium and pipecuronium, which still depend on renal mechanisms for elimination from the body, seem to have pharmacodynamics that are unaffected by advanced age. Of the intermediate-acting relaxants, vecuronium and rocuronium, both of which depend on end-organ elimination from the body, have prolonged durations of action. Atracurium and cisatracurium, which depend on the kidney only as a secondary means of elimination from the body, do not have a prolonged duration of action in the elderly. They are eliminated primarily by Hofmann elimination, which is a temperature and base catalyzed process of spontaneous degradation. The process is not affected by advanced age. Mivacurium's duration of action in the elderly is prolonged because of the decreases in plasma cholinesterase activity that accompany aging.

In choosing a nondepolarizing neuromuscular blocking agent to provide relaxation during an anesthetic, the use of the intermediate-acting agents is prudent as the duration of action of even a single dose of a long-acting agent may be too prolonged for the planned surgery. Mivacurium's only potential advantage as a muscle relaxant with a short duration of action may be lost in the elderly as it may behave pharmacokinetically as an intermediate-acting relaxant. In general, when maintaining neuromuscular blockade with nondepolarizing relaxants one can expect that the dosing interval will be increased and that fewer doses of relaxant will be required to maintain the desired depth of neuromuscular block. Atracurium and cisatracurium may be the only exceptions to this.

The choice of nondepolarizing neuromuscular blocking agent and monitoring of the depth of blockade are exceptionally important in this patient population as recovery of neuromuscular function is generally delayed in the elderly. Inadequate or incomplete recovery of neuromuscular function is associated with a greater incidence of perioperative pulmonary complications.

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Aging and the Central Nervous System

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Aging and age-related disease are not the same. Those manifestations that are universally present in all elderly individuals and that increase in magnitude with advancing age, represent aging.

Structure and Function

Effects of aging on the nervous system include:

1. selective attrition of cerebral and cerebellar cortical neurons
2. neuron loss within certain areas of the thalamus, locus ceruleus, and basal ganglia
3. general reduction in neuron density, with loss of 30 percent of brain mass by age 80
4. decreased numbers of serotonin receptors in the cortex
5. reduced levels of acetylcholine and acetylcholine receptors in several regions of the brain
6. decreased levels of dopamine in the neostriatum and substantia nigra and reduced numbers of dopamine receptors in the neostriatum.

The association of serotonergic, cholinergic and dopaminergic systems, respectively with mood, memory, and motor function, may partially account for depression, loss of memory and motor dysfunction in the elderly.

Afferentation

There is also a generalized reduction in afferentation, evident as progressively increased thresholds for virtually all forms of perception, including vision, hearing, touch, joint position sense, smell and peripheral pain and temperature.

Sleep

Normal physiologic changes in sleep occur with advancing age, with probably the most common change being a decline in slow-wave, or delta, sleep. Delta sleep is thought to be the deepest level of sleep and perhaps the most restoring. Increased latency to sleep onset is often present, as well as increased awakenings and periods of wakefulness during the night. Simultaneous with this increasing wakefulness at night is an increasing tendency for sleeping and sleepiness during the day. The timing of natural sleeping/waking cycles probably changes with age. In general, the usual bedtimes and awakening times of the elderly tend to occur earlier and are referred to as "sleep phase advancing". Two sleep disorders, sleep-disordered breathing (SDB) and periodic limb movements in sleep (PLMS), are commonly seen in the elderly.

Memory

Memory and reasoning performance decline linearly with advancing age. Age-related decline in frontostriatal function, as supported by neuroimaging studies, most likely accounts for the majority of normal age-related decline in memory performance.

Plasticity

Experience is the major stimulant of brain plasticity, which is the brain's ability to change structure and function. It is thought that an increase in dendritic growth and number of synapses with aging helps to compensate for the loss of neurons.

Age-related Diseases

Age-related diseases such as cerebral arteriosclerosis, Alzheimer's and Parkinson's disease are all more common with advancing age. Most strokes affect those older than 70 years and the risk doubles every 10 years after age 55. The prevalence rates for dementia and Alzheimer's disease double approximately every five years from rates of 2 to 3 percent in the age category of 65 to 75 years to more than 30 percent in persons age 85 and older. Onset of symptoms in Parkinson's disease usually occurs between ages 60 and 69, although in 5 percent of patients the first signs are seen prior to age 40. About 1 percent of persons age 65 and older and 2.5 percent of those older than age 80 have Parkinson's disease.

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Postoperative Delirium in the Elderly

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Postoperative delirium, a transient mental dysfunction, can result in increased morbidity, delayed functional recovery and prolonged hospital stay in the elderly. The distinguishing features of this transient global disorder are impaired cognition, fluctuating levels of consciousness, altered psychomotor activity, and a disturbed sleep-wake cycle. It is usually seen on the first or second postoperative day and symptoms are often worse at night. The condition can be silent and go unnoticed, or it may be misdiagnosed as depression. Postoperative delirium is defined as clinical situations in which patients think and speak incoherently, are disoriented and show impairment of memory and attention. The Mini-Mental Status Exam (MMSE) and other tests can assess speech, consciousness, perception, orientation, coherence, memory and motor activity. The MMSE is easy to conduct, reliable and can be used for serial testing in fluctuating conditions.

The reported incidence of postoperative delirium varies from 1 percent to 61.3 percent in different studies. Differences in diagnostic criteria, populations under study and methods of surveillance used probably account for the wide range of figures. However, some surgeries such as joint replacement, are particularly likely to result in delirium. One hypothesis for the mechanism behind postoperative delirium is a decrease in the oxidative metabolism of the brain, which results in the decline of neurotransmitter levels within the brain and causes mental dysfunction. Another hypothesis suggests that an increase of serum cortisol from the stress of surgery or anesthesia may be responsible for postoperative confusion.

Aging, pathologic states in the brain, polypharmacy and drug interaction, alcohol and sedative-hypnotic withdrawal, endocrine and metabolic problem, depression, dementia and anxiety and gender are considered to be preoperative risk factors. Hypoperfusion and microemboli of air or blood cells in cardiac surgery, fat embolism in orthopedic surgical patients, regular use of anticholinergic drugs or drops and severe bilateral loss of vision in ophthalmologic patients may also contribute to the postoperative confusion. Anticholinergics, barbiturate premedication and benzodiazepines are implicated in the development of postoperative delirium. There is no difference in the effects of general, epidural or spinal anesthesia on postoperative confusion. Perioperative hypoxia, hypocarbia and sepsis are also risk factors for postoperative confusion.

Preoperative assessment of the patient's physical and mental status and medications is very important. Pre-existing sensory or perceptual deficits compound a patient's chances of developing confusional states. The mainstay of intraoperative preventive measures is maintaining good oxygenation, normal blood pressure, correct drug dosage and normal electrolyte levels. Drug cocktails should be avoided. Atropine, scopolamine and flurazepam should be used only if necessary, and the dose should be as low as possible. Glycopyrrolate may be a better choice than atropine as the former is a quaternary amine and should penetrate the blood-brain barrier less effectively than will atropine. Ambulatory surgery should be encouraged because elderly patients are maintained in the familiar home environment. Adequate postoperative analgesia, especially in patients who cannot communicate easily because of endotracheal tubes or tracheostomy, is crucial. Nurses should be well versed in detecting the earliest signs of delirium, which in the elderly may be withdrawal rather than agitation. The central nervous depressants, H2-antagonists, anticholinergics, digitalis, phenytoin, lidocaine and aminophylline should be used with discretion. In general, drugs with short elimination half-lives are preferable to long-acting drugs.

In all likelihood, patient predisposition, type of surgery and postoperative factors may be even more important to the development of delirium than the choice of anesthesia. Prevention of delirium will therefore involve control of many more factors than just the drugs used during surgery (though as mentioned above, certain classes of drugs should be avoided). Not much is known about prevention in surgical patients, but in hospitalized elderly medical patients a regimen designed to manage pre-existing cognitive impairment, sleep deprivation, immobility, visual impairment, hearing impairment and dehydration reduced the incidence of delirium to 10% in comparison to a 15% incidence in patients who received standard ward medical care.

Once postoperative confusion has been diagnosed, the patient should be managed with extra vigilance. First, the underlying organic cause of the confusion should be found and treated. For acute control of delirium, doses of 0.25-2 mg oral haloperidol 1-2 h before bedtime is the preferred treatment. For more agitated patients, IM haloperidol can be used. A small dose of 0.5 mg is given every hour until symptoms are adequately controlled. Droperidol has been used for rapid tranquilization. Although chlorpromazine is extremely effective, it can lead to a severe drop in blood pressure. Diazepam, used alone or in combination with other antipsychotic drugs, is especially effective for delirium tremens. Thiamine is the key drug for the management of Korsakoff's psychosis. Neither muscle relaxants nor physical restraints are particularly effective. Finally, if delirium progresses to coma, standard treatment for control of airway, breathing and circulation should be instituted. After recovery from an acute episode, a psychiatric or psychosocial referral may aid early functional rehabilitation. Similarly, the use of nursing assistance at home will permit a quicker discharge from the hospital. Physiotherapy and occupational therapy are also important adjuncts in the management of postoperative delirium.

A final concern that may be related to the phenomenon of postoperative delirium is the development of postoperative cognitive decline. Cognitive decline is not the same as delirium; patients who suffer cognitive loss are generally fully alert and oriented. In the past, changes in cognition have mostly been reported in an anecdotal fashion. More recently, a study that performed extensive neuropsychological testing demonstrated significant decrements in cognition in 10% of the subjects at three months after surgery. Age was the only significant risk factor. Whether the changes are permanent is unknown, nor is it apparent how it can be prevented.

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Safe Sedation of the Elderly Outside the Operating Room

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Within the next decade, it is estimated that 20-40 percent of anesthetic cases may be performed outside the operating room. Patient demand has also influenced this trend, with surveys showing the elderly preferring more ambulatory settings.[1] In addition, Medicare also favors outpatient protocols for certain procedures.

This expansion of outpatient procedures for the elderly must be viewed with caution because perioperative complications increase with age. The etiology of this observation is controversial but is probably more a function of associated concurrent diseases than age in and of itself.[2] In addition, liability claims for adverse events associated with sedation have substantially increased. Levels of injury are comparable with general anesthetics, with those injured tending to be older, more debilitated and performed on an outpatient basis.

One must appreciate that geriatric patients have limited physiologic reserves. There is less heart rate responsiveness in response to hypotension.[3] Ventilatory responses to hypoxia and hypercarbia are reduced, with greater risks for apnea. Impairments in thermoregulation and water balance increase vulnerability for hypovolemia and hypothermia. Changes in volume of distribution, bioavailability and receptor sensitivity lead to alterations in pharmacodynamics for most drugs. Limitations in renal clearance and hepatic function require attenuation of dosage. Since many elderly have prolonged circulation time, longer periods are required for interval dosing. Thus, titration to effect is an important principle in applying clinical judgment to the geriatric patient.[4]

Delirium may occur in a high percentage of elderly surgical patients.[5] This should give rise to caution for similar potential in the sedated geriatric patient. Procedures in remote locations often have anesthetic requirements that rival many operating room procedures. The risk of delirium may be increased with agents such as midazolam, meperidine and anticholinergics. Immobilization and prolonged nothing by mouth (NPO) status are prominent contributing factors for periprocedure delirium. Because of increased sensitivity to medications, patients with any baseline disorientation should be insured of overnight observation. There is evidence that interventions such as repeated orientation, maintaining sensory aids and familiar family contacts are key factors in delirium prevention.[5]

When sedating the geriatric patient, the agent of choice should have a short half-life, with minimal active metabolites and limited side effects. One should avoid using standard dosages calculated on a mg/ kg basis. These boluses frequently produce unwanted respiratory depression and hypotension. Likewise, slower administration of an agent and allowing more time for peak effects often achieves the desired goals with less overall dose.

Midazolam and fentanyl are a common combination used for conscious sedation. Due to increased sensitivity in the elderly and decreased clearance of these agents, smaller doses and more delayed increments must be used. Propofol also has a reduced clearance in the elderly. Older patients require lower doses for any given effect, in many cases as little as 50 percent of the expected "standard" dose.[6]

Remifentanil is the newest ultra short-acting agent on the market and its use is currently being explored. It offers potent, rapid analgesia, but its rapid offset may be a double-edged sword in cases involving prolonged discomfort. In the elderly, its use appears to be associated with an increased incidence of hypoventilation.[7] While clearance is quite rapid and independent of age, the dosage required for clinical effect in the elderly is at most 50 percent of package insert guidelines. Its utility as a sedative needs to be more thoroughly evaluated, but at this time there appears to be only modest enthusiasm compared to other currently available agents.

Safe sedation of elderly patients also includes maintaining appropriate practice standards in all areas where these agents are administered. The Joint Commission on Accreditation of Healthcare Organizations addressed this issue by mandating that institutions develop protocols for conscious sedation. While they do not set specific standards for practice, they state that institutions should have polices dealing with evaluation, personnel, equipment, monitoring and recovery. They also require evidence of monitoring for compliance. Anesthesiologists should be involved in the establishment of these protocols because they optimize patient safety through identification of patients who require care beyond the scope of conscious sedation.

Among various logistic considerations, geriatric patients take longer to accomplish many tasks. Thus, more time must be allowed for preprocedure preparation. Also, older patients' skin may be fragile, so adhesive tape should be used with caution to avoid torn skin. Extra padding should be used on procedure tables to prevent compression sores. The elderly are less agile and may require equipment aids (e.g., chair raisers or footstools). Many elderly are hearing impaired, so verbal and written post-procedure instructions may foster comprehension.

Several novel approaches to sedation have recently evolved, and a few may prove useful in enhancing the care of geriatric patients undergoing procedures in remote locations. Similar to patient controlled analgesia, the concept of patient controlled sedation is now being explored. Several studies have demonstrated its safe and efficacious use for conscious sedation in the operating room.[8,9] However, one study, which used Propofol in the treatment of the elderly, found an increased incidence of profound sedation.[9] The boundaries of this technique have yet to be defined.

Bispectral index monitoring (BIS) is currently being evaluated as a level of consciousness monitoring. The processed EEG signal is quantitated and used as an indicator of sedation level. It may permit more effective titration of drug administration, thus speeding up recovery time.[10]

For anesthesia departments noting increased usage of conscious and deep sedation outside their operating rooms, we may see the advent of formal anesthesia sedation services available throughout a hospital community. Advantages of such a service include providing a hospital with timely, reliable, high-quality service with an optimization of recovery and turnaround time.

In summary, sedation of the geriatric patient in remote locations requires appreciation of their physiologic limitations and underlying co-morbid conditions. The clinician must pay attention to periprocedural care, including use of short acting agents, in conjunction with a judicious dosing strategy.

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Age-Related Disease

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In the 1950s, it was very unlikely that one would live to be more than 100 years old, or even 90. At that time, 35 was considered middle age. However, less than half a century later the age group of 85 and above is the fastest growing population in the United States. Thanks to advances in medical science (prevention, early diagnosis and treatment), Americans are living longer than they ever have before.

While people are living longer, there are also more diseases and other disorders in the aging population. Thus, geriatric medicine is rapidly developing as more studies of the aged are being done. Concomitant existing disease cannot be ignored when preparing the geriatric patient for anesthesia and surgery. This article will concentrate on diseases and other disorders of the geriatric population.

The cause of aging is unknown, but genetic and environmental factors play important roles.

GENERAL CHANGE DURING AGING

Externally, one's hair turns gray and the skin begins to wrinkle. Internally or physiologically, aging means that atrophic changes affect many organs as well as decrease the function of many systems due to a slowing of the metabolism. The aging process decreases the volume of body fluids and increases fatty tissue. These changes, coupled with a frequently sedentary lifestyle, predisposes the elderly to obesity. However, the very old tend to lose weight, perhaps due to a decrease in appetite occasionally bordering on anorexia.

Environment and life style affect the body concomitantly with advancing age and disease. Education and socioeconomic status and character traits are particularly important because they can be modified and may potentially alter the aging or disease process. Lifestyle habits such as exercise, diet, cigarette smoking and alcohol use also affect the aging process

CENTRAL NERVOUS SYSTEM (CNS) DISORDERS

The aging process often causes brain atrophic changes. There are substantial age-related declines in brain function, i.e., decrease in norepinephrine and dopamine synthesis. The righting reflexes and Stage 4 sleep also decrease. Some neurons gradually die in the brain; however, others will grow to compensate for the age-related deaths of their neighbors, similar to what happens in hippocampus. There are also age-related neurological and psychiatric disorders.

1. **Neurologic Disorders**

   Neurological symptoms in the elderly are common, such as impairment of memory, decreased cognitive or intellectual functions, deterioration of mobility (e.g., change in gait), altered sleep pattern, decreased sensory input, (visual, acoustic, taste, smell, etc.), and autonomic nerve system imbalance.

2. **Psychiatric Disorders**

The symptoms are often depression, dementia, confusion, catatonia and delirium. The CNS diseases in the elderly are often Parkinson's disease, depression, dementia and delirium.

AUTONOMIC NERVOUS SYSTEM DISORDERS

The autonomic nervous system serves as a vigilant guardian for homeostasis of the human body. In other words, the autonomic nervous system is capable of maintaining a constant internal environment in spite of external challenges. However, since the homeostatic mechanisms slow and weaken during advancing age, changes are reflected in the alterations of sympathetic and parasympathetic responsiveness, i.e., decreased sensitivity of baroreceptor and change in thermoregulation.

Consequently, orthostatic hypotension and syncope are common problems for the elderly and are only worsened by disease, especially diabetic autonomic dysfunction.

Thermoregulation is affected by autonomic impairment, as well as changes to the skin and blood vessels. Thermoregulation is further impaired by many chronic medications. The overall effects of these conditions include inadequate heat production and conservation, increased heat loss and reduced heat tolerance. The elderly, especially the poor elderly, may lack resources for environmental control (adequate heating/cooling systems, clothing, mobility, etc.), which is vital to temperature control.

As a consequence, the elderly are vulnerable to heat stroke and hypothermia and die in disproportionate numbers every year.

EYE AND EAR DISORDERS

Eye Disorders - Physiological changes of presbyopia and lens opacification subsequently cause decreased accommodation and increased susceptibility to glare. These physiological changes often result in decreased visual acuity as well as blindness.

Ear Disorders - For the ear, the physiological change is decreased high frequency acuity, making it difficult to discriminate words if noise is present in the background. Consequently, there is deafness and a decrease in acoustic acuity.

CARDIOVASCULAR SYSTEM DISORDERS

Physiological change in the aging individual produces decreased arterial compliance (decreased elasticity) and increases in systolic blood pressure, subsequently causing left ventricle hypertrophic (LVH). It also results in decreased beta-adrenergic receptor responsiveness as well as decreased baroreceptor sensitivity. There is also a decrease in SA node automaticity.

Diseases include hypertension, coronary disease, congestive heart failure as well as heart block or arrhythmia.

RESPIRATORY SYSTEM DISORDERS

Physiologically, aging also affects the respiratory system with decreases in responsiveness to hypercapnia, and often with hypoxia due to decreased carotid and aortic body sensitivities. There is an increase in chest wall rigidity, chest wall compliance and muscle strength. Also, as the airway from the nose to the terminal bronchi become more narrow or stiff, there is a decrease in the exchange of gas. The lung parenchyma contains three important gas exchange structures: 1) alveolar, the gas exchange airways distal to the terminal bronchioles, 2) capillary bed and 3) the interstitial structure of the lung (elastic recoil). Under normal situations, the distal airways maintain patent by the elastic recoil forces of the surrounding lung parenchyma. The forces that hold intraparenchymal airways (small airways) open will therefore decrease as the aging lung loses its elastic recoil due to thickening of parenchyma. The thickening of parenchyma will also decrease gas exchange between the alveolar and capillary bed.   There is ventilation perfusion mismatching and decreased arterial oxygen.

The respiratory system is also affected by environmental changes, including smoke, dust, air pollution, etc. Respiratory diseases include emphysema, dyspnea, and hypoxia.

GASTROINTESTINAL SYSTEM DISORDERS

The gastrointestinal system in the elderly is often characterized by decreased hepatic function, gastric acidity and absorption of certain foods and substances, such as calcium. There is also a decrease in colon mobility and motility, as well as in anal/rectal function.

Subsequently, the elderly may have hepatic cirrhosis, constipation, fecal impaction, fecal incontinence, osteoporosis or vitamin B_{12} deficiency due to poor absorption.

RENAL DISORDERS

As one gets older, the kidneys change morphology due to atrophic change of the parenchyma and sclerotic change of the vasculature. The result is profound functional changes: decreased renal plasma flow, decreased glomerular filtration rate and decreased ability for urinary concentration or dilution. These changes delay responses to electrolytes fluid restriction or overload.

In the final stages, renal changes cause increased serum creatinine, blood urea nitrogen, renal failure and increased or decreased electrolyte retention.

GENITOURINARY SYSTEM DISORDERS

In the female there are atrophic changes of the vaginal and urethral mucosa. In the male, prostate enlargement often causes urinary tract incontinence or retention, which can lead to urinary infection.

ENDOCRINE SYSTEM DISORDERS

In elderly individuals, the activity of the endocrine system also decreases, causing impaired glucose hemostasis, decreased thyroxine clearance or production, decreased production of renin, aldosterone and testosterone, decreased vitamin D absorption and activation and increased plasma concentration of antidiuretic hormone.

So, the consequences of all of these changes include the development of diabetes mellitus, thyroid dysfunction, decreased sodium retention, increased potassium absorption, impotence and osteoporosis, which causes bone fractures.

HEMATOLOGICAL AND IMMUNE SYSTEM DISORDERS

Bone marrow production is decreased in the elderly, as is T-cell function. There is an increase in autoantibodies. In such cases, the combination of a poor dietary intake and poor vitamin absorption often causes the development of anemia and autoimmune disease.

MUSCULAR SKELETAL SYSTEM DISORDERS

Decreased muscle mass, bone density and lubrication of the joints causes stiffness of the joints, osteoporosis, frequent fractures of the hip and bone/joint functional impairment.

CANCER AND AGING

Age is the most significant risk factor for cancer. Two-thirds of all cancer cases occur in the population aged 65 years or older. Thus, the probability of a person developing cancer is age-dependent: 1:58 men, and 1:52 women for age 0-39; but 1:11 men, and 1:13 women from age 40-59; and 1:3 men, and 1:4 women for the age range of 60-79 years.

DRUG METABOLISM DISORDERS

Drug metabolism often relates to the organ system functions and their reserve. Because of the decreased CNS, hepatic, renal, gastric and lung function and decreased cardiovascular reserve, as well as decreased lean body mass, decreased body fluid volume and increased fatty tissue, the elderly often metabolize drugs differently from the younger age group. In general, drug metabolism may be significantly reduced due to the failing function of the systems previously mentioned. Due to the increase in fatty tissue, the decrease in total body water, the distribution of the medication either from oral, intravenous or intramuscular routes and increases in volume of drug distribution, the elderly often have a change in uptake, and thus reduced clearance. Decrease in the metabolism and excretion is also due to decreased hepatic and renal functions. The elderly group should be treated differently when prescribing medication, and more attention should be paid in particular to drug interaction. Further study definitely needs to be done for drug metabolism in the aged group so that drugs can be prescribed intelligently to avoid adverse reactions.

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Anesthetic Risk and the Elderly

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With the aging of the United States' population and the progressive lengthening of life expectancy, the number of elderly patients requiring anesthesia and surgery will continue to grow. Thus, perioperative risk in the elderly is an increasingly important issue.

Many studies have documented that the frequency of perioperative complications increases with age. For example, a large prospective survey performed in France from 1978 to 1982 documented an approximately 10-fold increase in the rate of complications specifically attributed to anesthesia as the age of patients increased from 30 to 80 years old.[1] This finding is not surprising given that the prevalence of significant co-morbid conditions such as cardiovascular disease is increased in the elderly[2]. However, it is unclear whether the increased frequency of complications can be attributed to these co-morbid conditions or whether advanced age itself is an independent risk factor. In other words, is the *healthy* elderly patient at increased risk? The answer to this question may depend upon the specific disease process and complication addressed, and it is probably unwise to make generalizations.

As an example of the difficulties encountered in assessing age itself as an independent risk factor, many studies examine risk factors for perioperative cardiovascular events in both cardiac operations and noncardiac surgery. Although several studies find that age is an independent predictor of risk, many do not.[3] Interpretation of these studies is complicated by heterogeneous definitions of disease and outcomes, differing modes of clinical care and diversity in the type of surgical procedures examined. Furthermore, subclinical preoperative cardiovascular disease, which is more prevalent in the elderly, may be difficult to detect. This subclinical disease may increase risk, yet it will not be included as a factor in analysis of risk.

Although the overall frequency of perioperative complications is increased in the elderly, it is still relatively low. For example, in the above-mentioned French survey, the frequency of complications related to anesthesia was 0.5 percent in patients greater that 80 years old.[1] In a case series of 795 patients 90 years of age and older undergoing surgery at Mayo Clinic, 9.4 percent experienced serious morbidity within 48 hours after surgery, with the mortality rate being 1.6 percent.[4] In a similar study, of 31 patients aged 100 to 107 years undergoing surgical procedures, only one major complication within 48 hours was observed, and the long-term survival rate was comparable to the expected rate for this population[5]. These findings suggest that appropriate surgery should not be denied simply on the basis of age.

Most studies of perioperative risk concentrate on physiologic measures such as presence and occurrence of specific pathologic states as predictors of risk and as outcome variables. However, the functional status of the elderly may also be an important predictor of risk. Functional status is defined as behaviors necessary to maintain daily life (e.g., activities of daily living), and includes aspects of social and cognitive functioning. Several studies have now shown that these functional measures may be even more important than standard burden-of-illness indices (such as acute physiologic scores) in predicting mortality in hospitalized patients.[6]

These measures have not yet been applied specifically to studies of perioperative outcome. Indeed, from the standpoint of the patient, the most important perioperative outcome measure may be a change in functional status, rather than the occurrence of an acute physiologic complication that may or may not affect the ultimate quality of life. More subtle effects of anesthesia and surgery, such as the prolonged cognitive decline recently noted after surgery in some elderly patients, may be better appreciated utilizing this approach.[7]

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   Documented by careful neuropsychiatric evaluation that there is a significant, long-term (at least 3 months) cognitive dysfunction associated with anesthesia and surgery in approximately 10% of elderly patients.

Perioperative Complications in Elderly Patients

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Introduction

By the year 2030, it is estimated that 20 percent of Americans will be older than 65, while one out of four elderly individuals will be older than 85 years of age. Twenty-one percent of those over age 60 will undergo surgery and anesthesia as compared with only 12 percent of those aged 45 to 60 years. Despite the higher numbers of elderly patients having surgery, mortality and morbidity rates have been declining. Old age appears to have assumed less influence as a determinant of adverse outcome as perioperative care has improved. A better understanding of the associated risk factors leading to perioperative complications may help anesthesia providers to further lower the risk. This chapter will review recent studies examining common perioperative adverse events in elderly patients and their associated risk factors.

Mortality

Recent studies have shown a decline in the perioperative mortality rates from 20 percent in the 1960s to 10 percent in the 1970s, and to 5-6 percent in the 1980s. This trend of declining mortality rates even extends to those on the extreme end of the age spectrum. For example, a study by Warner from 1998 reported on 31 patients over 100 years of age.[1] The patients had postoperative mortality rates of 0 percent, 16.1 percent and 35.5 percent on 48 hours, 30 days and one-year follow-up, respectively. The survival rate was the same for the patients who underwent surgery as for controls who did not have surgery.

Several risk factors for perioperative mortality have been identified. Emergency procedures are associated with a higher mortality rate regardless of the age group. In 795 patients above 90 years of age, the 48-hour mortality rate for patients undergoing emergency surgery was 7.8 percent versus .6 percent in those who were age matched but undergoing elective surgery.[2] The location of the surgical site also has an important impact on mortality rate. Procedures involving the thorax or abdomen have been shown by multiple studies to have higher complication and mortality rates.[3] In addition, coexisting diseases have been found to be important risk predictors of perioperative mortality. Current data support the view that the effects from coexisting disease outweigh the effects of age alone on anesthetic outcome. When age and severity of illness are compared, the number of coexisting diseases is more significant. Recently, several studies have identified albumin level to be a good predictor of postoperative mortality.[4] Albumin, a marker of nutritional status, may serve as a surrogate marker for the preoperative health status of the surgical geriatric patient.

Since emergency procedures increase perioperative risk, early surgical treatment should be considered whenever possible. Delaying surgery just because of the patient's age is not supported by the literature. Every effort should be made to perform a thorough preoperative evaluation, including nutritional assessment, and to optimize the status of the patient's chronic medical diseases as much as possible before surgery. That assessment and care should continue postoperatively, especially after emergency surgery where there may be insufficient time for preoperative improvement.

Cardiovascular Morbidities

The elderly are more prone to develop cardiovascular complications. A study by Pedersen et al. in 1990 examined patients over 80 years of age who were undergoing anesthesia.[5] He reported a 16.7 percent cardiovascular complication rate compared to 2.6 percent in those less than 50 years of age. A high rate of cardiovascular complications (40 percent) was found in patients with preoperative heart disease, especially those with clinical signs of congestive heart failure, prior history of ischemic heart disease or previous myocardial infarction. Our recent study also found a similar cardiovascular complication rate of 12.5 percent in 367 patients over 80 years of age undergoing noncardiac surgery.[6] Our results, along with those from previous studies, suggest that the type of anesthesia does not appear to influence perioperative cardiovascular morbidity. Rather, hemodynamic control may be more important.

While some of the risks associated with adverse cardiovascular outcomes have been identified, randomized studies are lacking in determining whether modifying risks may improve outcomes. Some risk factors such as a history of congestive heart failure may be difficult to diagnose preoperatively. In fact, one-third of geriatric patients with heart failure may have diastolic dysfunction despite having normal systolic function. In the absence of specialized tests for estimating preoperative heart function, the goal should be to optimize symptomatic complaints as much as possible prior to surgery.

Pulmonary Morbidities

In a study of 7,306 anesthetics administered to patients over 80 years of age by Pedersen et al., 10.2 percent developed pulmonary complications, similar to a rate of 7 percent found in our recent study of patients 80 years or older.[5,6] In our study, we further demonstrated that a prior history of congestive heart failure and prior neurologic history increased the odds of an adverse postoperative pulmonary event by multivariate analysis.

Preoperative optimization of respiratory function is important in decreasing adverse pulmonary events. Cessation of smoking is associated with better outcomes even immediately prior to surgery since carbon monoxide levels have been shown to decrease soon after cessation. Good exercise capacity may also impact perioperative outcome. In a study investigating patients scheduled for abdominal and noncardiac thoracic surgery, patients who were unable to raise their heart rate above 99 beats per minute or perform two minutes of supine bicycle exercise had a higher cardiopulmonary complication rate (42 percent versus 9.3 percent).[7]

Neurologic Morbidities

There is a wide variation in the reported incidence of postoperative cognitive deficit (POCD) in the literature. One of the largest studies of elderly surgical patients was conducted by Moller et al.[8] The authors found that POCD was present in 25.8 percent of patients one week after surgery and in 9.9 percent of patients three months after surgery. This was compared to a control group of hospitalized patients not undergoing surgery who had a POCD rate of 3.4 percent one week after hospitalization and 2.8 percent three months after hospitalization. Increasing age, duration of anesthesia, lack of education, a second operation, postoperative infections and respiratory complications were identified as risk factors for early cognitive dysfunction.

Several studies have looked at general versus regional anesthesia, since general anesthesia may lead to changes in cerebral blood flow and cerebral metabolic oxygen consumption. The evidence to date suggests that although cognitive deficits may occur postoperatively, no particular anesthetic technique appears to be implicated.[9] Furthermore, a history of preoperative neurologic disease has been demonstrated by our study to also increase the rate of POCD.[6] Until more definitive clinical studies become available, minimizing the number of medications used, avoiding hypoxemia and hypercarbia, providing adequate postoperative pain control and involvement of geriatricians in postoperative care appear to be the best approach in minimizing the occurrence of POCD in the geriatric surgical patient.

Conclusion

Surgery in the geriatric population is not without risk, but the mortality rate has markedly decreased. Chronological age is much less important as an independent risk factor. A more important predictor is the presence of coexisting disease. Although prospective trials involving risk modification are lacking, medical optimization, adequate planning preoperatively, including scheduling surgery electively as opposed to emergently, and improving nutritional status may be helpful. Anesthetic technique is probably not as important as meticulous control of hemodynamics perioperatively. Opportunity to improve perioperative outcomes in the elderly will be possible when risk factors for these adverse events can be modified and outcomes evaluated in prospective trials.

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Preanesthetic Evaluation for the Elderly Patient

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Fifty percent of all Americans over 65 will undergo a surgery prior to death; thus it is important to understand the basic physiological changes that occur during aging. The elderly are a heterogeneous group and aging is not always a predictable process. Although the preoperative assessment must be tailored to the individual, some basic guidelines for elderly patients are discussed in this section.

The preoperative evaluation of an elderly patient is best accomplished several days before the surgery and ideally not before medical information has been obtained from the surgeon or primary care physician. An evaluation in a preanesthetic clinic is advantageous and provides the patient with the additional opportunity to meet with nursing and social work staff.

The anesthesiologist's assessment includes a history, physical examination and review of the medical chart. Laboratory testing is indicated by comorbid conditions and the type of surgery contemplated; tests should not be performed solely because of advanced age. A discussion about anesthetic techniques and risks can reduce patient anxiety. The visit also provides the opportunity to refute preconceived negative beliefs about the safety of anesthetic techniques such as spinal and regional anesthesia.

Some specific areas and questions to be addressed during the visit might include:

- What is the patient's mental status? Is the patient able to answer coherently, or is the family answering for him or her? Will regional techniques and outpatient surgery be feasible?
- Does the patient have cardiac disease? Coronary artery disease is prevalent in elderly patients, and it may be unrecognized due to limited function prior to surgery. Is a prior cardiac work-up available? Why was it performed? Is more needed?
- Assessing functional capacity - this may provide an excellent estimate of reserve. For instance, can the patient walk up and down stairs with and without groceries?
- Does the patient have pulmonary disease? Is he or she short of breath in the clinic or lying flat? Document room air oxygen saturation.
- Is the patient hypertensive? This may alter cerebral autoregulation and require higher systemic pressure intraoperatively. Make sure to document baseline blood pressure.
- Is the patient markedly anorexic, dehydrated or very frail (e.g., in a wheelchair)? Or does the patient appear young and vigorous for his or her age?
- Does the patient have an understanding of their medications?
- Has the patient had a prior surgery? How did he or she tolerate the anesthesia? Were there complications that may influence the choice of the next anesthetic, such as confusion or congestive heart failure?

Guidelines for Elderly Patients:

1. Expect interindividual variability
2. Advanced chronological age is not a contraindication to surgery
3 Clinical presentation of disease is frequently atypical, leading to delays and errors in diagnosis
4. Most older patients are on multiple medications and have multiple illnesses (individuals older than 65 have on average 3.5 medical diseases)
5 Diminished organ reserve can be unpredictable - limitations may only become apparent during the surgery
6. A disproportionate increase in perioperative risk may occur without adequate preoperative optimization - adverse events are more frequent with emergency cases
7 Meticulous attention to detail can help avoid minor complications that can rapidly escalate into major adverse events in elderly patients
8 Impact of extrinsic factors - smoking, environment, socioeconomic, etc. - is difficult to quantify

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Managing Medical Illness in the Elderly Surgical Patient

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Anesthesiologists and geriatricians share the role of managing medical illness among elderly surgical patients. During the immediate perioperative period, anesthesiologists provide the principle care and generally function in an acute illness model of practice. Problems that arise, such as hypertension, hypoxemia or hyperglycemia are judged correctable and an appropriate intervention is initiated to correct them. In contrast, geriatricians, as primary care physicians for older persons over the last years of their lives, more often operate in a chronic disease model. Activity of chronic illness is quite variable over time, and a long-term treatment plan is the most effective approach to managing problems that will most likely not be cured. When an older person with stable osteoarthritis, heart disease, hypertension and diabetes falls and breaks a hip, physicians caring for this patient must address both the acute illness and its potential effects on various organ systems and the longer term management of chronic illnesses to reestablish homeostasis and optimize function. The best outcomes can be expected from comprehensive, coordinated and attentive management of both the acute and chronic disease states of older surgical patients.

Beyond appropriate management of accumulated chronic illnesses, anesthesiologists and geriatricians can contribute to improved outcomes by comprehensive risk assessment and management. There is a long history of this tradition in anesthesiology as evidenced by the remarkable value of the ASA Physical Status scoring system that has been used to successfully risk stratify operative patients for over 50 years.[1] Additional methods have been developed to predict specific complications, e.g., the Goldman criteria for cardiac complications of noncardiac surgery, and the timed-walk test to predict pulmonary complications.[2,3] More recently, the American Heart Association and the American College of Cardiology have developed a practice guideline for cardiovascular evaluation for noncardiac surgery.[4] A significant advantage of this guideline is its explicit recommendations for specific clinical situations. Clinicians are prompted to consider comorbid conditions, functional abilities and the risk of the surgical procedure in a step-wise approach to determine what measures should be taken before the patient arrives in the operating room. From the perspective of the geriatrician, two aspects of these guidelines are especially notable. First, "advanced age" is included among the minor clinical predictors, acknowledging that chronological age is a much less important risk factor than the extent of concomitant medical problems. Second, physical functional status, a central concern in geriatric medicine, is featured prominently in the guideline. As this guideline becomes implemented, we hope to see reports of improved patient outcomes.

A particularly worrisome outcome of surgical interventions among older persons is cognitive decline. Considerable attention has been directed at the acute, reversible postoperative cognitive changes recognized as delirium.[5] More recently, attention has been directed at more persistent cognitive decline. A multinational study of over 1,200 patients 60 years of age and older who underwent major noncardiac surgery reported a 25.8 percent incidence of cognitive decline at one week and a 9.9 percent incidence at three months.[6] Risk factors for the short-term decline included age, duration of anesthesia, little education, a second operation, postoperative infection and respiratory complications. The only risk factor for the longer term decline that achieved statistical significance was age. The investigators carefully monitored patients for arterial hypotension and hypoxemia and found that these were not significant risk factors for short- or long-term cognitive decline. No attempt was made in this first study to examine the contribution of various anesthetic techniques. There is still considerable work to be done to first identify mutable risk factors, and then develop strategies to optimally manage patients at risk so that cognitive decline is minimized as a complication of operative therapy among older persons.

Important studies have been done to examine the role of intraoperative anesthetic management of selected patient outcomes.[7,8] While regional and general anesthesia have been compared with respect to mortality, thromboembolism, blood loss and pulmonary function among other outcomes, no widespread consensus has emerged regarding the application of these approaches. Combined approaches are also being investigated, but more studies need to be done on older persons facing a variety of different operations. Postoperative pain management strategies have also been compared, with limited attention to outcomes other than analgesia.[9,10] Working together, anesthesiologists and geriatricians could design studies that will address acute illness and chronic disease outcomes that are important to the overall health status and quality of life of older persons.

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Ethical Challenges in the Anesthetic Care of the Geriatric Patient

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Introduction

Geriatric patients face special medical, economic and social challenges that affect the ethical and legal issues in their medical care. Ethical principles guiding the care of elderly patients are no different from those involved in the care of other adult patient populations. Common ethical challenges include conflicts over patient autonomy and choice, surrogate decision-making and do-not-resuscitate (DNR) order in the operating room.

Respecting Patient Autonomy

The ethical principle of respect for patient autonomy requires that medical decisions be made by the patient, whose life is directly and most affected by the consequences of the decision. Physicians can provide information, recommendations and rational argument to convince a patient to agree to medical therapies, but the ultimate decision of what will be done to them rests with the patient. The legal doctrine embodying this principle is that of informed consent and has been upheld in U.S. courts since 1914. [1,2]

Informed Consent

Informed consent requires several elements. First, consent must be voluntary and free of undue influence or coercion. Second, consent must be made based on sufficient information. Finally, the decision-maker must be able to understand the information given to them, apply it in some rational way to the medical issue at hand and arrive at a decision based in part on the information given to them.[3] Patients have the right to refuse medical therapy, even if the decision is at odds with what the physician feels "is best" for them.[4]

Voluntary decisions, by definition, must be free of force, intimidation, duress or coercion. Social and economic pressures affecting elderly patients may hinder the ability of elderly patients to make truly voluntary choices. Pressures from family members to undertake, or not undertake medically onerous treatments can cause an elderly patient considerable duress. Economic pressures on patients with limited monetary resources may play a hidden albeit significant role in the patient's decisions. Fears of dependency or of burdening the family may encourage some patients to forgo treatment that might otherwise be beneficial. These influences affect any patient population, but geriatric patients are particularly likely to face such pressures while suffering from medical conditions that require difficult treatment decisions.

A patient must have sufficient *information* to give informed consent. In the "reasonable person" standard, used in about half of the United States, the physician must provide information that any "reasonable person" would need.[1] About half of the United States apply an "individual" standard, recognizing that some individuals may have special informational requirements. In general, patients should be told in lay terms the diagnosis to be treated, the proposed treatment, the foreseeable risks and benefits of the procedure and the viable alternatives to the procedure, including no treatment.[5] Anesthesiologists should pay particular attention to explaining the risks of common problems that generally do not have significant long-term impact (e.g., nausea, sore throat, delirium) as well as rare problems that have significant long-term impact (e.g., death, neurologic injury, myocardial ischemia or infarction).[6]

"*Competency*," is a legal term describing a patient's ability to perform certain functions. Medical authors often refer to the ability of a patient to make medical decisions as "capacity" to distinguish it from the related legal term.[7] Capacity is a relative, not an all-or-none, phenomenon. Incapacity to handle finances, for example, does not preclude capacity to make personal decisions about medical care.[8,9] Capacity can wax and wane with environmental factors, such as time of day, familiarity of surroundings, the presence of distractions and reactions to medications. Decision-making capacity can be impaired by medical conditions that afflict elderly patients, such as dementia, cerebrovascular accidents and depression. Physical impediments to communication that are more common in elderly patients, such as aphasia and hearing loss, can give the false appearance of impaired capacity when no impairment exists.

Determining that an elderly patient has the capacity to make medical decisions can be a challenge for the anesthesiologist, who is often a stranger to the patient, and has limited time and resources for making what can sometimes be complex determinations. Many patients who carry the diagnosis of dementia have sufficient abilities to make medical decisions, yet studies demonstrate that patients with dementia are likely to be referred for competency evaluations when they disagree with their physician, and are unlikely to be referred if they agree.[10] When decisions are required regarding resuscitation in ICU patients, there is evidence that many physicians will not have discussed DNR decisions with competent patients either before or during the ICU stay.[11,12]

Assumptions about patient capacity based on diagnosis categories or age is not consistent with ethical medical care. Determination of decision-making capacity should focus on the patient's functional capacity. Basic questions to ask include:

1. Can the patient receive and understand information relevant to the decision at hand?
2. Can the patient understand possible consequences of their choice and alternatives, including risks and benefits?
3. Can the patient make and express a decision and discuss his/her values and desires in relationship to the medical advice provided?

Some patients are clearly too impaired to make medical decisions, but when questions arise, expert consultation can be helpful, both in determining a patient's capacity to make decisions and in overcoming physical barriers to communication. Consent in impaired patients may required extra time, patience and effort, but anesthesiologists are ethically obliged to promote and respect the autonomy of patients in making medical choices.

Surrogate Decision-Making

When patients are too impaired to make medical choices, a surrogate decision-maker may be involved. Proxy decision-making is based on three assumptions:

1. That a competent patient's decisions can be implemented by proxy.
2. That the proxy will make the same decision that the patient themselves would make if they were competent (the proxy would "don the mantle" of the patient).
3. That, in the absence of proxies, doctors might act less outof interest for the patient than out of fear of litigation.

Usually doctors turn to family members, assuming that families have the patient's best interests at heart and, by virtue of coming from a common cultural background, are more likely to actually know what the patient would decide.[13] But studies have shown that family proxy decision makers often come no closer than chance alone at predicting what a family member would want under hypothetical circumstances, and that proxies and patients infrequently discuss issues and values surrounding the use and withdrawal of life-sustaining technologies.[14,15] Moreover, it has been demonstrated that physicians are incorrect in predicting resuscitation preferences in 25 percent of their patients.[16] Proxy decision-making is a poor substitute for patient decision-making and should be avoided unless the patient is truly unable to participate in decisions.

Mechanisms for proxy decision-making include living wills, durable power of attorney or legal hierarchies. Living wills (advanced directives) are documents of a competent patient's wishes, executed in front of qualified witness, which can then be used on occasions when a patient is no longer competent to guide medical decision-making. A durable power of attorney is a mechanism for the competent patient to designate a specific person as their proxy for medical decision-making should they later become incompetent. Each state has a legal hierarchy through which a medical decision-maker is appointed if the patient has not executed a living will or durable power of attorney. Sometimes the court may appoint a legal guardian apart from family or other surrogate decision-makers who is legally responsible for health care decisions for the patient.

Do Not Attempt Resuscitation Orders (DNR)

Any adult with decision-making capacity has the right to refuse specific medical interventions, including cardiopulmonary resuscitation, even in the operating room.

Studies have shown that DNR orders are frequently entered in patient charts without a discussion with the patient and informed consent, *even if the patient is competent to participate in such a discussion.*[17] Physicians often turn to surrogate decision-makers and leave competent patients out of the decision-making process if the patient is elderly or carries the diagnosis of dementia. Paternalism (the doctor "knows" what is best), a desire to promote good and do no harm (the discussion might stress, and therefore harm, the patient) or more selfish motivations (the doctors wants to avoid a discussion that may be distressing to them) have been used as rationale to avoid having difficult conversations that are nevertheless ethically required.

The implications of cardiac arrest under anesthesia differ from those for arrest in other areas of the hospital; over 60 percent of patients resuscitated in the OR survive to discharge versus 7-17 percent of patients on the ward. [18,19] This is probably because OR arrests are witnessed, receive immediate intervention, and usually occur from reversible causes--medication effects and hemorrhage, while arrests on the ward may go unwitnessed for varying lengths of time and are often related to the severity of the underlying disease process.

Cardiac arrests, resuscitations and outcomes are different between the ward and the operating room, but the moral principles governing conduct with respect to patient autonomy are the same. As with other medical interventions, patients must be given appropriate information and provide informed consent (or "informed refusal) for cardiopulmonary resuscitation in the operating room. Because some procedures commonly thought of as resuscitation (e.g., mechanical ventilation) may be required for the anesthetic care of the patient, the anesthesiologist should discuss the ways in which resuscitation can practically be limited in the OR and still permit reasonable anesthetic care to proceed.

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Critical Care of the Elderly Patient

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Case: A pale, frail, but intellectually active 71 y/o female presents with hematemesis and tarry stools over the past 24 h. Her BP is 110/60 with a 30 – 40 mm drop when she sits up, pulse 110, RR - 20. She has long-standing rheumatoid arthritis and is treated with daily hydroxychloroquine, ranitidine and aspirin 650 mg q 4 – 6 h (it was more efficacious than her NSAI or COX-2 inhibitor). She was slowly tapered off steroids 4 months prior to admission. Her baseline creatinine is 1.4 mg/dL and hematocrit (Hct) 30. Her Hct today is 22.

Discussion

The importance of age to our critically ill patients is clear: advanced age (> 65) has been shown in multiple studies to be an independent risk factor associated with increased morbidity and mortality.[1] However, in the trauma and burn populations, age > 50 may also impact on outcome when compared to younger patients.[2] The presence of co-morbid diseases such as chronic obstructive pulmonary disease (COPD), atherosclerotic heart disease (ASHD), diabetes, renal or hepatic insufficiency and immune suppression further compound the effect of age on survival. Although questioned in the past, there is good data in the United States that critical care improves outcome in the elderly and that age should not be arbitrarily used to withhold admission. There is also increasing data that early, direct ICU admission for some elderly critically ill patients not only prevents a later transfer from the general ward, but favorably impacts survival as well.

It is necessary to recall the normal decline in end-organ function that occurs in the elderly and remember that even modest appearing insults can precipitate significant sequelae. For example, our frail elderly female develops orthostasis from an aspirin-induced gastritis or ulcer with hemorrhage and significant hypovolemia. Although her baseline creatinine of 1.4 is only moderately elevated (normal is <1.0), with her low muscle mass and modest nitrogen intake, this may reflect significant renal compromise (intrinsic disease related to nephrosclerosis, rheumatic disease, drug toxicity, etc.) that can be further exacerbated by under-resuscitation.

Decline in Organ Function

All of us suffer a decline in basic organ function as we age, independent of disease processes. This is true across the board, affecting basic receptor function and intracellular second messenger systems, as well as all major organ systems (see Table #1). The common thread running through the organ changes is the decreased ability to adapt to a challenge to homeostasis.[3]

Our frail GI bleeder has systemic disease that further compromises her reserve. She appears to have anemia of chronic disease, decreased renal function, may be unable to mount a normal stress response secondary to adrenal suppression and may have other end-organ problems such as restrictive pulmonary disease, cardiomyopathy, and/or diastolic dysfunction.

Decreased Physiologic Reserve

Changes in the heart, vasculature, lungs, kidneys and liver bring about a decreased physiologic reserve. The obligatory decrease in function (e.g., the increased [A-a O_2] gradient secondary to the decreased ratio of FRC to closing capacity) means less "headroom" above baseline for our elderly critically ill patients.

Increased Prevalence of Chronic Disease

The elderly suffer an increased prevalence of chronic disease. Across a greater span of years, the cumulative effects of inactivity and poor choice of habits increase. Add to this the increase in exposure to both the environment and genetic pedigree. Unless we are both *good* (exercise, eat an optimal diet, never smoke, use alcohol in moderation and avoid trauma) and *lucky* (good genes, low cholesterol, avid immune responder), few of us will reach latter years free of chronic and potentially debilitating disease.

It is clear that much of the increase in morbidity and mortality in the elderly is related to concomitant disease, and *not* to age alone. Both in critically ill elderly patients and in elderly patients having major surgery, the increase in risk is secondary to the presence and number of disease states.[3-7]

What do these principles imply? Older patients have more physiologic variability than younger patients. They are *more* dissimilar. The mandated changes in basic function and physiology notwithstanding, an active, healthy 80-year-old may be very different from an inactive, chronically ill 70-year-old. The presence of chronic diseases and their number make for very different risk profiles.

All elderly patients have decreases in cellular and organ function. All walk much closer to the limits of their ability to compensate for a perturbation in homeostasis. The variability between patients requires an individualized plan, with the risks determined in light of the patient's history, the limits on reserve dictated by age and by the current disease process. In the elderly, the difference between "poor" health and "good" health is very important.

Summary

This elderly patient has chronic compromise secondary to the systemic effects of rheumatoid arthritis and its therapy. She is at risk for adrenal (iatrogenic steroid deficiency) and immune suppression (secondary to RA and its therapy) and progression of her renal insufficiency. In addition, she has decreased physiologic reserve related to the aging process; this may be unmasked if therapy is delayed or overly aggressive therapy is undertaken. Therefore early ICU admission, consultation with gastroenterology and general surgery, and definitive therapy with blood, fluids and steroids are required.

She should have an arterial and central venous catheter placed. This will facilitate monitoring of volume status, adequacy of her fluid replacement and pre-emptive care if she requires additional endoscopic, radiographic or surgical care. It would be reasonable to obtain a co-syntropin stimulation to evaluate her hypophyseal-adrenal axis. In contradistinction to hydrocortisone or methylprednisolone, dexamethasone will provide stress hormone coverage without interfering with this test. Further steroid dosing will depend on test results.

The optimal hematocrit for the critically ill continues to be open to discussion, but it is crucial to provide adequate intravascular volume.[8] Finally, additional monitoring (gastric mucosal pH_i, mixed venous oxygen saturation, or the like) may be used on a patient-to-patient basis to identify adequate tissue oxygenation.[9]

Table: Organ System Changes with Age

Circulatory	↓ vascular compliance, ↑ resistance Subsequent ↑ systolic BP, ↓ effective circulating volume
Cardiac	↑ afterload leads to ↑ LV wall stress and leads to LVH and ↓ LV compliance Cardiac output ↑ with an ↑ in LVEDV, not with an ↑ in inotropy
Pulmonary	↓ chest wall compliance: ↓ TLC, VC, ↑ FRC, ↓ lung elastic recoil, ↑ lung compliance, ↑ closing capacity
Renal	Fewer cortical nephrons, ↓ GFR
Nervous	↓ responsiveness to autonomic nervous system, ↓ decreased response to exogenous α and ß agonists (mix of receptor and second messenger defects) ↓ response to stress

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The Elderly Trauma Patient

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Case: A 100kg, 5'8", 71 y/o male falls 10 feet from his deer hunting tree-stand and sustains multiple rib fractures, a left hemopneumothorax and contusion. He has a 20-pack-per-year smoking history, hypertension and type II diabetes. He had an angioplasty and stent two years prior to injury. He takes glypizide, enalapril and atenolol. After fluid resuscitation of 2 liters of normal saline, his BP is 140/90, respiratory rate 30, pulse 90 and Sa02 – 90 percent on 50 percent. His Hct is 33, creatinine 1.5 mg/dL and K+ = 5.4meq/dL.

Discussion

Critical care of this elderly trauma patient is more complicated than care of his traumatized 18-year-old counterpart. Statistically, the 18-year-old is essentially healthy and the alteration to his physiology is almost entirely secondary to his injuries. The elderly patient, however, has suffered the varying toll of the vagaries of a long life as well as age-related diminution in end-organ function (see chapter on *Critical Care of the Elderly Patient*). So, first off, why did this occur? Bad luck, bad timing, hypoglycemia, cardiac dysrhythmia, CNS or CV ischemia, drug side effect, or other? The role of such underlying event(s) is much more common and greater for the elderly trauma victim.

Decline in Organ Function/Reserve

The physiologic substrate of the elderly is different than that of the 18-year-old. As mentioned in the previous article "Critical Care of the Elderly Patient," all people suffer a decline in organ function as they age, affecting autonomic responsiveness and the endocrine response to stress, as well as the more obvious major organ systems. Many maintain homeostasis perfectly well, some despite chronic disease. However, when they are traumatized they have a decreased ability to maintain homeostasis or to regain it if lost. Our patient is hypertensive, most likely from multiple etiologies including chronic CV disease, pain, marginal gas exchange and response to fluid resuscitation. He has decreased physiologic reserve and may not tolerate the increased work of breathing and increased [A-a O_2] gradient after his pulmonary trauma. He is at risk for progressive multiple-organ dysfunction from this and from ongoing systemic inflammatory response.

Greater Likelihood of Chronic Disease

The prevalence of chronic disease is much greater in the elderly and correlates with age. One study states that 30 percent of trauma patients over 55 have pre-existing disease. Many will have hypertension, diabetes, COPD or arteriosclerotic heart disease. In the setting of obligatory decrease in organ function simply because of age, the presence of one or *more* of these diseases should raise a red flag. An overweight, elderly deer hunter with significant coronary disease (recent coronary angioplasty, smoking history and diabetes) may already consume most of his "reserve" just to maintain his vital signs and a saturation of 90 percent, but his trauma could precipitate widespread decompensation.

Priorities

Treating our elderly man requires:

- An accurate history to determine the underlying cause of his injury. If it is just a simple fall (falls, by the way, are the most common cause of trauma in the elderly), so be it, but rule out myocardial ischemia, sudden death event, metabolic process or CNS event.
- Definitive therapy with an arterial catheter, CVP (with or without a PAC catheter), serial monitoring of adequate O_2 delivery, chest tube, pain management (consideration of an intrapleural catheter, thoracic epidural, PCA, etc., to control his pain), noninvasive (CPAP, BiPAP) or expeditious invasive ventilatory support with appropriate fluid resuscitation.
- Elderly patients will not tolerate failures or even ambiguities in resuscitation. Therefore, we must exclude a metabolic or ischemic etiology for his fall and evaluate his response to our fluids, pain management, and means to optimize gas exchange.
- Early admission to the ICU to allow timely invasive monitoring and optimization of O_2 delivery once surgery is excluded and the patient is stabilized. Additional non-life-threatening diagnostic tests should be deferred until the patient is stabilized and adequately monitored in the ICU.
- Adequacy of volume restoration. The choice of fluid for resuscitation is not felt to be key (colloid versus crystalloid).

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Postoperative Pain Control in the Elderly Patient

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Introduction:

Poorly controlled pain in the postoperative period can lead to slow recovery and life threatening complications. Meeting the needs of an elderly patient can be especially challenging. Elderly patients often have multi-system disease in conjunction with physiologic changes associated with aging. Not infrequently, mental impairment and polypharmacy render these patients susceptible to adverse effects of analgesic medications used in pain control.

Some of the problems encountered in caring for the elderly include:

1) Misconceptions -
   - pain perception decreases with age
   - elderly cannot tolerate opioids
2) Inadequate assessment -
   - difficult in patients with cognitive impairment, dementia, aphasia
3) Lack of education -
   - fear of addiction (patient, health care giver)
   - patient expects to have pain
   - patient unfamiliar/unwilling to use equipment, e.g., PCA

Ways to Optimize Pain Control:

Assessment

Frequent assessment, especially after interventions for pain control.

Questions: What is the level of pain?
How much relief from previous dose?
What activities? Able to deep breathe?
Any side effects?

Frail, debilitated patients and cognitively impaired patients benefit from frequent assessments. Enlist the help of a family member in order to try to "understand" the patient. It may be helpful to note the patient's posture (rigid, not moving, etc.), facial expressions, verbal cues such as moaning. In a confused patient (who is previously not confused), rule out hypoxia, drug interaction, nighttime confusion and pain. A history of alcohol abuse warrants preventive measures against withdrawal.

Education

Educate the patient and the patient's family on commonly held misconceptions such as addiction to opioids used in acute pain. Patients should be encouraged and instructed to use equipment, e.g., epidural or intravenous PCA.

What Are the Analgesic Options for Pain Control?

Pharmacologic options

In the elderly patient, changes in drug absorption, distribution, metabolism and elimination may affect the eventual plasma level and effect of a given analgesic drug. Drug absorption may be altered as a result of increased gastric pH and decreased gastric motility. Distribution of drugs may change due to a decrease in lean body mass or to a decrease in plasma proteins and albumin from chronic illness and poor nutrition. Hepatic blood flow, renal blood flow and glomerular filtration rate are decreased in the elderly. Consequently, hepatic drug metabolism may be decreased, and elimination of drugs may change as renal and hepatic clearance decreases.

The oral route of analgesic drug administration is simple and cost-effective. Nonsteroidal anti-inflammatory agents and opioid analgesics are prescribed for patients who experience mild to moderate pain and can take oral medications postoperatively.

Acetaminophen:

- oral analgesic, antipyretic
- dose around the clock
- do not exceed total daily dose of 4 grams
- hepatotoxicity a concern
- opioid sparing

NSAIDS:

- use those with short half-lives (e.g., ibuprofen, ketoprofen, diclofenac - oral route)
- parenteral NSAID Ketorolac (use 15mg IV q6 hr, not to exceed 5 days)
- dose around the clock
- opioid sparing effect
- beware of gastrointestinal, renal and platelet effects

NSAID Toxicity:

Gastrointestinal:

- risk of bleeding with high dose, long duration, concurrent steroid use, prior ulcer
- least risk with ibuprofen, diclofenac
- intermediate risk with indomethacin, naproxen, piroxicam
- highest risk with ketoprofen, azapropazone
- nonacetylated salicylates well tolerated

Renal:

- avoid NSAID in patients with renal failure, insufficiency, CHF, shock
- chronic progressive renal failure with long-term use, high dose

Platelets:

- NSAIDs inhibit platelet aggregation (reversible)
- nonacetylated salicylates less of an effect

Opioids:

- use those with short half-lives (morphine, hydromorphone, oxymorphone, oxycodone)
- do not use meperidine as first line opioid. Normeperidine metabolite relies on renal elimination, accumulation is CNS toxic.
- avoid IM administration (painful, unpredictable absorption due to less muscle, more fat)
- side effects, decrease dose if adequate analgesia
- patient monitoring for sedation, respiratory depression
- use around-the-clock dosing
- start with low dose (25 percent to 50 percent of usual adult dose), titrate up slowly
- use adjuncts (acetaminophen or NSAID) for opioid-sparing effect
- patient monitoring for sedation, respiratory depression

Other routes of administration of analgesics include parenteral, epidural or intrathecal. Transderm opioid (fentanyl) is not easily titratable and is not appropriate (contraindicated in elderly) for use in acute postoperative pain. Local anesthetics are useful in wound infiltration, regional blocks (e.g., brachial plexus block) for prolonged postoperative analgesia, and in low concentrations in epidural analgesia.

Intramuscular injections are suboptimal; muscle wasting may be present in the elderly patient and may contribute to unpredictable levels of analgesic drug.

IV PCA Opioid Use:

- instruct patient on concept and use of machine
- patient should be physically able to push the button
- designate family member or nurse to activate button if patient unable
- use basal rate with caution

Epidural Analgesia with Opioids:

- decrease dose of opioid, especially morphine sulphate
- decrease concomitant parenteral opioid administration
- patient monitoring for sedation, respiratory depression

Common Side Effects of Opioids:

- respiratory depression, sedation
- nausea, vomiting
- ileus
- pruritus
- urinary retention

Less Common Side Effects:

- confusion, psychosis
- dizziness, orthostatic hypotension

Nonpharmacologic options

These can be helpful to patients with anticipated prolonged postoperative recovery, a high level of anxiety or fear, who have to undergo treatments during their recovery (i.e., cancer patients) and who continue to have discomfort despite pharmacological interventions and wish to avoid adverse effects of increasing doses of analgesic drugs.

Physical agents include heat or cold, massage or exercise and transcutaneous electrical nerve stimulation (TENS). Cognitive-behavioral techniques include education/instruction, relaxation, imagery, music and biofeedback

Conclusion:

The elderly patient often presents with multisystem disease and changes in drug metabolism and elimination leading to increased sensitivity to analgesic medications. Even so, it is possible to provide these patients with good pain control by selecting the analgesic modality and drugs best suited to each individual patient. Using careful titration of analgesic doses, and by assessing patients frequently for inadequate pain control and for adverse side effects, elderly patients need not be denied the benefits of modern technology in the management of acute pain.

Goals of optimized pain management in the postoperative period are to provide patient comfort and satisfaction, to restore function and to decrease perioperative morbidity, thereby decreasing hospital stay and health care costs.

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Chronic Pain in Older Individuals: Consequences and Management

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Introduction

The fastest growing segment of the U.S. population are those individuals who are 85 years of age and older.[1] It is estimated that 25 percent to 50 percent of community-dwelling older people experience substantial pain on a regular basis, and about one-fifth are taking analgesic medications regularly. Older people are more likely to suffer chronic pain from arthritis, bone and joint disorders, back problems and neuralgias, along with all the other chronic conditions that typically cause pain. The consequences of unrelieved chronic pain in this population, similar to others, include depression, decreased socialization and sleep disturbance. It is now recognized that pain is greatly under-recognized and no less under-treated in the elderly population.[2,3]

Unique to older individuals is the interactional, or synergistic, nature of chronic pain superimposed upon other commonly occurring coexisting diseases and chronic conditions (i.e., CAD, COPD, Alzheimer's and other dementias, Parkinson's, osteopenia, etc.). This leads to increased debility and morbidity from decreased ambulation, deconditioning and the additive effects of multiple drug prescriptions. For all these reasons, it is extremely important that all anesthesiologists recognize the frequency, consequences and management challenges of chronic pain in this population. For those who serve as chronic pain management consultants, these patients' unique characteristics need to be thoroughly understood in order to provide the greatest benefit to them.

Assessment

Understanding and validation of a patient's pain complaints through the process of thorough assessment is fundamental to the good practice of medicine. Management of pain should always address specific pathophysiology whenever possible.[4] Other than the usual components of a comprehensive pain evaluation, key points to focus on during assessment in aging patients include:

1. Recognition that words such as "burning," "discomfort," "aching," "soreness" and other terms may be substituted for 'pain,' per se.
2. Cognitive and language impairments are common, necessitating interpretation of nonverbal and vocalized pain behaviors, as well as eliciting a history of recent changes in function, as indicators of pain.
3. Detailed evaluation of activities of daily living (ADLs) and performance measures of function.
4. Influence of chronic pain on mood and psychosocial function, utilizing age-specific scales (e.g., geriatric depression scale).
5. Chronic medical conditions and medication use that influences chronic pain and treatment alternatives.

Principles of Management

An integrated treatment plan that incorporates pharmacotherapy, nonpharmacologic interventions and functional rehabilitation should be considered for all patients who have debilitating chronic pain.[5] For the purposes of this review, anesthesiologists need to have a thorough understanding of pharmacologic therapy. Nerve blocks and other invasive procedures have a place in selected cases, but over the long run the vast majority of patients will benefit from thoughtfully applied medication management. The underlying principles to this approach are summarized below.[6]

1. All older patients with diminished quality of life as a result of chronic pain are candidates for pharmacologic therapy.
2. The least invasive route of administration should be used.
3. Fast-onset, short-acting analgesic drugs should be used for episodic pains.
4. Acetaminophen is the drug of choice for relieving mild to moderate musculoskeletal pain. The maximum dosage of acetaminophen should not exceed 4,000 mg per day.
5. Nonsteroidal antinflammatory drugs (NSAIDs) of the cyclo-oxygenase type 1 class (COX-1) should be used with extreme caution.
6. Opioid analgesic drugs may be helpful for relieving moderate to severe pain (Table 1).
7. Drug titration should be conducted slowly and carefully, with close monitoring for adverse effects.
8. Drug-related constipation should be anticipated and prevented.
9. Nonopioid analgesic medications may be appropriate for some patients with some chronic pain syndromes, especially neuropathic pain (Table 2).

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Table 1: Opioid Analgesic Drugs

DRUG	ORAL EQUIVALENT	STARTING DOSAGE	AGING EFFECTS	PRECAUTIONS AND RECOMMENDATIONS
Short-acting drugs			Anticipate increased sensitivity and duration of action with advancing age	Best for episodic or intermittent pains
Morphine sulfate	30 mg	15-30 mg q 4h	Intermediate half-life	Start low and titrate to comfort and functional
Codeine	120 mg	30-60 mg q 4 h	Acetaminophen-NSAID combinations limit dose; constipation is a major issue	Anticipate and prevent side effects; begin bowel program early; do not exceed recommended maximum dose of fixed-dose combination formulations
Hydrocodone	30 mg	5-10 mg q 3-4 h	Acetaminophen-NSAID combinations limit dose; toxicity similar to morphine	Anticipate and prevent side effects; begin bowel program early; do not exceed recommended maximum dose of fixed-dose combination formulations
Oxycodone	20-30 mg	5-10 mg q 3-4 h	Acetaminophen-NSAID combinations limit dose; toxicity similar to morphine; oxycodone is available as a single agent	Anticipate and prevent side effects; begin bowel program early; do not exceed recommended maximum dose of fixed-dose combination formulations
Hydromorphone	7.5 mg	1.5 mg q 3-4 h	Half-life may be shorter than morphine (3 h); toxicity similar to morphine	Similar to morphine; start low and titrate to comfort and functional goals
Long-Acting Drugs			Anticipate increased sensitivity and duration of action with advancing age	Best for continuous pain
Sustained-release morphine	30 mg	15-30 mg q 12 or 24 h	Occasionally requires more frequent dosing than recommended on package insert if increasing dose for pain control results in increased adverse effects	Escalate dose slowly because of possible drug accumulation; short-acting opioid analgesic often necessary for breakthrough pain
Sustained-release oxycodone	20-30 mg	10-20 mg q 12 h	Similar to sustained-release morphine	Similar to sustained-release morphine
Transdermal fentanyl	Not applicable	>25 mcg /h patch not recommended in opioid-naïve patients	Effective activity may exceed 72 hour usual duration of action	Titrate slowly using short-acting analgesics for breakthrough pain; peak effects of first dose may take 18-24 hours; a responsible caregiver should be available during dose titration

Table 2: Non-Opioid Drugs for Pain Management

DRUG	STARTING ORAL DOSE	SPECIFIC INDICATIONS	POTENTIAL ADVERSE EFFECTS	PRECAUTIONS AND RECOMMENDATIONS
Corticosteroids, e.g., prednisone	2.5-5 mg daily	Inflammatory diseases	Hyperglycemia, osteo-penia, Cushing's	Avoid high dose for long-term use
Tricyclic Antidepressants, e.g. amitriptyline, desipramine, doxepin, imipramine, nortriptyline	10 mg HS	Neuropathic pain, sleep disturbance	Increased sensitivity to side effects, especially anticholinergic effects	Monitor carefully for anticholinergic side effects; desipramine may be as effective as amitriptyline with fewer side effects; start at lowest available dose (10 mg) and titrate HS dose upward by 10 mg every 3-5 days; schedule frequent follow-up visits
Anticonvulsants		Neuropathic pain		
Clonazapam	0.25-0.5 mg		Sedation, balance disturbance	
Carbamazapine	100 mg	Trigeminal neuralgia	Somnolence, ataxia, dizziness, leukopenia, thrombocytopenia, rarely aplastic anemia	Start at 100 mg qd, increase slowly bid, 200 mg qd, then bid; check LFTs, CBC, Cr/BUN at baseline; CBC at 2 and 8 weeks
Gabapentin	100 mg		Ataxia, ankle swelling, nausea	Appears to have less serious side effects than carbamazapine; titrate slowly to effective dose vs. side effects (up to 35 mg/kg/day)
Antiarrhythmics, e.g., mexiletine	150 mg	Neuropathic pain	Tremor, dizziness, ataxia, rarely blood dyscrasias, hepatotoxicity	Avoid use in patients with exigent or potential for conduction defects or block; start with low dose and titrate slowly to 10-15 mg/kg/day tid dosing; recommend initial and follow-up EKGs
Other Agents				
Baclofen	5 mg	Neuropathic pain, muscle spasms	Sedation, weakness, ataxia	Monitor for urinary dysfunction; discontinue via tapering to avoid possibility of CNS irritability withdrawal seizures; titrate slowly up to 1 mg/kg day tid dosing balancing therapeutic effects vs. toxicity

Palliative Care in Geriatric Anesthesia

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Palliative medicine is a recent addition to the list of medical subspecialties. In late 1987, the Royal College of Physicians of London recognized palliative medicine as a specialty within general internal medicine.[1] Palliative care arose out of the change from acute to chronic causes of death. Currently the emphasis of health care is on improving the quality of life. Palliative care has received increasing attention in the United States as the debate over euthanasia and AIDS have become political “hot button” issues.

It is now well established that a primary cause for a chronically ill patient to consider euthanasia involves the lack of adequate pain control, especially if the patient is already suffering from a terminal disease process. As the current generation ages, there will likely be an increase in the numbers of people dying from cancer. There is an anticipated 20 percent increase in men and a 12 percent increase in women dying from cancer between 1980 and the turn of the century. A study by Cartwright found that 84 percent of surviving relatives reported that cancer patients suffered pain in the last year of life.[2]

The World Health Organization (WHO) has also realized the efficacy of palliative care. In 1990, a WHO expert committee on cancer pain relief and palliative care suggested that 30-50 percent of cancer patients are experiencing pain or being treated for it. In an effort to advance the cause, the WHO provides this definition of palliative care:[3]

- Affirms life and regards dying as a normal process
- Neither hastens nor postpones death
- Provides relief from pain and other distressing symptoms
- Integrates the psychological and spiritual aspects of patient care
- Offers a support system to help the family cope during the patient’s illness and in their own bereavement.

In short, palliative medicine is the active total care of patients whose disease is not responsive to curative treatment. This requires a multidisciplinary approach to treat symptoms, control pain and address the psychological, social and spiritual needs of the patient. Palliative care can be provided with less expense and can provide more satisfaction to the patients and their families.[4]

The anesthesiologist, especially the anesthesiologist trained in pain management, should be a member of the multidisciplinary palliative care team. Given the fact that the primary complaint of terminal patients is pain, the anesthesiologist should be central in the palliative medicine model. There is no other medical/surgical specialty that can provide the medical and procedural expertise allowing a patient to remain functional until they die.

Cancer pain may be somatic or visceral due to tumor invasion. Terminal patients may also present with neuropathic, sympathetically mediated and centrally mediated pain either due to their end-stage disease or the treatment of the diseases. The anesthesiologist is uniquely trained to differentiate and treat these differing pain entities.

Providing medical management for pain to include non-narcotic analgesics, narcotics (with all their modes of administration), anticonvulsants, local anesthetics, steroids and sympathetic nervous system antagonists may not be the sole purview of anesthesiologists; members of other specialties may be well trained in all of these medical regimens. On the other hand, many medical specialists may not feel comfortable using narcotics in the doses sometimes required to ease the pain of the terminal patient.

After defining the pain syndromes of the palliative care patient, there are procedural skills the anesthesiologist possesses that aid in pain control, including epidural and/or intrathecal administration of narcotics via implantable pumps, chemical neurolysis of nerve roots and sympathetic ganglia, cryoanalgesia, radiofrequency ablation, TENS units and dorsal column stimulators. Many of these interventions provide long term, patient-controlled analgesia, thereby allowing the patient to continue to function and perform their activities of daily living.

There is little research that specifically addresses the utility of the anesthesiologist in palliative care. Future work in this area will be vital in expanding the role of the anesthesiologist as a perioperative physician.

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